HYDROGEOLOGY AND GROUND-WATER FLOW, FRACTURED MESOZOIC STRUCTURAL-BASIN ROCKS, STONY BROOK, BEDEN BROOK, AND JACOBS CREEK DRAINAGE BASINS, WEST-CENTRAL NEW JERSEY

by Jean C. Lewis-Brown and Eric Jacobsen

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APPALACHIAN VALLEYS-PIEDMONT REGIONAL AQUIFER-SYSTEMS ANALYSIS

Wsst Trenton, New Jersey
1995

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Slope	
foot per mile (ft/mi^2)	0.1894	meter per kilometer
	Area	
square mile (mi^2)	2.590	square kilometer
	Flow	
foot per day (ft/d)	0.3048	meter per day
inch per year (in./yr)	25.4	millimeter per year
cubic foot per day per square foot times foot of aquifer thickness [[(ft^3/d)/ft^2]ft]	0.09294	cubic meter per day per square meter times meter of aquifer thickness [[(m^3/d)/m^2]m]
foot squared per day (ft^2/d)	0.09294	meter squared per day
gallon per minute (gal/min)	0.06308	liter per second
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
cubic foot per second (ft^3/s)	0.02832	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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ABSTRACT

This study was undertaken to characterize ground-water flow in the Stony Brook, Beden Brook, and Jacobs Creek drainage basins in west-central New Jersey. The study area, an 89-square-mile area, is underlain by dipping beds of fractured siltstone, shale, and sandstone and by massive diabase sills. The density of fractures in all the rocks decreases with depth. Rocks on both sides of the major fault that extends through the study area are extensively fractured.

The average annual rates of precipitation and ground-water recharge in the study area are 45.07 inches and 8.58 inches, respectively. The rate of recharge to the diabase rocks is about one-half the rate of recharge to other rocks. Part of the surface runoff from the diabase rocks flows downslope and recharges the ground-water system where more permeable rocks crop out.

The decrease in the density of fractures with depth is reflected in specific-capacity data. The specific capacity per foot of open hole of wells that are less than 76 ft deep is two to six times greater than that of wells 76 to 100 ft deep. Because water-bearing units dip, they are more extensive in the strike direction than in the dip direction, and ground-water flow is skewed toward the strike direction. Ground-water divides generally coincide with surface-water divides, and most ground-water flow in the study area follows short flow paths from the point of recharge to a nearby stream. Most ground-water flow in the study area occurs between the water table and 75 ft below land surface. When the system is unstressed, only about 6 percent of the recharge at land surface reaches depths greater than 75 ft below land surface.

A three-dimensional digital model of steady-state, prepumping ground-water flow was developed to test hypotheses concerning the geologic features that control ground-water flow in the study area. The decrease in the density of interconnected fractures with depth was simulated by dividing the model into two layers of different hydraulic conductivity. Over most of the model area, the upper layer represents the part of the system between the water table and 75 ft below land surface, and the lower layer represents the part of the system deeper than 75 ft below land surface. The pinching out of water-bearing units in the dip direction at land surface and at depth was represented by setting the hydraulic conductivity in the dip direction 2 times lower than in the strike direction for the upper layer and 10 times lower than the strike direction for the lower layer. The vertical conductivity was slightly higher than the dip-direction horizontal conductivity. This model is appropriate for the analysis of ground-water flow in areas greater than about 0.5 square mile in size and if analysis of flow in discrete water-bearing units is not needed.

INTRODUCTION

This report is a result of the Appalachian Valleys-Piedmont Regional Aquifer-System Analysis (RASA) study. The Appalachian Valleys-Piedmont RASA is one of several regional investigations being conducted to assess the Nation's principal aquifer systems (Sun, 1986). The U.S. Geological Survey (USGS) began the RASA program in 1978, as mandated by Congress, and was given the task of "initiating a program to identify the water resources of the major aquifer systems within the United States . . .and . . . establish the aquifer boundaries, the quantity and quality of the water within the aquifer, and the recharge characteristics of the aquifer" (Sun, 1986, p. 2).

The objectives of the Appalachian Valleys-Piedmont RASA include an identification of the major hydrogeologic terranes within the Valley and Ridge, Piedmont, Blue Ridge, and New England physiographic provinces (fig. 1) and a quantitative assessment of the components of the ground-water flow systems in typical areas within each major hydrogeologic terrane (Swain and others, 1991, p. 3).

The Mesozoic structural basins of the eastern United States comprise one of the major hydrogeologic terranes studied by the USGS as part of the Appalachian Valleys-Piedmont Regional Aquifer-Systems Analysis. The basins extend from Massachusetts to South Carolina (fig. 2). Aquifers in three of these basins--the Newark, Gettysburg, and Culpeper Basins--are used extensively for ground-water supply. To characterize flow in these structural basins, an 89 mi^2 area of the Newark Basin in west-central New Jersey (fig. 3) was chosen for detailed study.

Ground water is the primary source of potable water in the study area. Water-supply systems serve Hopewell and Pennington Boroughs; most other residential and commercial users obtain their water from privately owned wells (Jacobsen and others, 1993, p. 4).

Effective management of ground-water supplies requires an understanding of the ground-water flow system. The flow system in Mesozoic-basin rocks, however, has been poorly understood because the hydrogeologic framework consists of layered dipping beds in which water flows primarily in a complex network of several types of fractures.

Purpose and Scope

This report describes ground-water flow in the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey. The hydrogeologic framework is discussed, and the effects of geology and depth on hydrologic properties are evaluated on the basis of results of 1,492 specific-capacity tests conducted in and near the study area. Transmissivity and storage coefficient estimated from results of 37 aquifer tests in the Newark Basin conducted before this study are also included. A conceptual model of the ground-water flow system that includes generalized ground-water flow paths and an identification of recharge and discharge areas is described. A map of prepumping water levels in 544 wells in and near the study area is included. The digital model that was used to analyze factors affecting ground-water flow in the study area and to test hypotheses developed in the conceptual model is described. An analysis of ground-water flow is presented, including the effect of diabase rocks on the ground-water flow system, the vertical distribution of ground-water flow, the source of water to wells, and the effect of anisotropy on base flow to streams. Average-annual water budgets for the Stony Brook, Beden Brook, and Jacobs Creek drainage basins also are included.

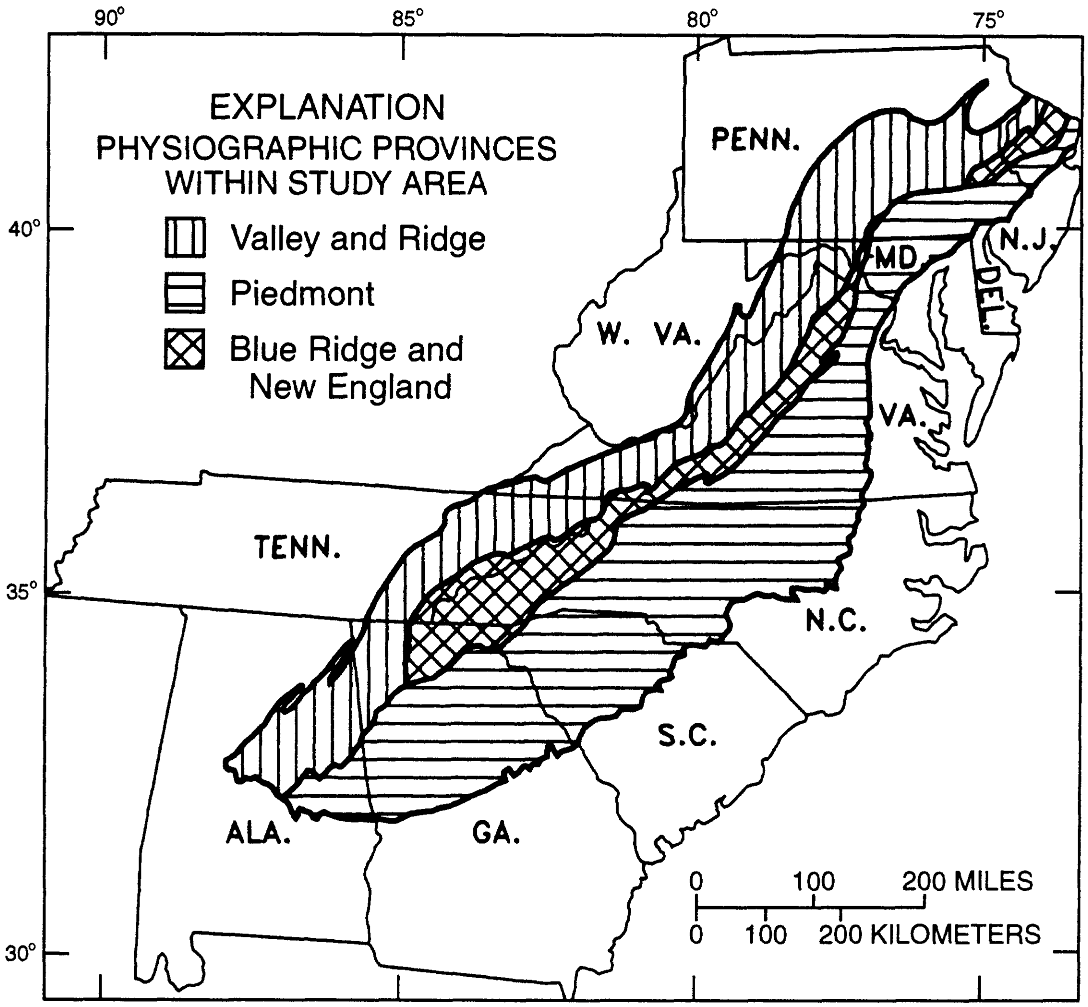
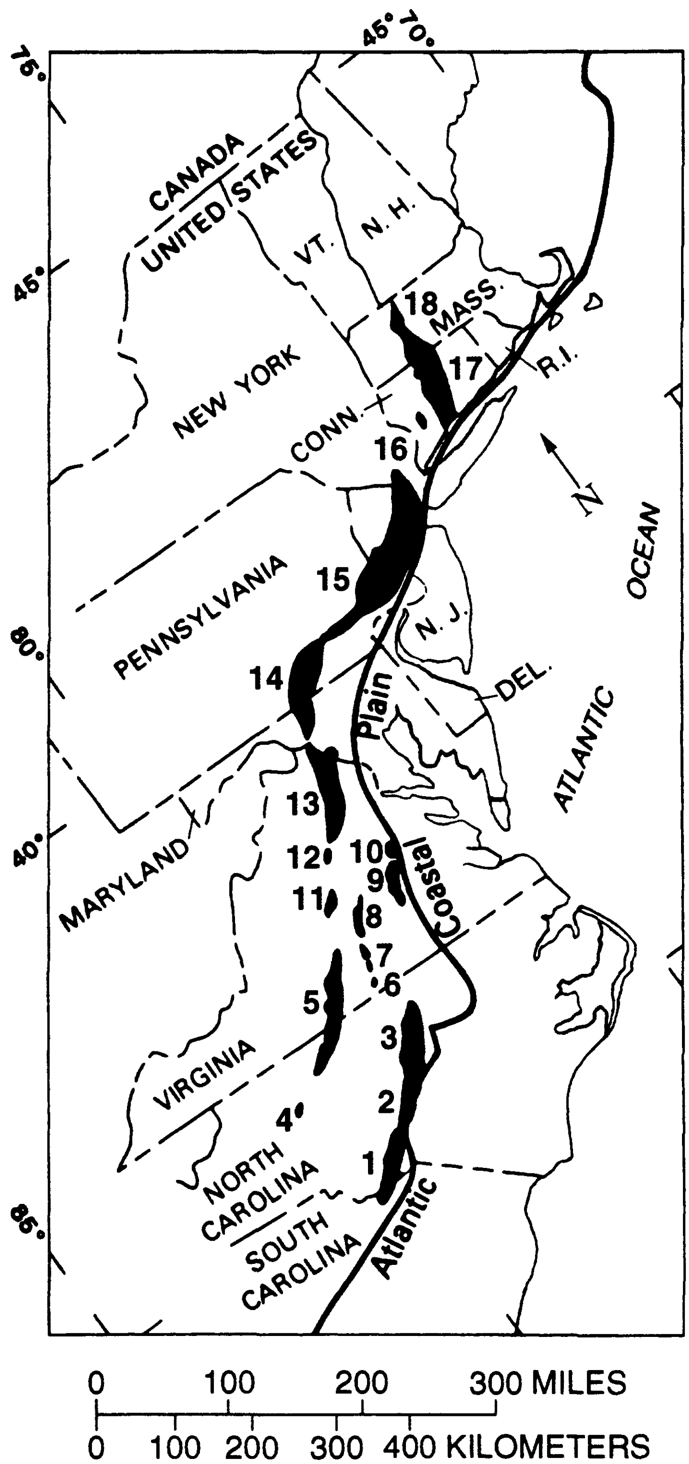


Figure 1. The Appalachian Valleys-Piedmont Regional Aquifer-Systems Analysis study area and physiographic provinces. (From Swain and others, 1991, fig1.)



EXPLANATION

Mesozoic basins:

1. Wadesboro (N.C.-S.C.)
2. Sanford (N.C.)
3. Durham (N.C.)
4. Davie County (N.C.)
5. Dan River and Danville (N.C.-Va.)
6. Scottsburg (Va.)
7. Basins north of Scottsburg (Va.)
8. Farmville (Va.)
9. Richmond (Va.)
10. Taylorsville (Va.)
11. Scottsville (Va.)
12. Barboursville (Va.)
13. Culpeper (Va.-Md.)
14. Gettysburg (Md.-Pa.)
15. Newark (N.J.-Pa.-N.Y.)
16. Pomperaug (Conn.)
17. Hartford (Conn.-Mass.)
18. Deerfield (Mass.)

Figure 2. Exposed Mesozoic basins in the eastern United States. (Modified from Froelich and Olsen, 1985, fig. 1.1.)

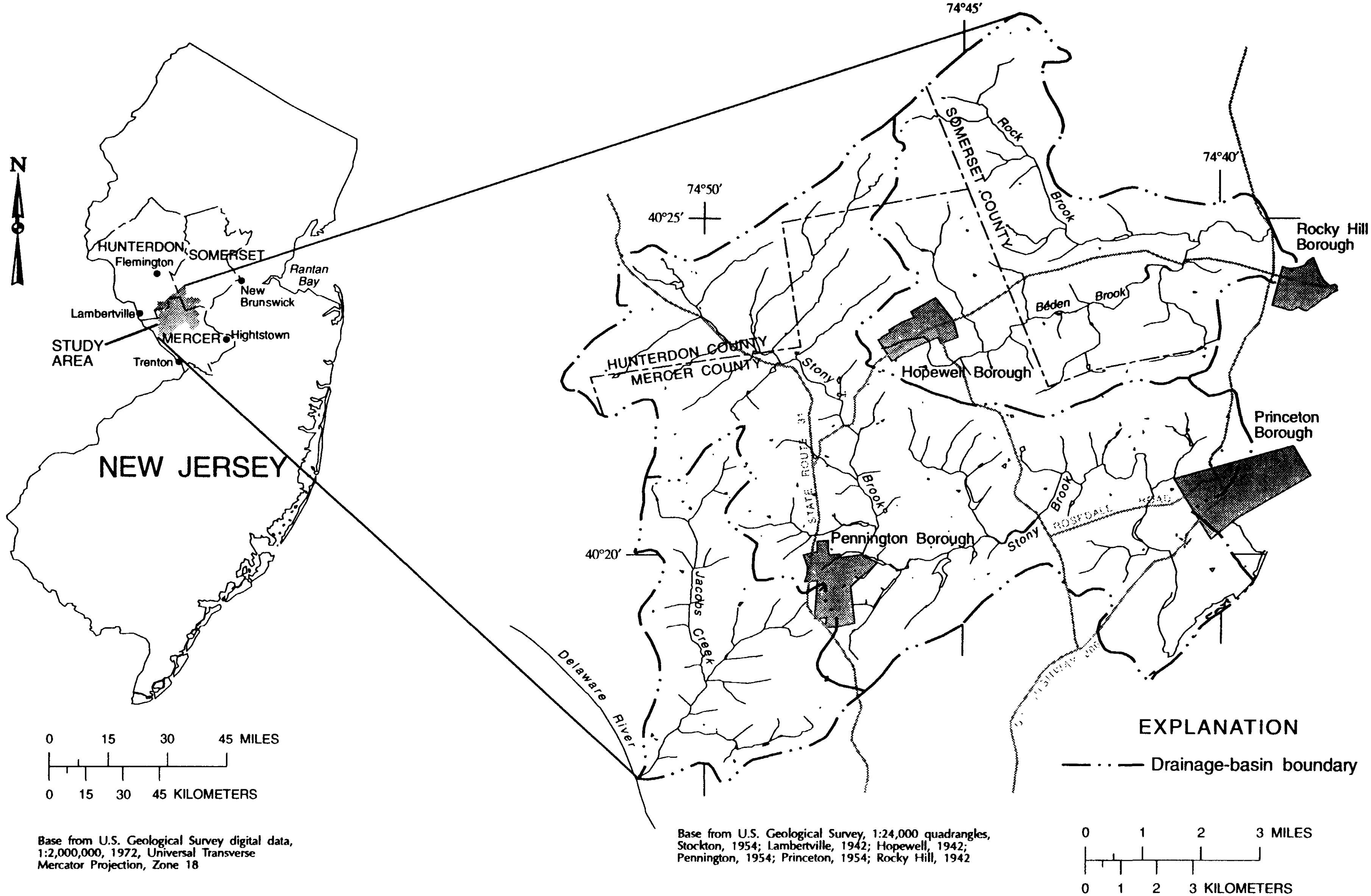


Figure 3. Location of the study area.

Description of Study Area

The study area is located in the southern part of the Newark Basin of New Jersey. It was chosen to typify the Mesozoic basins of the eastern United States because it contains most of the rock types and geologic structures prevalent in the basins, including the diabase intrusions and a major fault--the Hopewell Fault.

Location and Extent

The study area is located in west-central New Jersey and encompasses approximately 89 mi^2 in Mercer, Somerset, and Hunterdon Counties (fig. 3). It includes the entire Stony Brook and Jacobs Creek drainage basins and the part of the Beden Brook drainage basin upstream from U.S. Route 206. In this report, "Beden Brook drainage basin" refers specifically to the area contributing drainage to Beden Brook upstream from U.S. Route 206. The two larger basins, Stony Brook and Beden Brook, drain into the Raritan Bay. The smallest basin, Jacobs Creek, drains into the Delaware River.

The Boroughs of Hopewell, Pennington, Princeton, and Rocky Hill (fig. 3) border or lie within the study area. They are primarily residential communities that include or are surrounded by agricultural and wooded areas. Several corporate research facilities also are located within the area, but farms and woodlands still dominate the landscape.

The study area lies entirely within the Piedmont physiographic province. The topography consists of ridges and broad valleys; relief is greatest in the northwestern part and diminishes toward the southeast. Altitudes range from a high of 570 ft above sea level in the northwest to a low of about 20 ft above sea level at the mouth of Jacobs Creek.

Geologic Setting

The study area is underlain by three geologic units of the Newark Supergroup of Late Triassic and Early Jurassic age (table 1, figs. 4 and 5). Following deposition, the geologic rock units were intruded by diabase sills, tilted, fractured, and eroded. As a result of tilting, the units dip about 12 to 15 degrees toward the northwest and strike northeast (Vecchioli and Palmer, 1962, p. 10).

The Stockton Formation, the oldest unit, crops out in the southeastern corner of the study area. In the study area, the Stockton Formation consists of red and gray arkosic sandstone interbedded with shale. It is overlain by the Lockatong Formation, which crops out to the northwest of the Stockton Formation. The Lockatong Formation consists mainly of alternating beds of siltstone and shale with minor amounts of fine-grained sandstone. Many of the siltstone and sandstone beds are extremely hard, chemically cemented siltstone and fine-grained sandstone (argillite) (Houghton, 1990, p. E8). Zones of sandy siltstone within the Lockatong Formation that are similar to the rocks in the overlying Passaic Formation were mapped as separate units by Lyttle and Epstein (1987). The Passaic Formation of Olsen (1980), which crops out in the central part of the study area, is composed of dull red shale interbedded with siltstone and occasional layers of sandstone (Barksdale and others, 1943, p. 141). Some zones of rocks similar to those of the Lockatong Formation have been mapped within the Passaic Formation (Lyttle and Epstein, 1987).

Table 1. Geologic units in the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

[Modified from Lyttle and Epstein, 1987, sheet 2]

Geologic unit	Age	Lithology
Diabase	Early Jurassic	Dikes, sills, and sill-like intrusives. Fine- to coarse-grained (except very fine to fine-grained near chilled borders) diabase.
Passaic Formation of Olsen (1980)	Early Jurassic and Late Triassic	Thin- to thick-bedded shale, siltstone, and very fine to coarse-grained sandstone. Contains thin-bedded shale and siltstone similar to the rocks in the underlying Lockatong Formation.
Lockatong Formation	Late Triassic	Laminated to thick-bedded siltstone and shale. Contains interbedded sandy siltstone similar to the rocks in the overlying Passaic Formation.
Stockton Formation	Late Triassic	Thin- to thick-bedded, very fine- to coarse-grained sandstone, siltstone, and shale.

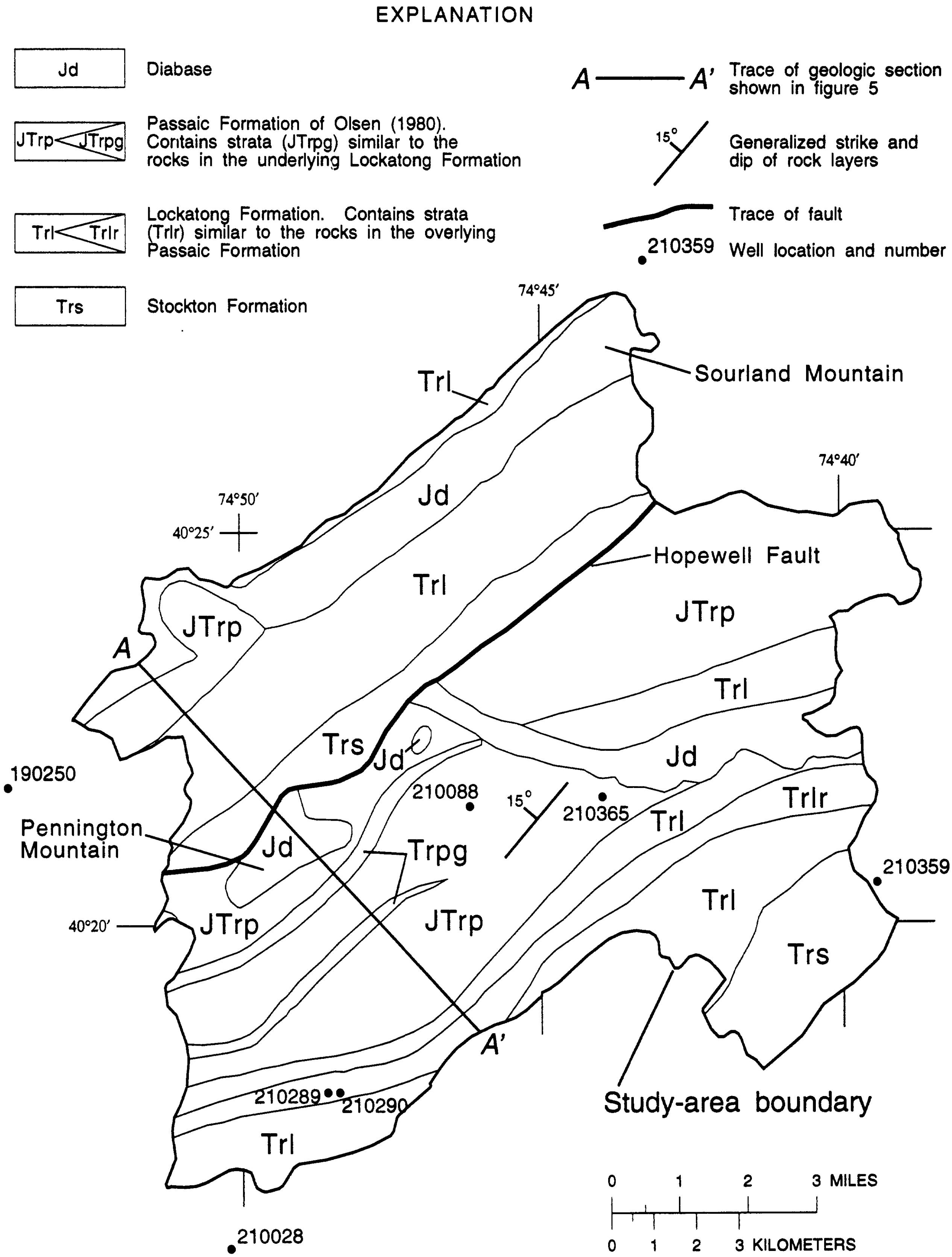
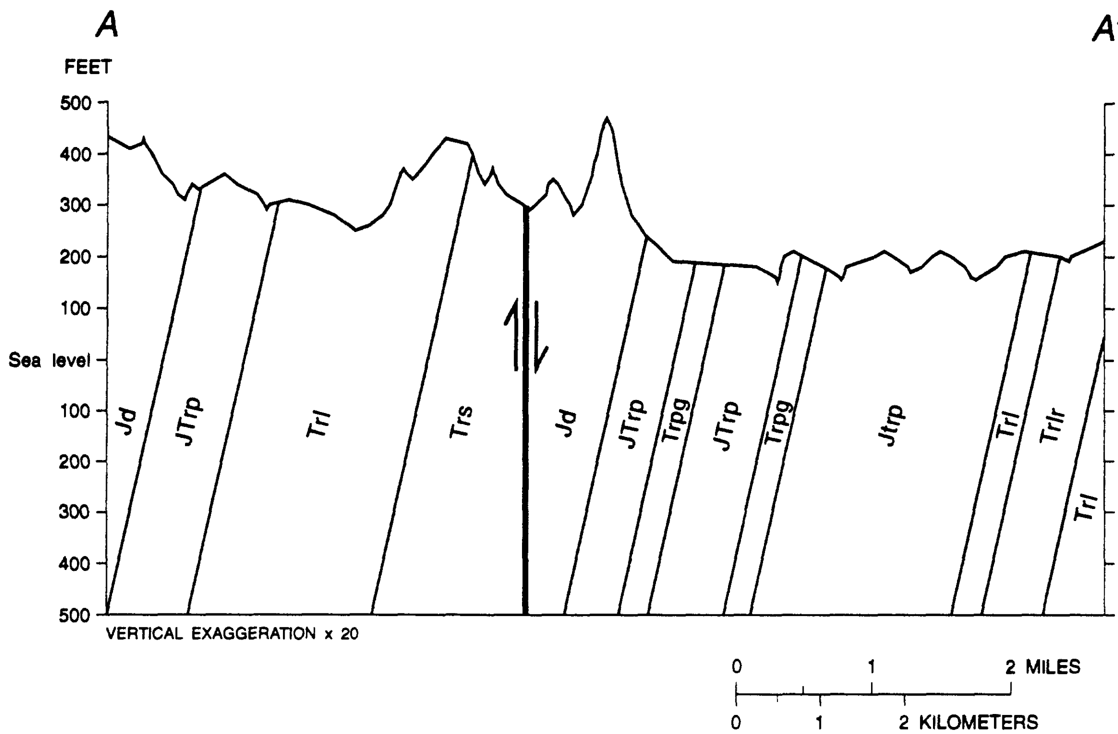


Figure 4. Geology of the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey. (Modified from Lytle and Epstein, 1987, sheet 1.)



EXPLANATION

Jd	Diabase
JTrp < JTrpg	Passaic Formation of Olsen (1980). Contains strata (JTrpg) similar to the rocks in the underlying Lockatong Formation
Trl < Trlr	Lockatong Formation. Contains strata (Trlr) similar to the rocks in the overlying Passaic Formation
Trs	Stockton Formation
———	Lines of contact between geologic units
⥮	Trace of Hopewell Fault and relative movement along the fault

Figure 5. Generalized geologic section through the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey. (Location of section shown in fig. 4.)

The sequence of the three outcropping sedimentary geologic units--the Stockton, Lockatong, and Passaic Formations--is repeated in the northwestern part of the study area as a result of the presence of the Hopewell Fault. The Hopewell Fault strikes northeast and dips about 30 degrees to the southeast (Ratcliffe and Burton, 1985, p. 38). When the fault occurred, the rock formations on the southeastern side of the fault slid downward relative to the rocks on the northwestern side. After faulting, rocks on the upthrown side of the fault escarpment were eroded extensively. Today, land surface on the upthrown side of the fault is only about 200 ft higher than that on the downthrown side. Extensive erosion on the upthrown (northwestern) side of the fault resulted in the exposure of older geologic units and the repetition of outcropping formations.

The thicknesses of the Stockton, Lockatong, and Passaic Formations in the study area are estimated to be 5,000, 6,000, and 14,000 ft, respectively. These estimates were made on the basis of outcrop widths (fig. 4) and an approximate average dip of 13.5 degrees to the northwest.

Diabase sills intruded into the sedimentary rocks in several places. The diabase is composed predominantly of very hard, fracture-resistant calcic plagioclase and augitic pyroxene (Houghton, 1990, p. E18). Because of its pronounced resistance to erosion, the diabase forms the highest ridges in the study area.

When the diabase intruded, the surrounding sedimentary rocks were altered by heat and pressure to hard hornfels rocks. The hydraulic properties of the hornfels rocks resemble those of the argillite rocks of Lockatong Formation (Kasabach, 1966, p. 33). The width of the altered zone probably does not exceed a few hundred feet (Greenman, 1955, p. 33).

Previous Investigations

The geology and ground-water resources of Mercer County have been described by Vecchioli and Palmer (1962) and Widmer (1965). The geology and ground-water resources of Hunterdon County were described by Kasabach (1966). Vecchioli and others (1969) reported on the occurrence and movement of ground water in shales of the Brunswick Group at a site in the Stony Brook drainage basin. Gerhart and Lazorchick (1988) described ground-water resources in the Susquehanna River basin of Pennsylvania and Maryland, which includes part of the Gettysburg Mesozoic structural basin, and Laczniak and Zenone (1985) reported on ground-water resources in the Culpeper basin of Virginia and Maryland. A geologic map of the Newark quadrangle that includes the study area was compiled by Lyttle and Epstein (1987). Betz-Converse-Murdoch, Inc. (1978), conducted a study of the effects of sewering and increased demand on ground-water resources in the northwestern part of Mercer County, New Jersey. Houghton (1990) reported on the hydrogeology of the Mesozoic rocks of the Newark Basin of New Jersey. Reading and Kurtz (1982) described the biology and chemistry of Beden Brook. Jacobsen and others (1993) conducted a study of surface- and ground-water quality, base-flow rates, and ground-water levels in the study area. Lewis (1992) reported on the effect of anisotropy on ground-water discharge to streams in the study area.

HYDROGEOLOGY

The distribution of fractures in the aquifers of the study area is the most important control on the rates and directions of ground-water flow because the fractures are the primary paths for ground-water movement and the primary reservoirs for ground-water storage in these rocks.

Hydrogeologic Framework

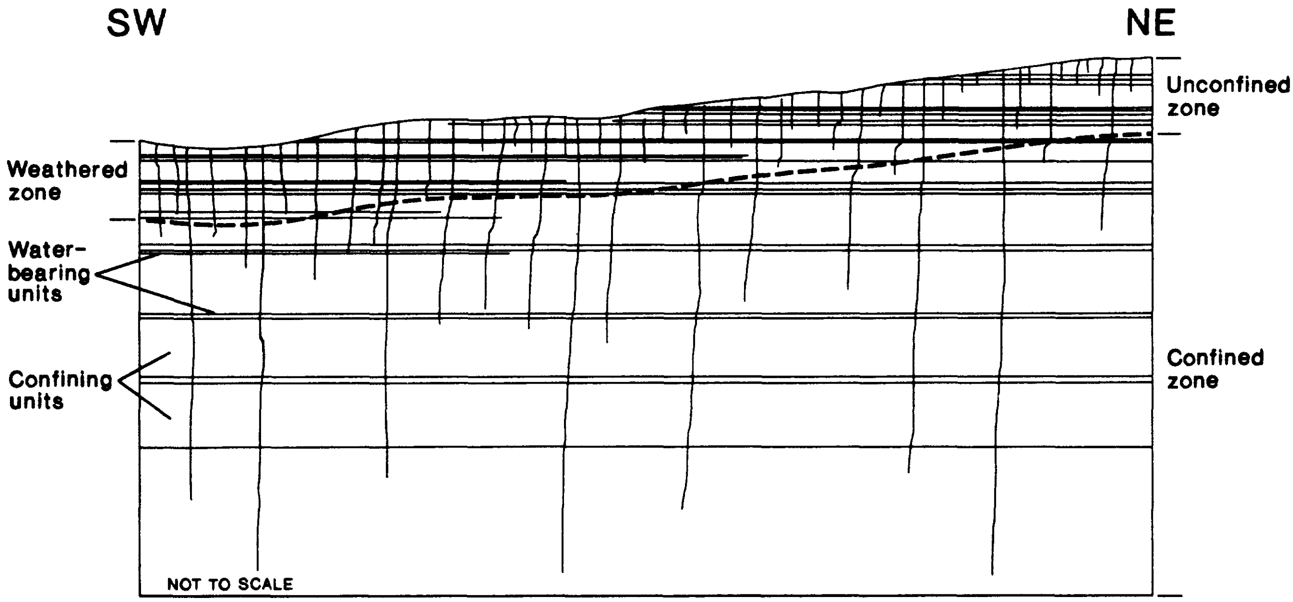
The aquifers in the study area consist of the fractured Mesozoic sedimentary rocks in the shallow parts of the Stockton, Lockatong, and Passaic Formations, and diabase rocks. These geologic formations extend thousands of feet below land surface, but interconnected, water-bearing fractures are present only from land surface to a depth of about 500 ft. Although the lithology and extent of fracturing differ among the three sedimentary formations, all three are characterized by several layers of extensively fractured rocks that typically are 1 to 10 ft thick interbedded with layers of sparsely fractured rocks that typically are 30 to 100 ft thick (Houghton, 1990, p. E18). In extensively fractured layers, joints parallel to bedding predominate. In this report, the extensively fractured layers are termed "water-bearing units," and the sparsely fractured layers are termed "confining units." The term "aquifer" refers to the entire 500-ft-thick sequence of water-bearing units and confining units. The hydrogeologic framework of the study area is illustrated schematically in figures 6a (section oriented parallel to strike) and 6b (section oriented parallel to dip). Each of these generalized sections represents only a small (about 1,000 ft wide and 500 ft deep) hypothetical part of the study area.

In the Stockton Formation, the water-bearing units are composed of sandstone and the confining units are composed of siltstone. In the Lockatong Formation, the water-bearing units are composed of fissile shale, and the confining units are composed of massive, thick-bedded argillaceous siltstone. The Lockatong Formation is one of the poorest sources of ground water in New Jersey but yields more water than the diabase rocks (Kasabach, 1966, p. 31). In the Passaic Formation, the water-bearing units are composed of fissile shale and siltstone, and the confining units are composed of massive siltstone.

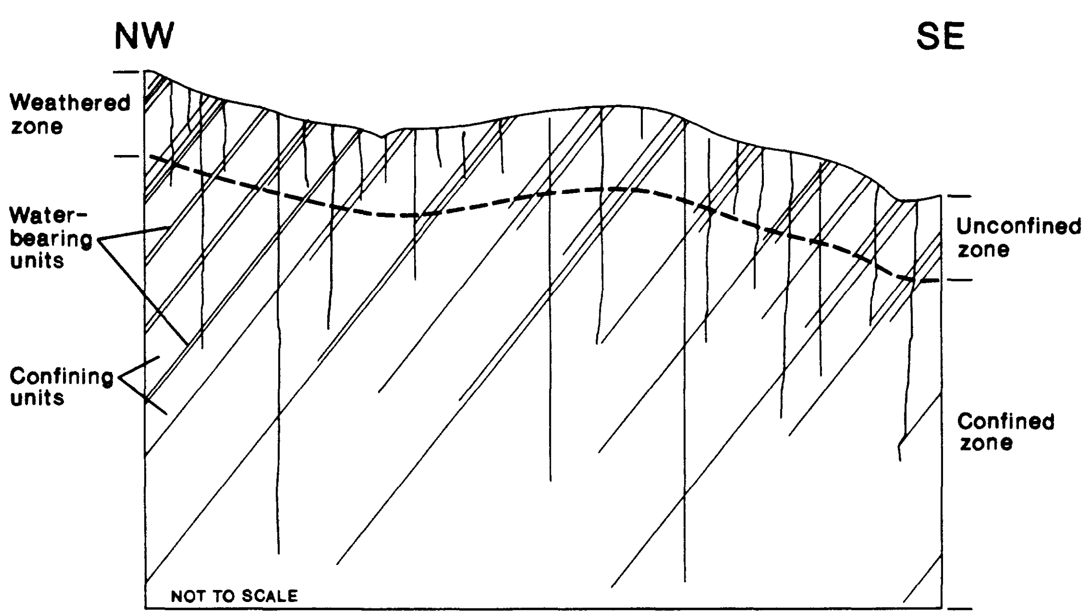
In areas underlain by these sedimentary rocks, stream patterns and topography are controlled by the outcrop patterns of rock layers. Valleys are present where the more easily eroded, extensively fractured rocks crop out, whereas ridges are present where the less easily eroded, sparsely fractured rocks crop out. Consequently, a typical landform in the study area consists of long ridges and valleys parallel to the strike of the beds. Streams in the strike-aligned valleys generally flow into streams that are aligned parallel or subparallel to the dip of the beds. This is especially true in the northwestern part of the study area. This area is underlain by the Lockatong Formation (fig. 4). The dip-aligned streams probably follow the traces of well-developed vertical joints that cut across strike. The stream patterns in the study area (fig. 3) illustrate the tendency for many streams or stream segments to be aligned along strike (northeast) or along dip (northwest).

The diabase rocks are massive, hard, and sparsely fractured. Vertical fractures are spaced 1.0 to 6.6 ft apart except at the fault, where they are more closely spaced (Houghton, 1990, p. E21). The range of orientations of fractures in the diabase sills typically is wider than that in sedimentary rocks (Houghton, 1990, p. E18). Because fractures in the diabase are so widely spaced, many unsuccessful wells have been drilled into these rocks (Vecchioli and Palmer, 1962, p. 36).

Three types of fractures control ground-water flow in Mesozoic-basin aquifers--joints parallel to bedding, high-angle joints nearly perpendicular to bedding, and high-angle faults. Joints parallel to bedding serve as the primary flow paths in many of the water-bearing beds. In water-bearing units composed of fissile mudstone and shale, some bedding-plane fractures are less than 1 inch apart (Houghton, 1990, p. E25).



a. Vertical section parallel to strike of bedding.



b. Vertical section parallel to dip of bedding.

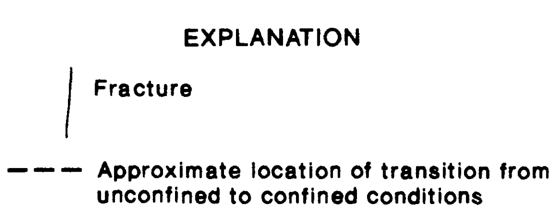


Figure 6. Generalized sections through the study area showing fracture patterns, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central, New Jersey.

High-angle joints provide interconnection between water-bearing units (Houghton, 1990, p. E24). High-angle joints are present in several orientations. The most common (principal) orientation of high-angle joints is northeast striking and southeast-dipping (Houghton, 1990, p. E23). Outcrop evidence indicates that these principal joints are extensive vertically and horizontally (Houghton, 1990, p. E23). Vertically, such joints commonly are continuous through massive (confining) units and terminate in shaly (water-bearing) units (Houghton, 1990, p E24). Other high-angle joints are found in up to three different directions at some locations.

The Hopewell Fault is typical of high-angle faults prevalent in the Mesozoic basins. Rocks on both sides of the fault are densely fractured. Many wells near the Hopewell Fault have higher yields than wells in similar unfaulted rock. These high yields indicate that the aquifers are more permeable in the fault zone than in surrounding areas.

Throughout the study area, the rocks near land surface are extensively weathered. In the weathered zone, circulating ground water has widened fractures and dissolved some of the intergranular cement in the sedimentary rocks, especially in the Stockton Formation (Houghton, 1990, p. E22). Rocks below the weathered zone, which is generally about 75 ft thick, have no intergranular porosity.

The density of horizontal and vertical fractures decreases with depth. The number of fractures in rock cores from the Stockton, Passaic, and Lockatong Formations of the Newark Basin in New Jersey is shown in figure 7 (Dorothy Payne, U.S. Geological Survey, written commun., 1991). The locations from which the rock cores were collected are shown in figure 4. At all three locations, the density of fractures decreases with depth. An analysis of geologic logs of wells drilled in the Newark Basin of Pennsylvania also indicates that the density of fractures decreases with depth (Greenman, 1955, p. 25).

Interconnected, water-bearing fractures are estimated to be present only in rocks less than 500 ft below land surface. This estimate was based on the fact that extending well depths beyond 500 ft usually does not increase well productivity (Greenman, 1955, p. 25).

Unconfined conditions commonly exist in the uppermost zone of water-saturated subsoil, weathered and broken bedrock, and competent bedrock because pores and fractures in this material commonly are well-connected (Houghton, 1990, p E20). Below a certain depth, which varies from about 50 to 150 ft, confined conditions are caused by the presence of low-permeability layers containing relatively few fractures (Houghton, 1990, p. E21).

Depth to bedrock in the study area generally is less than 10 ft. The material on top of the bedrock is unconsolidated clayey silt and sand made up of residual materials from the weathering of bedrock (Holman and others, 1954, p. 23, 39, 42, and 45).

Hydraulic Properties of Aquifers

Specific-capacity tests and aquifer tests have been performed in the aquifers of the Newark Basin to obtain estimates of hydraulic properties of the aquifers. Because tests were performed by using wells that are open to several water-bearing units, they provide information on the aquifer as a whole rather than on discrete water-bearing units.

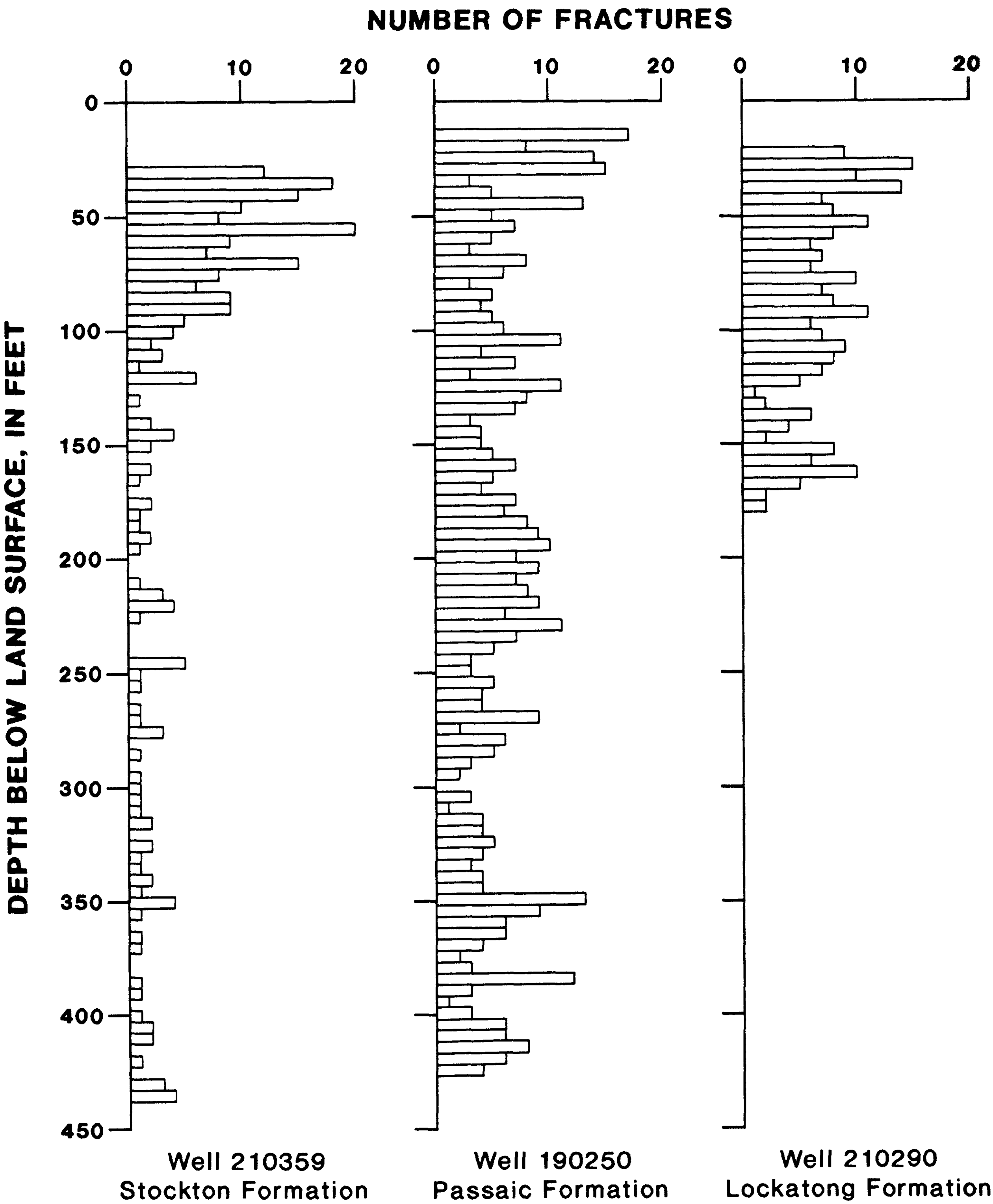


Figure 7. Fracture density in rock cores from wells 210359, 190250, and 210290, west-central New Jersey.

Specific Capacity

Results of specific-capacity tests of 1,492 wells in and near the study area were analyzed to determine the effects of lithology and depth on specific capacity of wells. All wells used in this analysis are domestic wells that are 6 inches in diameter. Public supply and industrial wells were excluded from the analysis because many of these wells are drilled by using methods that maximize yield, and many are located where yield is expected to be greatest. Consequently, these wells probably are not representative of average, or random, conditions. Most wells in the study area are 6 inches in diameter. Wells of other diameters were excluded from this analysis to eliminate the effect of well diameter on specific capacity.

The 1,492 wells include all wells listed in previously published reports (Vecchioli and Palmer, 1962 p. 48-108; Widmer, 1965, p. 52-59; and Kasabach, 1966, p. 58-127) that meet the above criteria and that are open to one of the aquifers in the study area. Wells in Mercer, Hunterdon, and Somerset Counties in the USGS Ground-Water Site Inventory data base also were included in the analysis. Although many of these wells are outside of the study area, they are in the same aquifers as those in the study area. The use of a larger number of wells than those in the study area alone (approximately 400) provided a sufficiently large sample for comparisons to be made among wells in various aquifers and wells of various depths (table 2).

Effect of lithology

A comparison of yield, specific capacity, and specific capacity per foot of open hole among the aquifers in the study area reveals that each aquifer has different hydraulic properties (table 2). Specific capacity per foot of open hole probably is a better measure of hydraulic properties than yield or specific capacity alone because the effect of the length of the open hole is taken into account and because the length of well openings in these wells ranges from 5 to 648 ft. Additionally, specific capacity per foot of open hole has been shown to be directly proportional to hydraulic conductivity (Theis and others, 1963). The median specific capacity per foot of open hole of wells in the Stockton, Lockatong, and Passaic Formations is 0.00545, 0.00115, and 0.00393 ((gal/min)/ft)/ft (gallons per minute per foot per foot), respectively. For wells in diabase rocks, the median specific capacity per foot of open hole is 0.00143. The wells in diabase rocks included in this analysis were all wells that were completed and put into service. Many unsuccessful wells have been drilled into diabase rocks, however; if data for these unsuccessful wells were available and were included in the analysis, the median specific capacity per foot of open hole for diabase rocks probably would be much lower. These data indicate that the Stockton Formation is the most permeable aquifer in the region and diabase is the least permeable.

Specific-capacity data are available for 49 wells in hornfels rocks of the Passaic Formation located at the edges of diabase sills. The median specific capacity per foot of open hole of these wells is 0.00097 ((gal/min)/ft)/ft, much lower than that of the other wells in the Passaic Formation.

Data also are available for 18 wells in the part of the Passaic Formation containing Lockatong-like rocks. The median specific capacity per foot of open hole of these wells, is 0.00130 ((gal/min)/ft)/ft.

Table 2. Yield, specific capacity, and specific capacity per foot of open hole of wells in and near the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

[All wells are 6 inches in diameter and are used only for domestic purposes; gal/min, gallons per minute; ft, foot]

Depth of wells (ft)	Number of wells	Median yield (gal/min)	Median specific capacity [(gal/min)/ft]	Median specific capacity per foot of open hole [((gal/min)/ft)/ft]
		Wells in Stockton Formation		
0- 75	31	18.0	0.952	0.03210
76-100	64	15.0	.620	.01061
101-125	63	20.0	.400	.00440
126-150	47	15.0	.300	.00282
151-175	18	27.0	.749	.00911
176-200	13	15.0	.324	.00257
201-250	17	12.0	.343	.00243
251-300	8	57.5	.434	.00172
301+	10	135.0	1.530	.00393
All wells	271	15.0	0.488	.00545
		Wells in Lockatong Formation		
0- 75	17	12.0	0.526	0.01240
76-100	67	9.0	.233	.00370
101-125	58	6.0	.128	.00167
126-150	58	7.5	.161	.00140
151-175	39	8.0	.133	.00086
176-200	27	6.0	.066	.00039
201-250	33	6.0	.080	.00042
251-300	15	8.0	.088	.00032
301+	34	5.5	.037	.00011
All wells	348	7.0	0.115	.00115

Table 2. Yield, specific capacity, and specific capacity per foot of open hole of wells in and near the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--**Continued**

Depth of wells (ft)	Number of wells	Median yield (gal/min)	Median specific capacity [(gal/min)/ft]	Median specific capacity per foot of open hole [((gal/min)/ft)/ft]
		Wells in Passaic Formation		
0-75	11	15.0	0.545	0.01520
76-100	58	15.0	.500	.00771
101-125	127	15.0	.461	.00536
126-150	180	15.5	.667	.00601
151-175	130	15.0	.644	.00471
176-200	75	17.0	.345	.00223
201-250	66	12.0	.227	.00109
251-300	32	11.0	.129	.00051
301+	30	19.0	.236	.00076
All wells	709	15.0	0.462	0.00393
		Wells in Passaic Formation--contact metamorphic zones		
All wells	49	6.0	0.113	0.00097
		Wells in Passaic Formation--Lockatong-like strata		
All wells	18	7.0	0.105	0.00130
		Wells in diabase rocks		
0-75	25	8.0	0.208	0.00906
76-125	39	5.0	.096	.00143
126+	33	5.0	.040	.00023
All wells	97	5.0	0.109	0.00143

Effect of depth

The specific-capacity data (table 2) indicate that hydraulic conductivity decreases as depth below land surface increases, and that the largest decrease in hydraulic conductivity occurs at about 75 ft below land surface. For wells up to 75 ft deep in the Stockton, Lockatong, and Passaic Formations, the specific capacity per foot of open hole is 2.0 to 3.4 times that of wells 76 to 100 ft deep. For wells in the diabase rocks, the specific capacity per foot of open hole of wells up to 75 ft deep is 6.3 times that of wells 76 to 125 ft deep. Because the open intervals of wells that are 76 to 100 ft deep encompass the depths above as well as below 75 ft, the actual specific capacity per foot of open hole for the zone 76 to 100 ft below land surface must be much less than the specific capacity per foot of open hole for the entire open interval of the wells.

The decrease in specific capacity with depth is a result of the decrease in the density of fractures and the decrease in the effects of weathering. Although the most transmissive zone generally is between land surface and 75 ft below land surface, most wells are drilled deeper than 75 ft for two reasons. First, the additional well bore provides increased storage for water entering the well bore, and the increased storage augments the water supply. Second, the water obtained from the first 75 ft may not be sufficient, and the well is deepened so that additional water-bearing zones contribute water to the well.

Transmissivity

Estimates of transmissivity are summarized in table 3. These data are compiled from the literature and are based on results of aquifer tests conducted during previous studies. Estimates range from 100 to 4,700 ft^2/d for the Stockton Formation, and from 900 to 4,300 ft^2/d for the Passaic Formation . No reports of aquifer tests in the Lockatong Formation or in diabase rocks are available. For most of these estimates, no information was given regarding the method used to estimate transmissivity from aquifer-test data. If the method was inappropriate for the type of aquifer, the estimated transmissivity may be higher or lower than the actual value. For example, if data on an anisotropic aquifer is analyzed by using methods applicable to isotropic aquifers, the estimated transmissivity could be either too high or too low depending on the location of the observation well relative to that of the pumped well. This may explain the wide ranges in transmissivity and storativity based on aquifer-test results.

Storage Coefficient

Reported storage coefficients estimated on the basis of results of aquifer tests in wells in the Stockton Formation range from 0.00001 to 0.367 (table 3). No estimates of storage coefficient have been reported for the other aquifers in the study area.

Porosity

The porosity of most rocks in the study area cannot be measured directly because it is due predominantly to fractures. Herpers and Barksdale (1951, p. 27) estimated that the volume of fractures in the upper 300 ft of the Passaic Formation was about 1 or 2 percent of the total rock volume, but the method used to estimate the volume of cracks is unknown. Rima and others (1962, p. 29) reported on laboratory tests on 12 samples of rock from the Stockton Formation in Pennsylvania. The porosity of those samples ranged from 7.1 to 30.6 percent. The depths from which these samples were obtained were not reported, but it is likely that they were from relatively shallow depths, where intergranular porosity is found in the Stockton Formation.

Table 3. Transmissivity and storage coefficient estimated from results of aquifer tests at selected sites in the Newark Basin, New Jersey and Pennsylvania

[ft^2/d, square feet per day; --, no data available]

Location	Transmissivity (ft^2/d)	Storage coefficient	Remarks	Reference
		Stockton Formation		
Phoenixville, Pennsylvania	2,400	0.0002	Mean, 2 tests, one well	1
Phoenixville, Pennsylvania	2,000	--	Mean, 2 tests, one well	1
Phoenixville, Pennsylvania	2,100	.002	Mean, 2 tests, one well	1
Norristown, Pennsylvania	3,100	.0007	One well	1
Norristown, Pennsylvania	3,200	.0013	Mean, 2 tests, one well	1
Blue Bell, Pennsylvania	130	--	One well	1
Doylestown, Pennsylvania	1,100	.0002	One well	1
Doylestown, Pennsylvania	2,100	.000	One well	1
Doylestown, Pennsylvania	1,900	.0002	One well	1
Langhorne, Pennsylvania	3,100	.0005	One well	1
Chester County, Pennsylvania	1,460	.000137	Pumped well open from 68 to 124 feet below land surface.	1
Chester County, Pennsylvania	260	.367	Pumped well open from 152 to 184 feet below land surface.	1
Middlesex County, New Jersey	1,750	.0002	Pumped well open from 30 to 81 feet below land surface	2
New Jersey and Pennsylvania	100-4,700	.00001-.001	"Few" tests	3
New Jersey and Pennsylvania	700	.00001	"Common" values	3
Mercer County, New Jersey	1,100	.0002	One well	4
		Passaic Formation		
Pennsylvania	900	--	--	5
Pennsylvania	1,200	--	Median, 19 wells	6
Pennsylvania	4,300	--	Mean, 19 wells	6

References:
1 - Rima and others, 1962
2 - Lewis and Spitz, 1987
3 - Barksdale and others, 1958
4 - Vecchioli and Palmer, 1962
5 - Sutton, 1984
6 - Longwill and Wood, 1965

GROUND-WATER FLOW

Ground water in the study area flows through a complex network of fractures further complicated by the presence of nearly impermeable diabase rocks and very permeable fault zones. For this study, both a conceptual and a digital model of the flow system were used to determine flow-system characteristics and the effects of geologic features on the flow system.

Conceptual Model of Ground-Water Flow

A conceptual model of ground-water flow was developed on the basis of the hydrogeologic framework, measured water levels, specific-capacity data, and conclusions of previous investigations. A water-level map of the study area was constructed to help conceptualize ground-water flow, identify recharge and discharge areas, determine the effects of geology on the water-level configuration, and calibrate the digital model (fig. 8).

All of the wells used to draw the water-level map are listed in tables 4a and 4b (at end of report). Most of the wells are open to both unconfined and confined water-bearing units. Therefore, the water levels in these wells are composite heads that include the effects of heads in several water-bearing units. Only 48 wells are less than 75 ft deep--the approximate extent of the unconfined system--and only 6 wells are cased to a depth greater than 75 ft. Consequently, water-level data in both the unconfined and confined systems are insufficient for drawing potentiometric-surface maps. Although the map is not a water-table map or a map of the potentiometric surface of the confined system or of any single water-bearing zone, it indicates the general trend of water levels and was used in this study as an approximation of the configuration of the water-table surface.

Water-level altitudes in wells are controlled primarily by land-surface elevation. The water table is a subdued version of the topography; water levels in topographically high areas generally are a little deeper below land surface than water levels in lowlying areas. In topographically high areas, the measured water levels generally were 25 to 35 ft below land surface, whereas water levels in lowlying areas generally were 0 to 10 ft below land surface. In areas where few water-level data were available, contours were based on the assumption that this water-level trend prevails throughout the study area.

The 544 ground-water levels that were used to draw the map were measured over a period of 83 years (1907-89). Consequently, they represent water levels in different seasons and under different climatic conditions; however, temporal variability in water levels caused by seasonal and long-term climatic fluctuations is assumed to be negligible relative to the spatial variability caused by topography. Water-level data (fig. 9) from three wells in the study area indicate that the long-term seasonal and climatic variability in water levels is less than 15 ft. At well 210365 in the Stony Brook drainage basin, the range in water levels measured from February 1987 through September 1994 is 6.8 ft. In the area of this well, the water-table surface slopes about 45 ft/mi. Water levels in this well have been measured daily except for an 89-day period in 1988 and a 51-day period in 1993. At well 210088 in the Stony Brook drainage basin, the range in water levels measured from January 1968 through September 1994 is 17.2 ft. However, the sharp drops in the water levels in this well during 1987 and 1992 probably are the result of withdrawals from an irrigation well located 800 ft east of this well (Jacobsen and others, 1987, p. 16). Except for these sharp drops, the range in water levels during the period of record is only 4.0 ft. In the area of this well, the water-table surface slopes about 50 ft/mi. Since 1968, water levels in this well have been measured 1 to 12 times per year, except in 1976, when no measurements were made. At

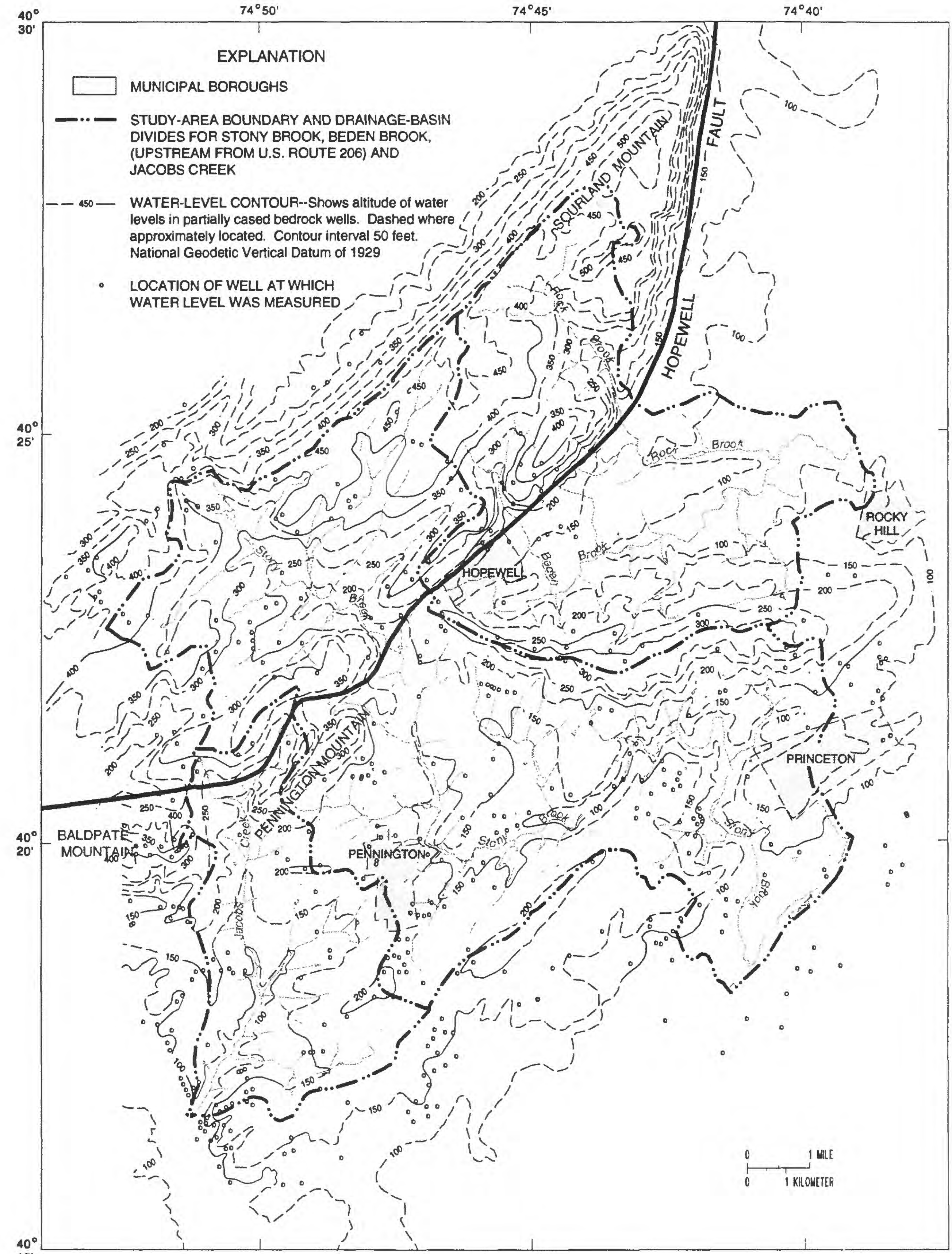


Figure 8. Prepumping ground-water levels in and near the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

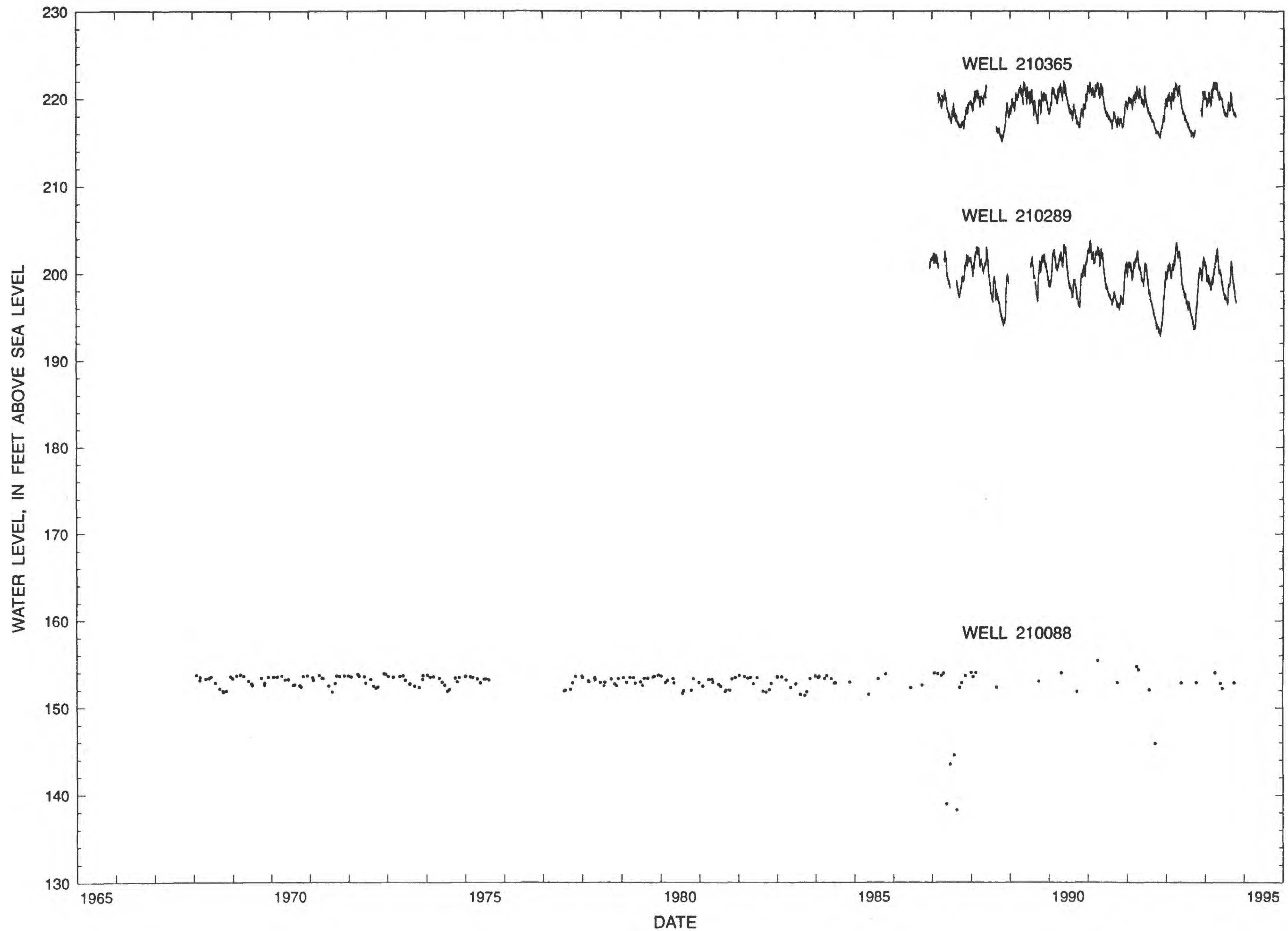


Figure 9. Hydrographs of water levels in wells in the Stony Brook and Jacobs Creek drainage basins, west-central New Jersey.

well 210289 in the Jacobs Creek drainage basin, the range in water levels measured from December 1986 through September 1994 is 10.9 ft. In the area of this well, the water-table surface slopes about 60 ft/mi. Water levels in this well have been measured daily except for a 50-day and a 60-day period in 1987 and a 200-day period in 1989.

Reported water levels in each well in the study area were analyzed to determine whether they represent prepumping conditions. Water levels that were not considered representative of prepumping conditions were not used in drawing the water-level map. Only initial water levels--levels measured at the time each well was constructed--were considered potential prepumping water levels. The water level in each well was further analyzed to determine whether it was affected by nearby pumpage. If the water level in a given well was anomalously low relative to levels in nearby wells, and if the nearby wells had been constructed before the given well, the water level in the given well was assumed to have been lowered as a result of pumpage in the nearby wells. For purposes of this analysis, an anomalously low water level was defined as a water level that was more than 15 ft lower than surrounding water levels if no corresponding depression in land-surface elevation was present. The 15-ft criterion was chosen because differences less than 15 ft could be attributable to seasonal or climatic variability, as discussed in the preceding paragraph.

In applying this criterion, it was found that pumpage from domestic wells had lowered water levels only within a radius of about 500 ft. This situation occurred where two or more wells were installed on the same property and in a housing development where several wells were installed within 200 ft of each other. In each of these areas, the water level in the oldest well was the highest water level and was considered to be representative of prepumpage conditions. The newer wells in these areas were considered to be affected by pumpage. Similarly, it was found that only wells less than 4,000 ft from public supply, industrial, and commercial wells were affected by pumpage from those wells.

The water levels in nearly all of the 544 wells used to develop the water-level map (fig. 8) were measured by personnel from drilling companies at the time the wells were installed. Consequently, the conditions under which the measurements were made are unknown. Some of the measurements could have been made before the water level in the well stabilized and may, therefore, be nonstatic water levels. These water-level data were submitted by drilling companies to the New Jersey Department of Environmental Protection in well-completion records and later compiled in reports by Kasabach (1966), Vecchioli and Palmer (1962), and Widmer (1965) and in the USGS Ground-Water Site Inventory data base. Although some of the data probably are erroneous, the water-level map is assumed to adequately represent the water table for purposes of developing a conceptual model of ground-water flow.

Water levels in streams also were used in the water-level map. Water levels in streams in the study area were assumed to be equal to the water-table altitude under prepumping conditions. This assumption was based on base-flow data collected by Jacobsen and others (1993, p. 20) at 63 sites in the study area. All measured reaches except one, which is near a pumped public supply well, were gaining reaches.

Recharge and Discharge Areas

Ground-water recharge areas, as approximated from the water-level map, are at topographically high areas and discharge areas are at streams. In general, ground-water divides coincide with, or are slightly offset from, surface-water divides, and water follows short flow paths through the shallow part of the system to the stream nearest the point of recharge. Some water does flow in the deep part of the flow system, however, as evidenced by a gradual increase in well yields as wells are deepened. The water in the deep part of the flow system is assumed to be water that recharges at topographic highs, such as areas underlain by diabase rocks, and then flows downward. When this water reaches lowlying areas, it flows upward to the shallow part of the flow system and discharges to major streams, such as Stony Brook, Beden Brook, Jacobs Creek, and the Delaware River. Hypothetical ground-water flow paths are shown in figure 10.

One area in which a ground-water divide is offset from the surface-water divide is at the western border of the study area, near Baldpate Mountain (fig. 8). In this area, the surface-water divide is delineated by a topographic high at the western edge of the Jacobs Creek drainage basin, but the ground water divide is farther west, at the crest of Baldpate Mountain, an area underlain by diabase rocks. The surface-water divide at the edge of the study area is at an altitude of about 240 to 260 ft, but the divide at Baldpate Mountain is at about 485 ft. Ground-water recharge at Baldpate Mountain flows east from the mountaintop under the divide at the study-area boundary and into the study area.

Anisotropy of Sedimentary Aquifers

Elliptical cones of depression around pumped wells are evidence of anisotropic conditions in Newark Basin aquifers. In the study area, for example, an aquifer test conducted by Vecchioli and others (1969, p. B155) resulted in 7.6 ft of drawdown 600 ft along strike from the pumped well and only 0.7 ft of drawdown 300 ft along dip from the pumped well (fig. 11). Similar elliptical cones of depression elsewhere in the Newark Basin have been described by Vecchioli (1967), Herpers and Barksdale (1951, p. 29-31), and Longwill and Wood (1965).

The anisotropic conditions observed in Newark Basin aquifers are a direct result of dipping interlayered water-bearing units and confining units. In the water-bearing units, water can flow long distances in the direction of the strike of the bedding without encountering barriers (fig. 6a). Water cannot flow long distances in the direction of dip, however, because each water-bearing unit contains fewer interconnected fractures as it deepens with dip, and at a depth of about 500 ft below land surface, all fractures are closed. Therefore, hydraulic conductivity is greater in the strike direction than in the dip direction.

In anisotropic systems, ground-water-flow directions are not necessarily perpendicular to lines of equal hydraulic head, as they would be in isotropic systems; rather, they are skewed in the direction of the highest hydraulic conductivity. Therefore, in the study area, lines drawn perpendicular to water-level contours do not accurately define ground-water flow paths except where they are parallel to the strike of the bedding. Elsewhere, ground-water flow paths are skewed away from those perpendicular lines toward the strike direction.

Effect of Diabase Rocks

Fractures are far more sparse in diabase rocks than in any of the other rocks in the study area. Low specific capacity per foot of open hole for wells in the diabase reflects this sparsity of fractures and is indicative of low hydraulic conductivity. Consequently, diabase rocks impede ground-water flow.

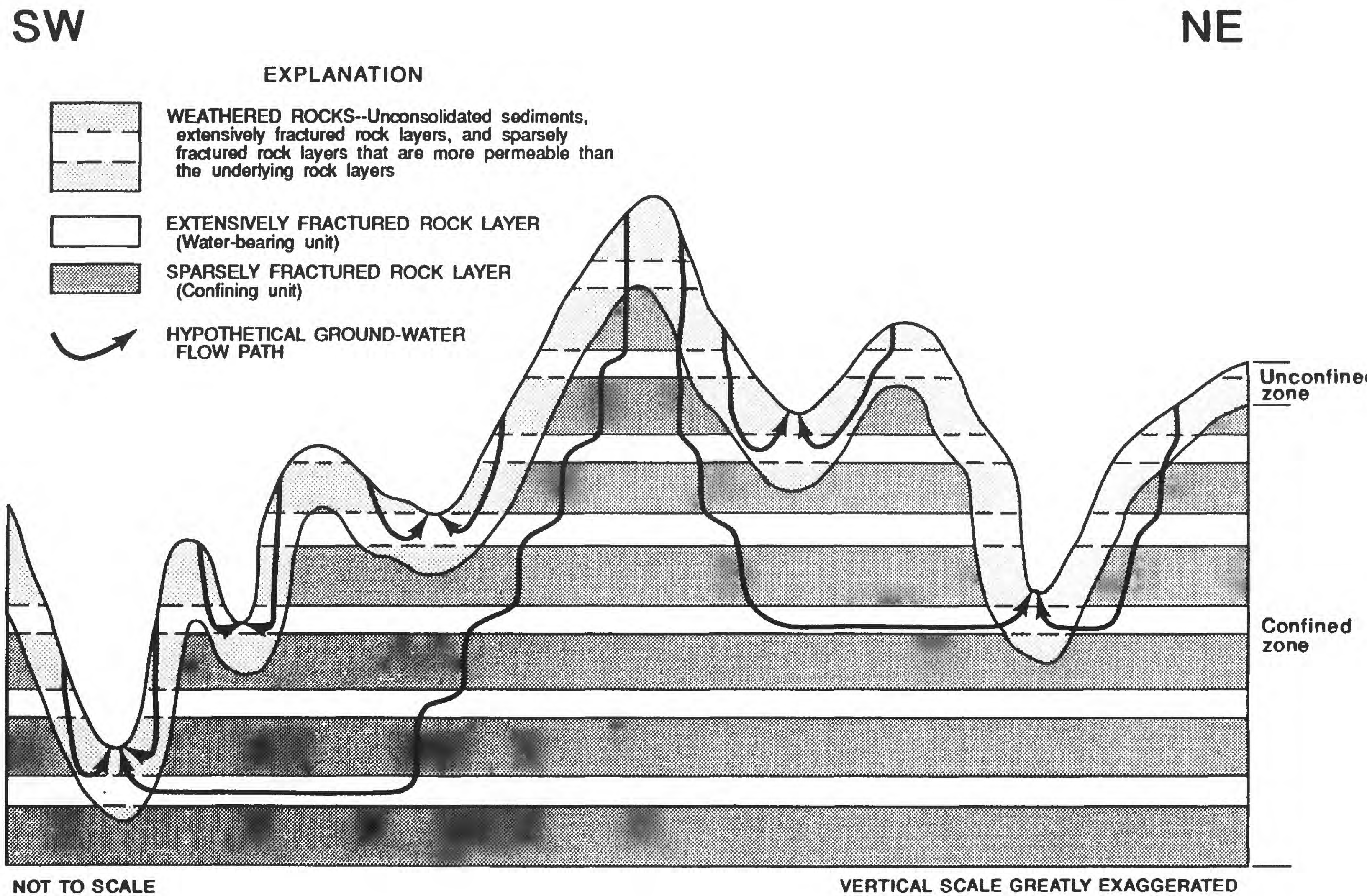


Figure 10. Hypothetical ground-water flow paths in the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey. (Section is oriented parallel to the strike of rock layers.)

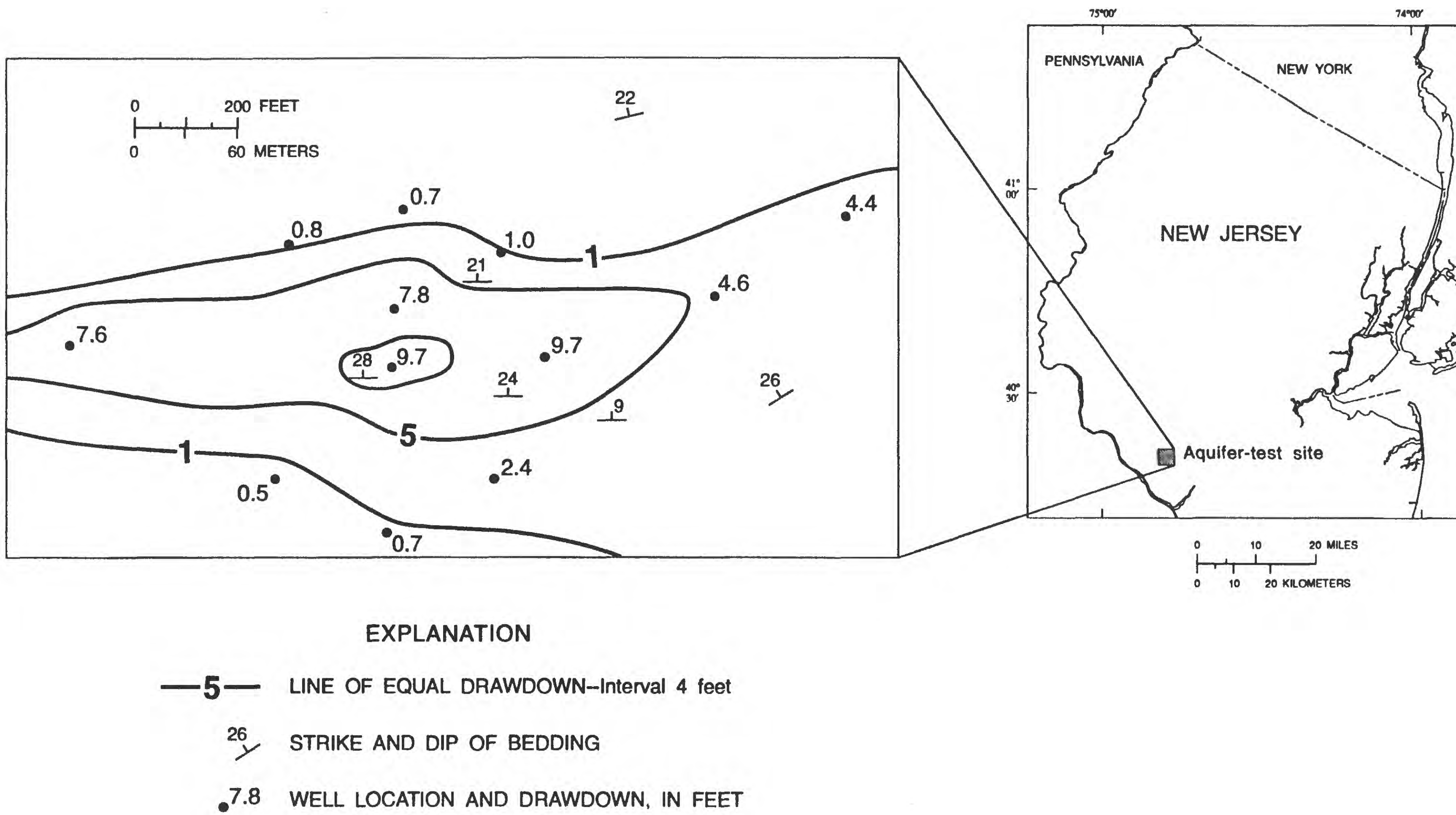


Figure 11. Drawdown at end of aquifer test in Stony Brook drainage basin, west-central New Jersey. (Modified from Vecchioli and others, 1969)

Source of Water to Wells

Water flowing to a pumped well is derived primarily from the water-bearing units that are intersected by the well and secondarily from other water-bearing units by leakage through the confining units. If one or more of the water-bearing beds intersected by a well is connected to an updip surface-water body, the well probably derives a significant part of its flow from the stream by induced infiltration. Vecchioli and Palmer (1962, p. 32-34) found that the average yield of wells near surface water is about twice that of wells that are not near surface water.

Stream-discharge data indicate the possibility of induced infiltration near pumped wells along a reach of Stony Brook. Base-flow measurements made during August and November 1987 (Jacobsen and others, 1993, table 4) indicate a loss of 0.16 ft^3/s between measurement sites 01400920 and 01400940 (fig. 17, farther on) in August and a loss of 0.23 ft^3/s along the same reach in November. Although the apparent decrease in discharge along the reach could be due to the measurement uncertainty (R.D. Schopp, U.S. Geological Survey, oral commun., 1991), it is also possible that the loss resulted from pumpage of nearby Pennington Borough public supply wells (fig. 18, farther on).

Simulation of Ground-Water Flow

A digital model that simulates steady-state, prepumping conditions was used to test hypotheses concerning the effects of geologic features on ground-water flow in the study area. These features include the decrease in the density of fractures with depth, the anisotropy caused by dipping water-bearing rock strata, the nearly impermeable diabase sills, and the relatively permeable Hopewell Fault. The model was developed with sufficient detail to simulate these features, but not all of the local complexities of the hydrogeologic framework are simulated in the model. Consequently, the model was not designed as a tool for detailed quantification of flow at discrete points or for development of water policies and regulations for any part of the study area.

Description of Digital Model

A three-dimensional, finite-difference Fortran code (MODFLOW) developed by McDonald and Harbaugh (1988) was used for the simulation. The code was revised to allow for variable anisotropy ratios within each model layer. The anisotropy ratio is the hydraulic conductivity along model columns (the dip direction) divided by the hydraulic conductivity along model rows (the strike direction).

Grid orientation and discretization

The model grid (fig. 12) was oriented so that the model rows coincided with the strike of the geologic units to allow simulation of the difference in horizontal hydraulic conductivity in the strike and dip directions. The model was discretized into 122 rows, 150 columns, and 2 layers. Of the 36,600 model cells, 19,838 are active. The inactive cells are outside the study area. Each model cell is 500 ft long and 500 ft wide. This horizontal discretization scheme allowed for adequate representation of each zone of different hydraulic conductivity. Each zone is at least two cells wide, and most are five or more cells wide.

The decrease in conductivity with depth was represented in the model by dividing the grid into two layers. The vertical discretization is based on the results of the analysis of specific-capacity data shown in table 2. The specific-capacity data indicate that specific capacity

EXPLANATION

□ Model cell

■ Model cell containing a stream simulated as a specific-head boundary with a semipermeable streambed

▩ Model cell containg a stream simulated as a flux boundary

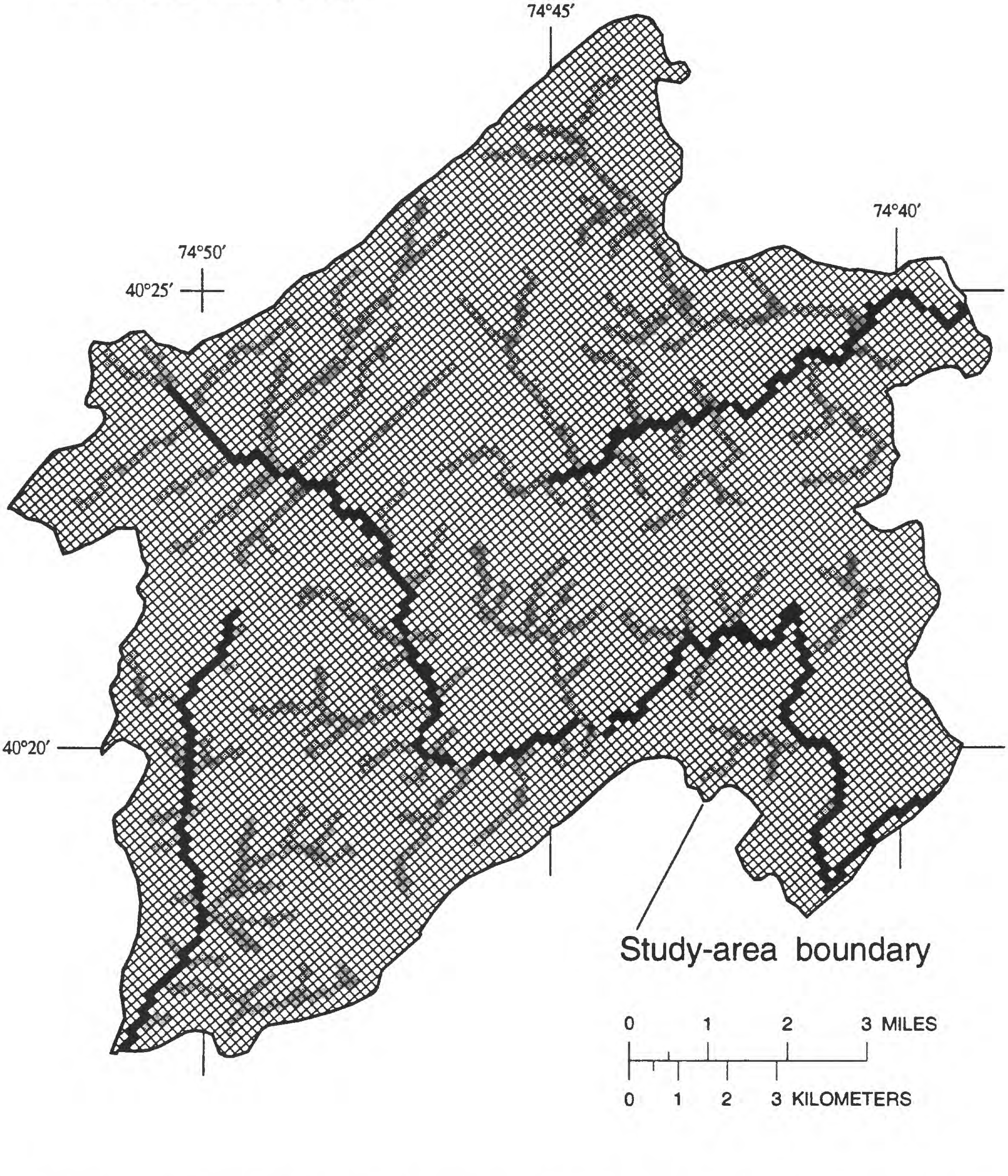


Figure 12. Discretization and orientation of digital-model grid and locations of model cells containing streams, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

decreases with depth below land surface, and that the largest decrease in specific capacity occurs at about 75 ft below land surface. Accordingly, model layer 1 is generally less than 75 ft thick and consists of the saturated portion of the interval between land surface and 75 ft below land surface. Model layer 2 consists of the depth interval from 76 ft to 500 ft below land surface.

Layer 1 was simulated as an unconfined aquifer and represents the part of the aquifer system in which fractures are much more abundant and interconnected than in the lower part of the system (figs. 6a and 6b). Layer 2 was simulated as a confined aquifer and represents the part of the aquifer system where water-bearing units are confined by interlayered confining units (figs. 6a and 6b). Each of the model layers spans several water-bearing and confining units.

In areas where land-surface elevation decreases abruptly, the bottom of model layer 1 is deeper than 75 ft below land surface. These areas are found at the edges of diabase sills, at the escarpment of the Hopewell Fault (fig. 8), and in the area northwest of the escarpment where streams have incised deeply into the rocks of the Stockton Formation. In these areas, the water table is farther below land surface than in other areas. The bottom of layer 1 was set deeper than 75 ft below land surface in these areas so that the saturated thickness of layer 1 would be approximately constant throughout the study area. The altitude of the bottom of layer 1 for each model cell in these areas was set at the average altitude of the bottoms of the cells immediately upslope and downslope from the cell. The bottom of layer 1 reaches its maximum depth below land surface (208 ft) in a model cell located near the eastern edge of the diabase sill known as Pennington Mountain (fig. 4). The bottom of layer 1 is more than 75 ft below land surface in only 8 percent of the model area, and more than 100 ft below land surface in only 2 percent of the area.

The bottom of model layer 2 is 500 ft below land surface throughout the model. The depth of 500 ft was chosen on the basis of reports that Newark Basin rocks deeper than 500 ft below land surface yield little or no water. A schematic representation of model layers and boundary conditions is shown in figure 13.

Boundary conditions

Model boundaries coincide with hydrologic boundaries. Except for the upper surface, most boundaries are no-flow boundaries.

Upper boundary and simulation of surface water.--The upper boundary was simulated as a free surface to represent the water table with specified flux applied to represent areal recharge. The method by which the rate of areal recharge was determined is discussed in the section "Areal recharge," farther on.

Surface water was simulated in two ways. Except for the uppermost reaches, the three major streams--Stony Brook, Beden Brook, and Jacobs Creek--were simulated as head-dependent-flux boundaries by using the "River module" of the MODFLOW model. In this module, the head in the stream is specified, and water flows between the aquifer and the stream through the streambed. The rate of flow between the aquifer and the stream is controlled by the head difference between the stream and the aquifer, the hydraulic conductivity and thickness of the streambed, and the length and width of the stream. The method by which these parameters were estimated is described in the section "Streambed hydraulic conductance," farther on.

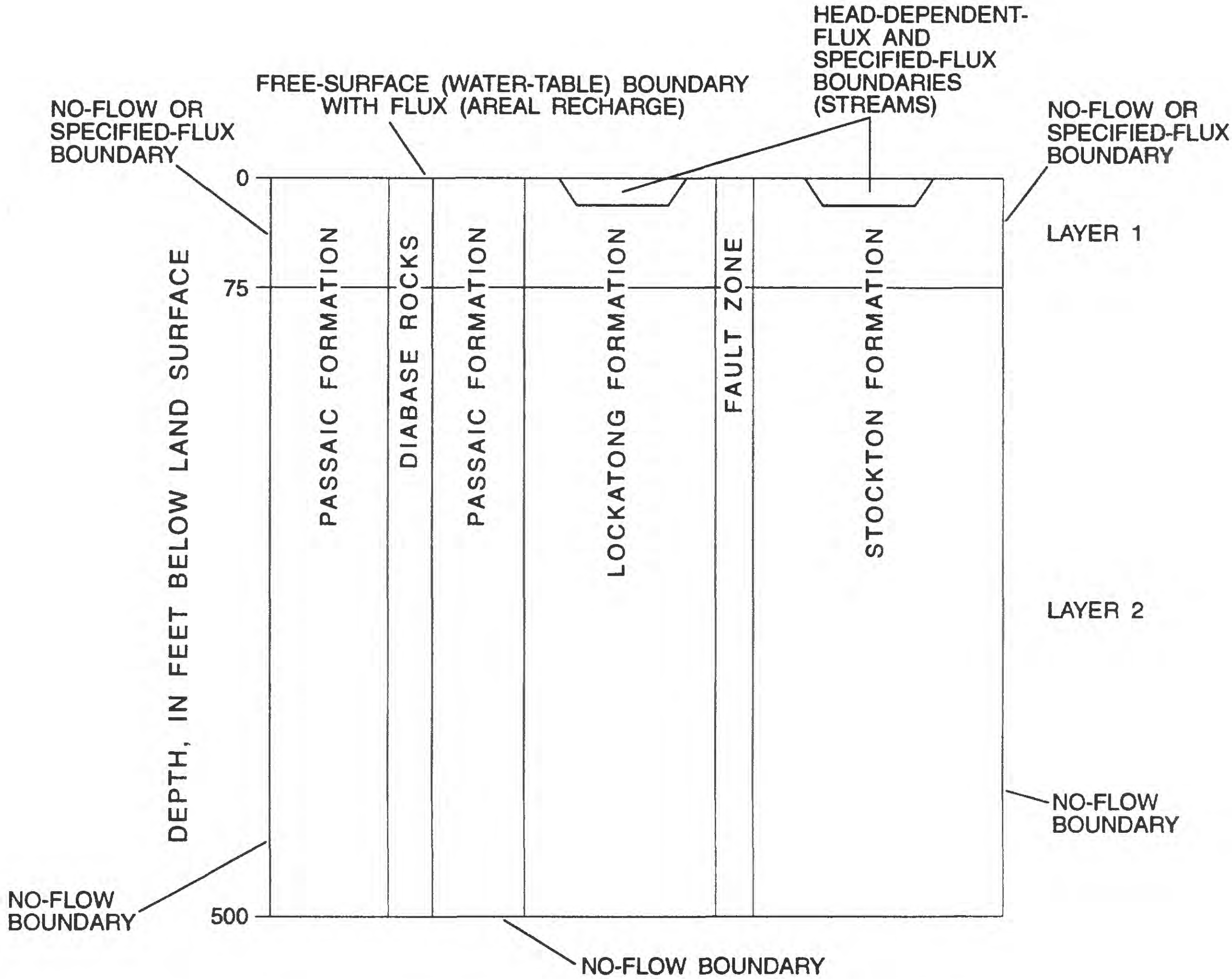


Figure 13. Schematic representation of model boundary conditions, layers, and zones of different hydraulic conductivity, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

The tributaries to and the uppermost reaches of Stony Brook, Beden Brook, and Jacobs Creek were modeled as specified-flux boundaries rather than head-dependent-flux boundaries. This was done because the model was found to be very sensitive to specified heads in streams, and the water level in these stream reaches falls as much as 20 ft over the length of a model cell. Therefore the average elevation of these stream reaches within a model cell is a poor representation of the stream elevation at all points in the cell. The method by which the flux to each model cell was determined is discussed in the section "Base flow and direct runoff," farther on.

The study area contains many lakes and ponds, none of which was assigned a boundary condition because all lakes and ponds are artificial and do not represent natural or prestressed conditions. Most of the ponds and small lakes were dug for irrigation or aesthetic purposes, and all of the larger lakes are dammed reaches of streams.

Lateral boundaries.--Lateral model boundaries coincide with the study-area boundary, which was defined by surface-water divides. In all but two areas, ground-water divides coincide with these surface-water divides, and no-flow cells were used in the model to represent the boundary. The two areas where ground-water divides do not coincide with surface-water divides are near Baldpate and Sourland Mountains (fig. 8). Water levels near Baldpate Mountain indicate that ground water flows from Baldpate Mountain eastward into the study area. There, layer 1 was simulated as a specified-flux boundary. The flux was placed only in layer 1 because Baldpate Mountain is just outside the model area. Consequently, the flow path from the mountaintop to the study area is relatively short and was assumed to be wholly in layer 1. To test the hypothesis that this flux occurs only in layer 1, the model was tested with some of the flux applied to layer 2. The model best simulated heads and base flow when flux was applied only to layer 1. The total amount of flow crossing this flux boundary was set at 104,500 ft^3/d distributed among 10 model cells at the model boundary. The method by which the amount of flux was determined is described in the section "Ground-water flow to and from adjoining drainage basins," farther on.

Flux also was applied at the model boundary in the area south of Sourland Mountain and north of Rock Brook (fig. 8) to simulate water flowing from Sourland Mountain into the study area. Sourland Mountain, which is underlain by diabase, extends northeast beyond the study area. Water that recharges the part of Sourland Mountain lying outside the study area probably flows southeast or south from the mountaintop toward the escarpment of the Hopewell Fault. After reaching the fault, which is much more permeable than the surrounding rocks, ground water probably flows along the fault southwest into the study area. The total amount of flow simulated crossing this flux boundary is 27,300 ft^3/d distributed across five model cells in layer 1.

Ground water in the deep part of the system may flow out of the study area and eventually discharge to the Delaware River. No flux boundaries were applied to the model to simulate this type of flow, however. The model was tested with various amounts of flux leaving the western border of the model through layer 2, but the matches between measured and simulated heads and measured and simulated base flow to streams were not improved by this flux. Also, because no wells that are open only to layer 2 are located near the model boundary, no field evidence exists of flow out of the study area in the deep part of the aquifer system.

Lower boundary.--The lower model boundary represents the depth below land surface at which ground-water flow is negligible. This depth was assumed to be 500 ft. The lower boundary was simulated as a no-flow boundary.

Calibration of Digital Model

All values of hydraulic properties initially used in the model were estimates. During model calibration, the initial estimates of horizontal hydraulic conductivity, anisotropy ratio, vertical conductance between model layers, and streambed conductance were adjusted until the model was an acceptable representation of the conceptual model. During calibration, it was assumed that no-flow boundaries adequately represent the actual flow system at the bottom of layer 2 and at the model perimeter except in the two small areas described in the preceding section, and no additional adjustments were made to the no-flow boundaries.

Determining the acceptability of the match between simulated and conceptual ground-water flow system is subjective. Although an attempt was made to match measured prepumping water levels and estimated base-flow rates as closely as possible, an exact match was not possible because many of the small-scale complexities of the geologic framework are not represented in the model. For example, in the model, hydraulic conductivity is constant over each outcropping geologic unit, whereas the actual conductivity probably varies because the spacing of interconnected fractures varies. Consequently, measured water levels in areas where the spacing between fractures differs from the average spacing will be outside the range of simulated water levels.

Water levels

Two sets of data were used to compare measured and simulated water levels. One data set consists of water levels measured by the USGS in October 1987, in 65 wells in the study area. In this report, this data set is referred to as the "U.S. Geological Survey water-level data." During model calibration, each of these 65 water levels was compared to model-generated heads (table 5). Water levels in this data set are known to be accurate to within 0.01 ft because the methods used and the conditions under which the measurements were made are documented (Jacobsen and others, 1993, p. 8). Seasonal and long-term variability in water levels in this data set are minimal because all the water levels were measured within a 21-day period. During this period, 2.05 inches of precipitation fell in the study area, but the water level in wells 210088 and 210365 (fig. 4) rose only 1.59 ft and 0.67 ft, respectively. In addition, the levels in all 65 wells could be assumed to be static levels and representative of unstressed conditions because none of the wells are within 4,000 ft of industrial, commercial, or public supply wells. In addition, none of the measured wells or nearby domestic wells had been pumped for at least 1 hour prior to measurement. Well locations and the difference between measured and simulated water levels are shown in figure 14.

The other data set consists of the 544 water levels used to draw the water-level map (fig. 8). In this report, this data set is referred to as "well-completion-record data." As described in the section "Conceptual model of ground-water flow," the accuracy of individual water-level measurements in this data set and the conditions under which the measurements were made is unknown. Therefore, these water levels were not compared individually with model-generated heads for model calibration. Instead, the water-level map (fig. 8) was compared with a contour map of model-generated composite heads (fig. 15b) to compare measured and simulated water levels throughout the study area, including areas where data are sparse (dashed contours on figure 8). Figure 15a includes the same water- level contours as figure 8 drawn to the same scale as figure 15b so that the two sets of water-level contours can be compared directly.

Table 5. Measured and simulated water levels in selected wells in the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

New Jersey well number	Measured water level (feet above sea level)	Simulated water level (feet above sea level)	Simulated water level minus measured water level (feet)	Water-level-measurement date
		Passaic Formation		
350053	163	125	-38	10-15-87
350058	170	136	-34	10-14-87
350057	152	122	-30	10-14-87
210333	248	224	-24	10-05-87
210341	176	162	-14	10-23-87
350050	86	74	-12	10-06-87
210329	167	162	-5	10-05-87
350028	91	86	-5	10-14-87
350055	72	68	-4	10-03-87
210328	114	111	-3	10-05-87
210355	157	154	-3	10-05-87
350059	66	68	2	10-14-87
210297	109	112	3	10-03-87
210327	106	109	3	10-05-87
210332	172	176	4	10-05-87
190242	285	290	5	10-06-87
350049	86	92	6	10-14-87
210353	184	191	7	10-06-87
210326	111	119	8	10-05-87
210354	136	145	9	10-05-87
350052	105	115	10	10-15-87
210340	144	155	11	10-05-87
210336	139	151	12	10-05-87
350054	110	122	12	10-15-87
210298	165	179	14	10-14-87
210321	138	152	14	10-05-87
210352	153	167	14	10-05-87
210301	125	144	19	10-05-87
210295	130	154	24	10-05-87
210337	128	152	24	10-05-87
		Lockatong Formation		
210300	205	186	-19	10-05-87
190241	297	282	-15	10-06-87
350060	164	151	-13	10-14-87
210331	169	157	-12	10-06-87
210357	127	116	-11	10-05-87
210324	61	54	-7	10-05-87
210356	161	156	-5	10-05-87
210325	209	209	0	10-06-87
210292	288	300	12	10-06-87
210347	185	197	12	10-05-87
350048	414	428	14	10-14-87
350061	257	272	16	10-14-87
210296	384	402	18	10-05-87
210350	180	201	21	10-06-87
210349	184	208	25	10-06-87
210313	294	320	26	10-06-87
350056	392	440	48	10-15-87
350041	353	408	55	10-15-87
350051	297	414	117	10-14-87

Table 5. Measured and simulated water levels in selected wells in the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

New Jersey well number	Measured water level (feet above sea level)	Simulated water level (feet above sea level)	Simulated water level minus measured water level (feet)	Water-level-measurement date
		Diabase rocks		
210315	323	272	-51	10-14-87
190239	370	339	-31	10-06-87
210345	289	258	-31	10-05-87
210346	254	228	-26	10-05-87
210314	207	188	-19	10-05-87
210334	238	225	-13	10-05-87
210338	262	261	-1	10-05-87
210302	321	325	4	10-15-87
210335	280	284	4	10-05-87
190240	421	460	39	10-05-87
210294	189	316	127	10-05-87
		Stockton Formation north of the Hopewell Fault		
210344	366	328	-38	10-05-87
210303	314	313	-1	10-05-87
210265	327	342	15	10-15-88
210316	386	410	24	10-15-87
350047	150	222	72	10-14-87

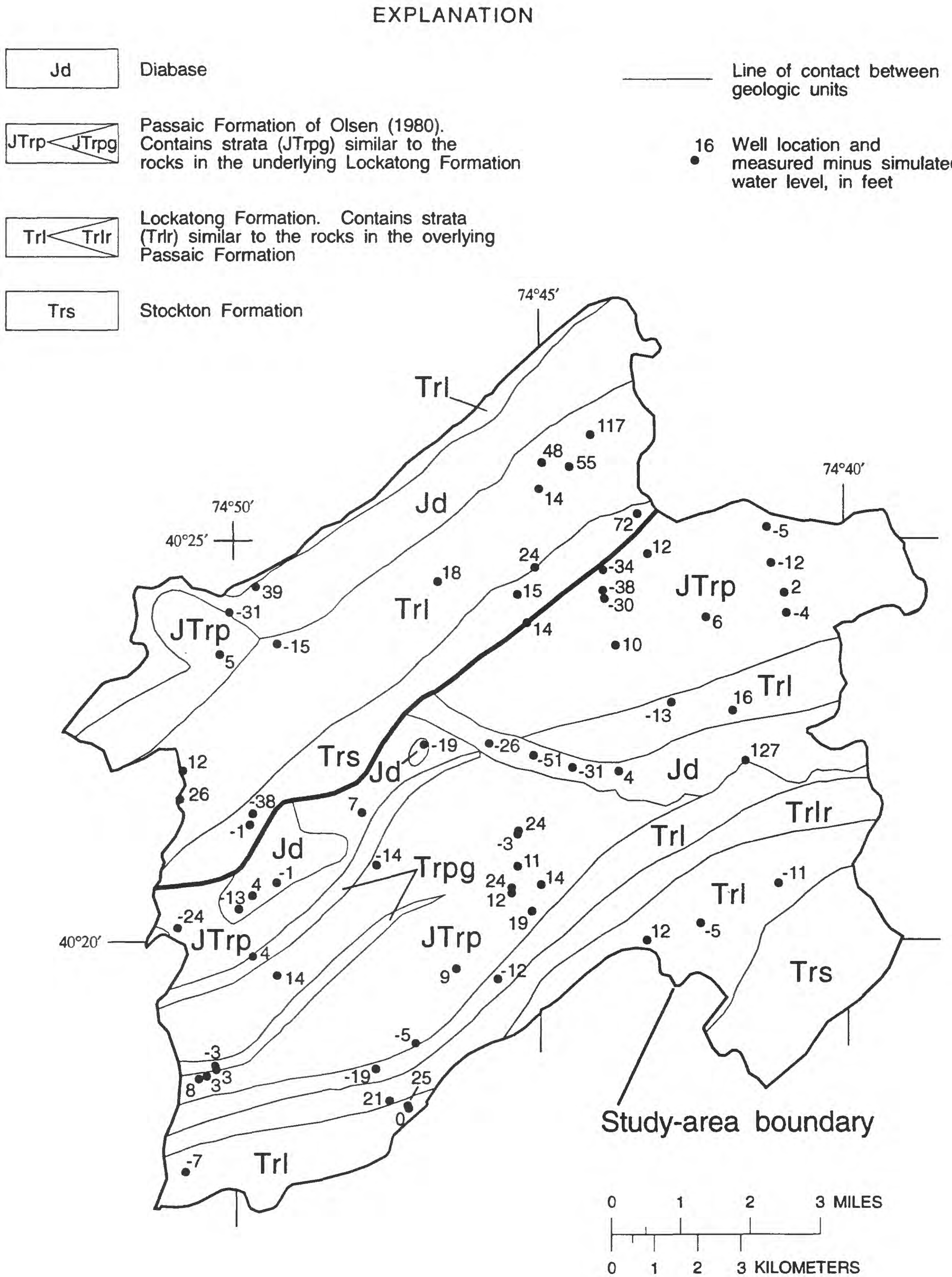


Figure 14. Location of water-level-measurement sites and difference between measured and simulated water levels, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

EXPLANATION

——250- - - - - INTERPRETED WATER-LEVEL CONTOUR-- Shows altitude of water level, in feet. Dashed where approximate. Contour interval 50 feet. Datum is sea level

STREAM

SURFACE-WATER DRAINAGE-BASIN BOUNDARY

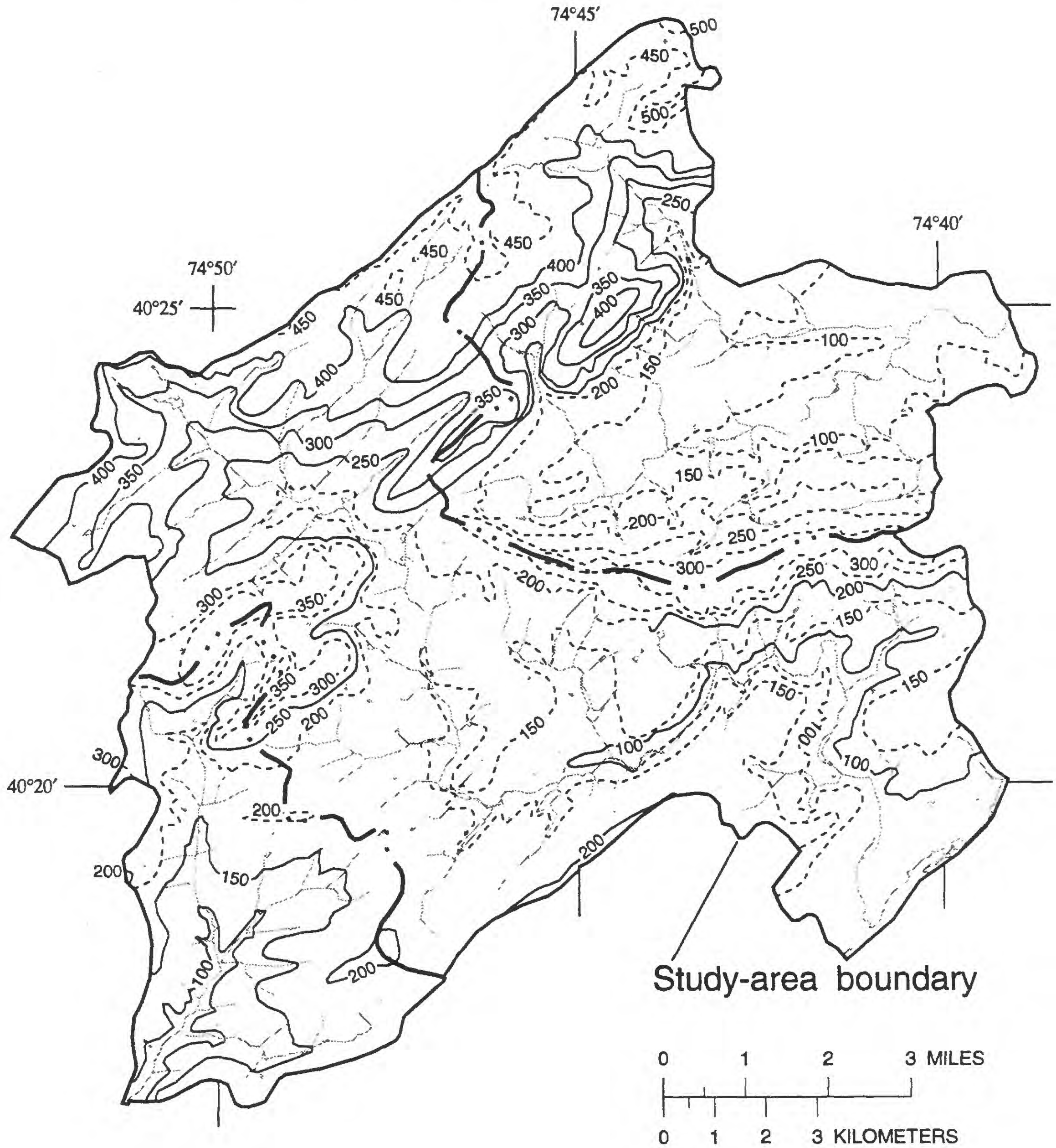


Figure 15a. Interpreted prepumping water levels in the study area Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

EXPLANATION

—— 250 - - - - SIMULATED WATER-LEVEL CONTOUR-- Shows altitude of water level, in feet. Dashed where approximate. Contour interval 50 feet. Datum is sea level

STREAM

— · · — SURFACE-WATER DRAINAGE-BASIN BOUNDARY

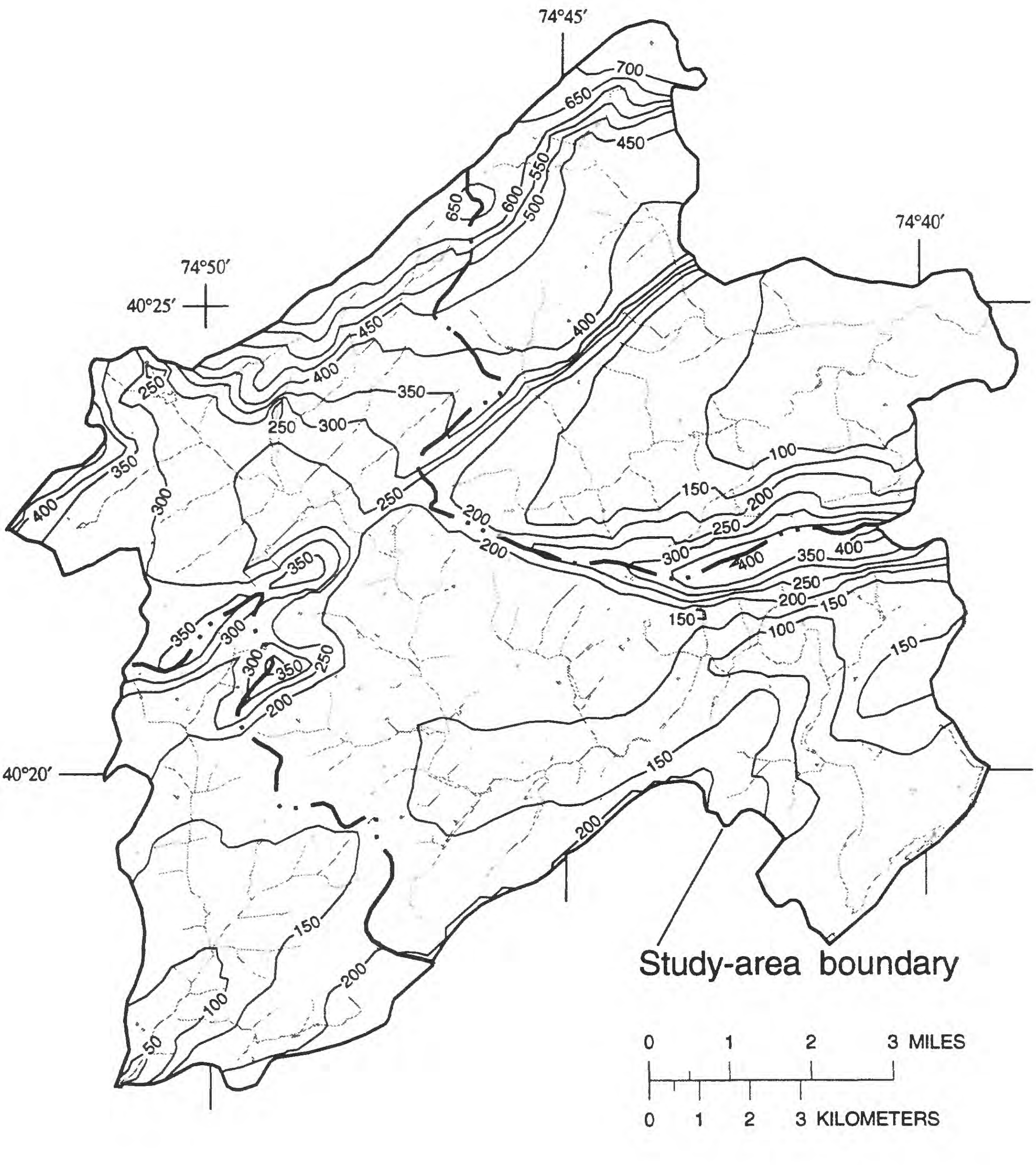


Figure 15b. Simulated prepumping water levels in the study area Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

To compare simulated heads in the two model layers to measured composite water levels, the simulated heads for layers 1 and 2 at each model-cell location were converted into a composite head. The following relation, described by Hearne (1985, p. 11), was used for the conversion:

$$h_w = \frac{b_1 K_1 h_1 + b_2 K_2 h_2}{b_1 K_1 + b_2 K_2} ,$$

where h_w = the composite simulated hydraulic head in the well;

h_1 = the simulated hydraulic head in model layer 1;

h_2 = the simulated hydraulic head in model layer 2;

b_1 = the saturated thickness of model layer 1, calculated by subtracting the altitude of the bottom of the layer from the simulated head;

b_2 = 83 ft--the average length of well opening in model layer 2. This equals the average depth of all domestic 6-inch-diameter wells in the study area (158 ft) minus the average depth below land surface of the top of model layer 2 (75 ft);

K_1 = the hydraulic conductivity of model layer 1 in the strike direction; and

K_2 = the hydraulic conductivity of model layer 2 in the strike direction.

That is, the hydraulic head in the well is the weighted average of the hydraulic heads in each of the layers with which the well is in hydraulic connection. The weighting factor is the product of the thickness and the horizontal hydraulic conductivity of the layer.

For wells that are 75 ft deep or less, the measured water level was compared to the simulated head in layer 1 rather than to the composite head, and for wells that are cased from land surface down to at least 75 ft, the measured water level was compared to the simulated head in layer 2.

U.S. Geological Survey water-level data.--For this data set, the model was considered adequately calibrated when measured water levels were simulated within the following limits:

-Within 25 ft in areas of low relief (about 100 ft). Low relief is found in areas underlain by the Passaic Formation and in the area underlain by the Stockton Formation at the southern boundary of the study area.

-Within 30 ft in areas underlain by the Lockatong Formation, where topographic relief is moderate (about 150 ft).

-Within 40 ft in areas of high topographic relief (about 200 ft). High relief is found in areas underlain by diabase rocks, at the escarpment of the Hopewell Fault, and in the area underlain by the Stockton Formation northwest of the fault, where streams are deeply incised.

A more rigorous calibration criterion was used in areas of low topographic relief than in areas of high topographic relief because areas of low topographic relief are also areas of low spatial variability in water levels as a result of the relation between the water table and topography. In areas of low, moderate, and high topographic relief, water levels vary about 5 to 20 ft, about 10 to 40 ft, and about 40 to 100 ft, respectively, within individual model cells, whereas the digital model simulated only a single average head in each model cell.

Because actual water levels within a model cell can vary as much as 100 ft, the actual water level at various points in the cell can differ significantly from the average head in the cell, especially at the cell edges. For this reason, the location within a cell of each water-level measurement was determined, and the simulated water level for each site was estimated by linear interpolation between simulated water levels in adjacent cells. Even with these interpolated water levels, however, the model cannot adequately simulate water levels in area of high topographic relief, especially where the change in water levels is not linear.

The measured and simulated water levels in this water-level data set are listed in table 5. Composite simulated heads in 27 of the 30 wells in the Passaic Formation were within 25 ft of the measured heads. None of the 65 wells in which water levels were measured in October 1987 was in the part of the Stockton Formation that crops out south of the Hopewell Fault, so no direct comparisons can be made between measured and simulated water levels in this area. For wells in the Lockatong Formation, 16 of the 19 simulated water levels were within 30 ft of the measured water level. For wells in the Stockton Formation north of the Hopewell Fault and wells in the diabase rocks, 13 of the 16 simulated water levels were within 40 ft of the measured water level.

Well-completion-record data.--The map of contoured water levels from the well-completion-record data set (fig. 15a) compared well with the map of contoured composite model-generated composite heads (fig. 15b) in most parts of the study area. Poor agreement was obtained, however, in the northeastern part of the study area, which is underlain mostly by diabase rocks. Water levels there range from about 330 to 550 ft (fig. 15a), but simulated water levels range from 450 to 750 ft (fig. 15b). Although water-level data in the area are sparse, and the interpreted water levels are approximate, actual water levels in this area most likely are less than 570 ft--the highest land-surface elevation in the area--because it is doubtful that wells in this area are flowing. The high simulated water levels could be caused by one of several factors. For example, a uniform recharge rate was applied to the entire diabase sill in this area; however, the rate of recharge to the crest of the sill may be lower than the rate to other parts of the sill. Also, some water that recharges at the ridge of the sill near the northern boundary of the model may flow north out of the model area.

The composite simulated heads in streams (fig. 15b) are higher than the stream stage (fig. 15a) in many parts of the study area, partly as a result of a difference in the method used to determine water levels at stream locations for the two maps. The composite heads in the aquifer at stream locations in figure 15a are equal to stream stage. The water levels at stream locations in figure 15b are the average composite heads in the aquifer for the entire model cell in which the stream is located. In the model, because all of the streams in the study area are assumed to be gaining under prepumping conditions, the water level in the aquifer surrounding the stream is higher than the stream level. Consequently, the average head in model cells containing streams is higher than the actual stream level.

Base flow

The model was considered adequately calibrated with respect to base flow if the total simulated base flow in the part of the Stony Brook drainage basin upstream from streamflow-gaging station 01401000 (fig. 17, farther on) was within 5 percent of the estimated average prepumping base flow, and if the total simulated base flows for the Beden Brook and Jacobs Creek drainage basins (ungaged basins) were within 15 percent of the estimated average base-flow rates. The calibration criterion for the gaged basin was more stringent than for the ungaged basins because the estimate of average-annual base flow is more accurate for gaged basins than for ungaged basins.

The estimated average prepumping base flows for the Stony Brook (upstream of the streamflow-gaging station), Beden Brook, and Jacobs Creek drainage basins are 2,280,000, 1,800,000, and 874,000 ft^3/d, respectively. The methods used to estimate base flow are described in the "Base flow and direct runoff" section (farther on).

Simulated total base flows for the Stony Brook (upstream from the streamflow-gaging station), Beden Brook, and Jacobs Creek drainage basins are 2,320,000, 1,590,000, and 789,000 ft^3/d, respectively. The simulated flow for each basin was determined by use of a computer program (ZONEBUDGET) that calculates subregional water budgets from cell-by-cell flow in the model (Harbaugh, 1990). For each basin, total simulated base flow was assumed to be the sum of the flow to streams simulated as constant-flux boundaries ("Well module" of MODFLOW) and the flow to streams simulated as head-dependent-flux boundaries ("River module" of MODFLOW) minus the flow from streams to the aquifer at head-dependent-flux boundaries.

For the part of the Stony Brook drainage basin upstream from the streamflow-gaging station, the simulated base flow is 1.75 percent higher than the estimated average prepumping base flow. For the Beden Brook and Jacobs Creek Basins, the simulated base flows are 11.7 and 9.73 percent lower, respectively, than the estimated average prepumping base flows.

Limitations of Digital Model

Because the model necessarily is a simplified representation of the ground-water-flow system, its discretization limits its ability to simulate flow accurately. The vertical discretization of the model, in which two layers are used to represent the flow system, does not address the intricacy of the hydrologic framework. Ideally, each water-bearing unit would be represented by a separate model layer, but this is not feasible in a model that represents an area as large as the study area. First, the location and configuration of each water-bearing unit is not known and could be known only if many exploratory holes were drilled and logged. Second, far too many water-bearing units (approximately 125) are present in the study area for each to be modeled as a separate layer. Modeling this many units is not feasible because of the time required for each model run made during calibration and analysis.

In this model, the effect of the discontinuity of water-bearing units in the dip direction is simulated by assigning a lower hydraulic conductivity in the dip direction than in the strike direction. This representation of the flow system is adequate on a large scale but not in individual water-bearing units. For a local, or site-specific, problem, where the area of interest is less than about 0.5 mi^2, precise determination of flow paths within and between individual water-bearing units is necessary. For the purposes of this study, however--analysis of the effects of relatively large-scale features on ground-water flow--the model is adequate.

The other complexity this model does not address is the variability of fracture spacing within each geologic unit. This limitation also precludes use of the model for site-specific problems but does not detract from its usefulness as a tool for studying the effects of large-scale geologic features on ground-water flow.

Prepumping Water Budgets

Ground-water budgets simulated with the digital model for all three surface-water drainage basins in the study area are shown in figure 16. The budget for the Stony Brook drainage basin pertains to the part of the basin upstream from streamflow-gaging station 01401000, which is about 2 miles upstream of the point at which Stony Brook crosses the study-area boundary (fig. 17). This gaging station has provided a continuous record of streamflow since October 1953. The part of the basin upstream from the gaging station consists of 44.5 mi^2; the downstream part is 3.5 mi^2.

Initial estimates of base flow and areal recharge were made on the basis of records of streamflow, precipitation rates, and air temperature, and reported pumpage and sewage-outflow rates. Initial estimates of ground-water flow into the study area were made on the basis of the estimated amount of recharge to and direct runoff from the source areas of these flows. These initial estimates were adjusted within reasonable ranges during model calibration. The methods by which initial estimates were made and adjustments during model calibration are discussed in the following sections.

Base Flow and Direct Runoff

Base-flow rates are strongly affected by geologic and topographic features. The total base flow per unit area is significantly different among the three basins in the study area; the differences are attributable mostly to the areal distribution of diabase rocks.

Initial estimates

The initial estimate of average annual base flow in the Stony Brook drainage basin was based on streamflow at streamflow-gaging station 01401000. For the other two basins, which are not gaged, the estimates were made by developing correlations between flow at the gaged station and flow at the ungaged stations.

Stony Brook drainage basin.--The initial estimate of base flow in the part of the Stony Brook drainage basin upstream from streamflow-gaging station 01401000 was made by using the streamflow-partitioning method described by Rutledge (1992), in which daily base flow is separated from direct runoff on the basis of daily changes in streamflow. Estimated average base flow and direct runoff in the Stony Brook Basin are 8.08 in/yr (2,290,000 ft^3/d) and 11.8 in/yr (3,340,000 ft^3/d), respectively, for the period January 1954 through December 1991.

In the Stony Brook basin, a relatively high portion of streamflow is derived from direct runoff. For comparison, direct runoff to streams in the Coastal Plain of New Jersey is negligible (Martin, 1990, p. 59). The high rate of direct runoff in the study area is caused by both lithology and topographic features. The soils in the study area are rich in silt and clay, which impede infiltration of precipitation (Holman and others, 1954, p. 39, 42, 45), and the sloping topography enhances runoff.

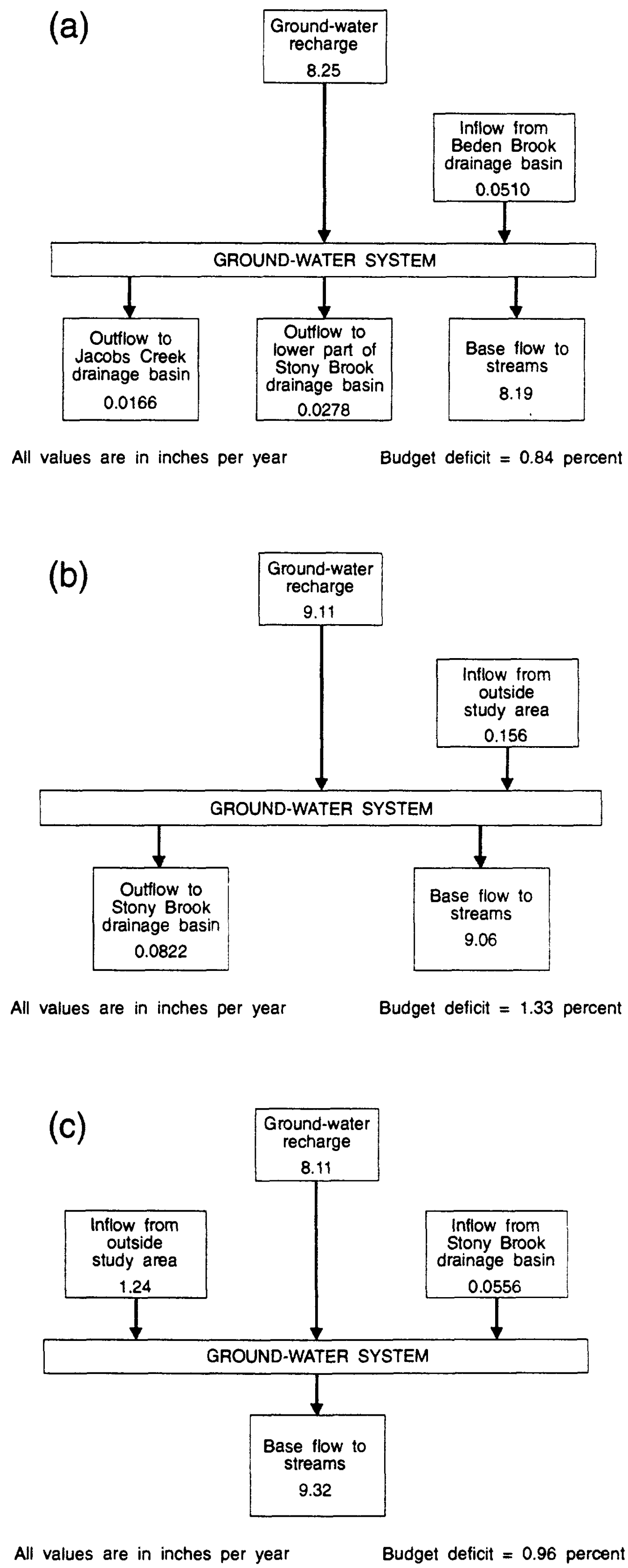


Figure 16. Simulated average-annual prepumping water budgets, 1954-91: (a) Stony Brook drainage basin, west-central New Jersey, upstream from streamflow-gaging station 01401000, (b) Beden Brook drainage basin, west-central New Jersey, (c) Jacobs Creek drainage basin, west-central New Jersey.

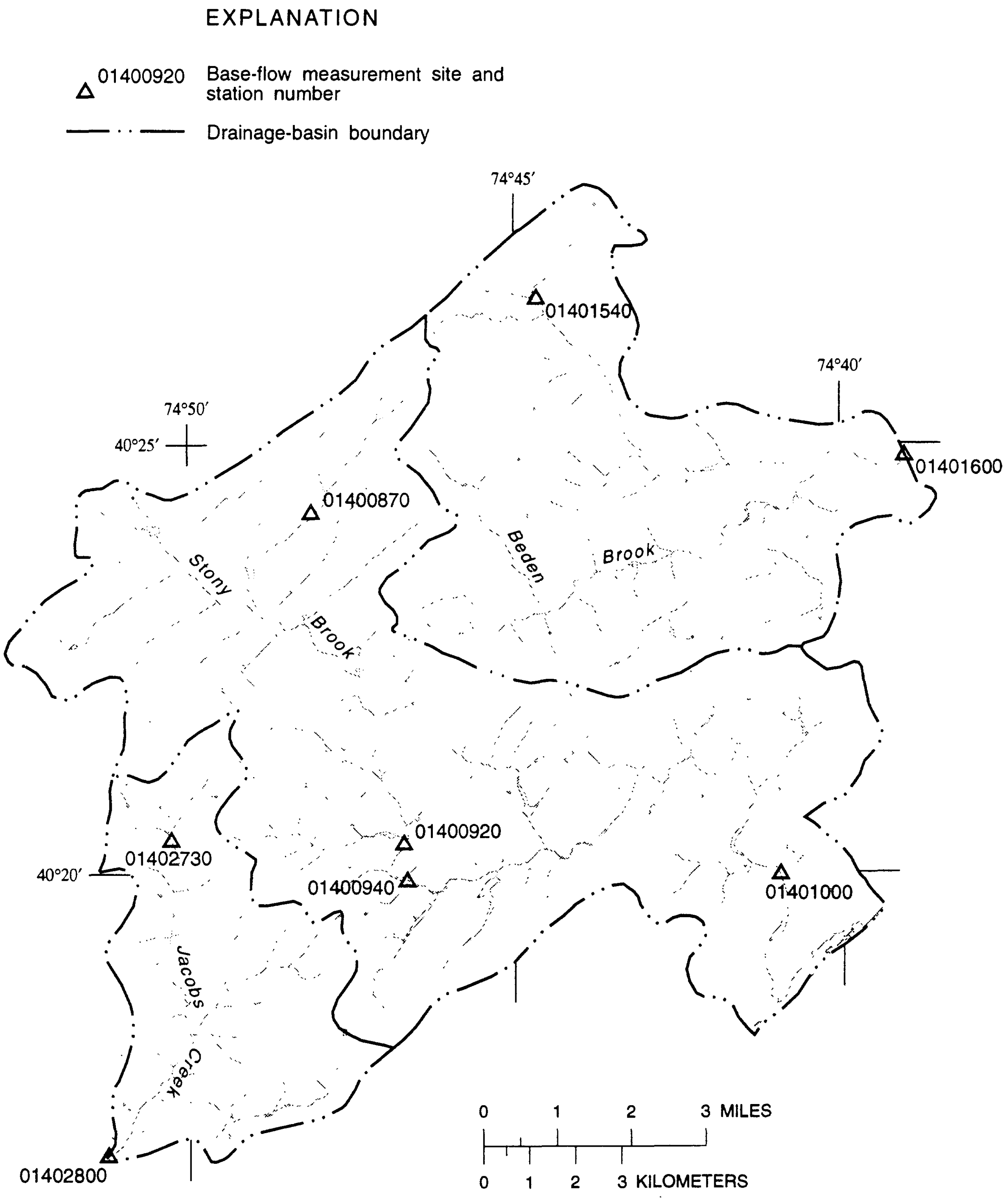


Figure 17. Base-flow-measurement sites, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

The estimate of base flow derived from 1954-91 streamflow records was assumed to include sewage. After subtracting the 0.158 in/yr (44,700 ft^3/d) of average-annual sewage outflow introduced into streams in the basin, the estimated base flow for Stony Brook is 7.92 in/yr (2,240,000 ft^3/d). Prepumping base flow was assumed equal to 1954-91 average annual base flow plus ground-water pumpage, as discussed in the section on ground-water pumpage, below. The estimated prepumping base flow in the Stony Brook drainage basin is 8.06 in/yr (2,280,000 ft^3/d).

Beden Brook and Jacobs Creek drainage basins.--Because continuous records of streamflow are unavailable for the Beden Brook and Jacobs Creek Basins, average-annual base flow was estimated on the basis of several discharge measurements made under base-flow conditions during 1954-91. These measurements were made at station 01401600, which is located where Beden Brook crosses the study-area boundary, and station 01402800, at the mouth of Jacobs Creek (fig. 17). To estimate the 38-year average base flow at the two ungaged stations, statistical correlations between discharge at each of the ungaged stations--27 measurements at the Beden Brook station and 14 at the Jacobs Creek station--and discharge at the Stony Brook station were developed. The estimated average base flow, after subtracting sewage outflow, is 10.1 in/yr (1,770,000 ft^3/d) in the Beden Brook Basin and 10.1 in/yr (855,000 ft^3/d) in the Jacobs Creek Basin. Prepumping base flow was 10.2 in/yr (1,800,000 ft^3/d) in the Beden Brook drainage basin and 10.3 in/yr (874,000 ft^3/d) in the Jacobs Creek drainage basin.

The estimated base-flow rates per unit area for the Beden Brook and Jacobs Creek Basins are higher than that of the Stony Brook Basin as a result of flow into the basins from topographically high areas underlain by diabase (Baldpate and Sourland Mountains) outside the study area.

Effect of anisotropy

Because anisotropy affects ground-water-flow directions, it affects flow paths to streams and the size and shape of the recharge area that contributes water to each stream. Lewis (1992) found that streams in the study area that are aligned along the dip of the rock layers receive some of the ground water that would have discharged to nearby streams aligned along strike if the system were isotropic.

Under isotropic, unconfined conditions, the area that contributes ground water to a stream is approximately equal to the stream's surface-water drainage area. Under the anisotropic conditions in the study area, however, ground-water flow paths are skewed toward the strike direction. For example, where a strike-aligned tributary flows into a dip-aligned stream, some of the water that would, under isotropic conditions, flow to the tributary instead flows along strike into the dip-aligned stream. Therefore, the area that contributes ground water to the dip-aligned stream is larger than the stream's surface-water drainage area, and the area that contributes ground water to a strike-aligned tributary is smaller than its surface-water drainage area. Consequently, in the study area, the amount of base flow per unit surface-water drainage area is larger for dip-aligned streams than for strike-aligned streams.

An analysis of simulated base flow in reaches of Stony Brook, Beden Brook, and Jacobs Creek that were simulated as head-dependent-flux boundaries illustrates the preferential discharge of ground water to dip-aligned stream reaches. Strike-aligned reaches comprised a total stream length of 61,300 ft and 142 model cells. Total base flow to these reaches was 530,000 ft^3/d, which is equal to 8.65 ft^3/d per foot of stream length or 3,730 ft^3/d per model cell. Dip-aligned reaches comprise a total stream length of 44,600 ft and 95 model cells. Total base flow to these reaches was 683,000 ft^3/d, which is equal to 15.3 ft^3/d per foot of stream length or 7,190 ft^3/d per model cell. Therefore, dip-aligned stream reaches receive 1.77 times as much base flow per unit length as strike-aligned reaches, and 1.93 times as much base flow per model cell as strike-aligned reaches.

Base-flow rates in the digital model

The initial estimates of total average base flow in each drainage basin were used to determine of the initial flux rate applied to each stream cell that was simulated as a specified-flux boundary (fig. 12). For each drainage basin, the specified flux in each cell initially was estimated by distributing the total estimated base flow in the basin among all the stream cells in the basin on the basis of stream length. For each cell simulated as a specified-flux boundary, these initial estimates of base flow were adjusted to reflect variations in base flow caused by geologic features. For tributaries underlain by diabase rocks, the initial estimate of base flow was multiplied by 0.4 to reflect lower amounts of recharge in these areas. For tributaries aligned along the strike of the rock layers, the initial estimate of flux was multiplied by 0.8. For tributaries aligned along the dip, the initial estimate was multiplied by 1.2.

The total simulated prepumping base flow, including all stream cells simulated as specified-flux boundaries and as head-dependent-flux boundaries, is 2,320,000 ft^3/d (8.19 in/yr) in the part of the Stony Brook Basin upstream from the streamflow-gaging station, 1,590,000 ft^3/d (9.06 in/yr) for the Beden Brook basin, and 789,000 ft^3/d (9.32 in/yr) in the Jacobs Creek Basin. The total simulated base flow in the part of the Stony Brook drainage basin downstream from the gaging station is 234,000 ft^3/d (10.4 in/yr).

In the Stony Brook drainage basin upstream from the streamflow-gaging station, 1,140,000 ft^3/d was simulated as head-dependent flux and 1,180,000 ft^3/d was simulated as specified flux. In the Beden Brook drainage basin, a total of 352,000 ft^3/d of base flow was simulated as head-dependent flux and 1,240,000 ft^3/d was simulated as specified flux. In the Jacobs Creek drainage basin, a total of 339,000 ft^3/d of base flow was simulated as head-dependent flux and 450,000 ft^3/d was simulated as specified flux. All stream reaches downstream from the Stony Brook streamflow-gaging station were simulated as head-dependent-flux boundaries.

Ground-Water Pumpage

Reported ground-water pumpage in the study area for 1987 is 406.74 million gallons (table 6). The largest purveyors in the study area are Hopewell Borough, Pennington Borough, and Elizabethtown Water Company. Water pumped by Hopewell and Pennington Boroughs is used for domestic needs for residents of those two boroughs. Water pumped by Elizabethtown Water Company[1] enters a large distribution system that extends well beyond the study area. Most of the water pumped from the study area by Elizabethtown Water Company probably is used outside the study area. The locations of wells listed in table 6 are shown in figure 18.

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[1] The use of company names in this report is for identification only and does not impute responsibility for any present or potential effects on the natural resources.

Table 6. Reported ground-water pumpage exceeding 1 million gallons per year in the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey, 1987

[Data from N.J. Department of Environmental Protection; pumpage was reported as totals for each owner because withdrawal data for individual wells for 1987 are not available; USGS, U.S. Geological Survey; e, pumpage estimated by apportioning total reported 1987 pumpage for the purveyor on the basis of reported 1986 pumpage from individual wells]

USGS well number	Well owner	Geologic unit	Total pumpage (millions of gallons)
	Stony Brook drainage basin upstream from streamflow-gaging station 01401000		
210257	Hopewell Valley Golf Course	Passaic	2.27
210090	Pennington Borough	Passaic	e27.63
210269	Pennington Borough	Passaic	e23.74
210373	Pennington Borough	Passaic	e7.67
210309	Educational Testing Service	Lockatong	11.210
210308	Educational Testing Service	Lockatong	
210251	Educational Testing Service	Lockatong	
210242	Mobil Research and Development Corp.	Passaic	30.650
210376	Mobil Research and Development Corp.	Passaic	
210267	American Telephone and Telegraph	Passaic	3.6
210408	American Telephone and Telegraph	Passaic	
210250	American Telephone and Telegraph	Passaic	
210409	American Telephone and Telegraph	Passaic	
	Stony Brook drainage basin downstream from streamflow-gaging station 01401000		
210196	Elizabethtown Water Co.	Stockton	183.56
210288	Elizabethtown Water Co.	Stockton	
	Beden Brook drainage basin		
210087	Hopewell Borough	Stockton	73.710
210189	Hopewell Borough	Stockton	
210277	Hopewell Borough	Passaic	
	Jacobs Creek drainage basin		
210275	Pennington Borough	Passaic	e34.87
210244	Washington Crossing Water Co.	Passaic	7.831

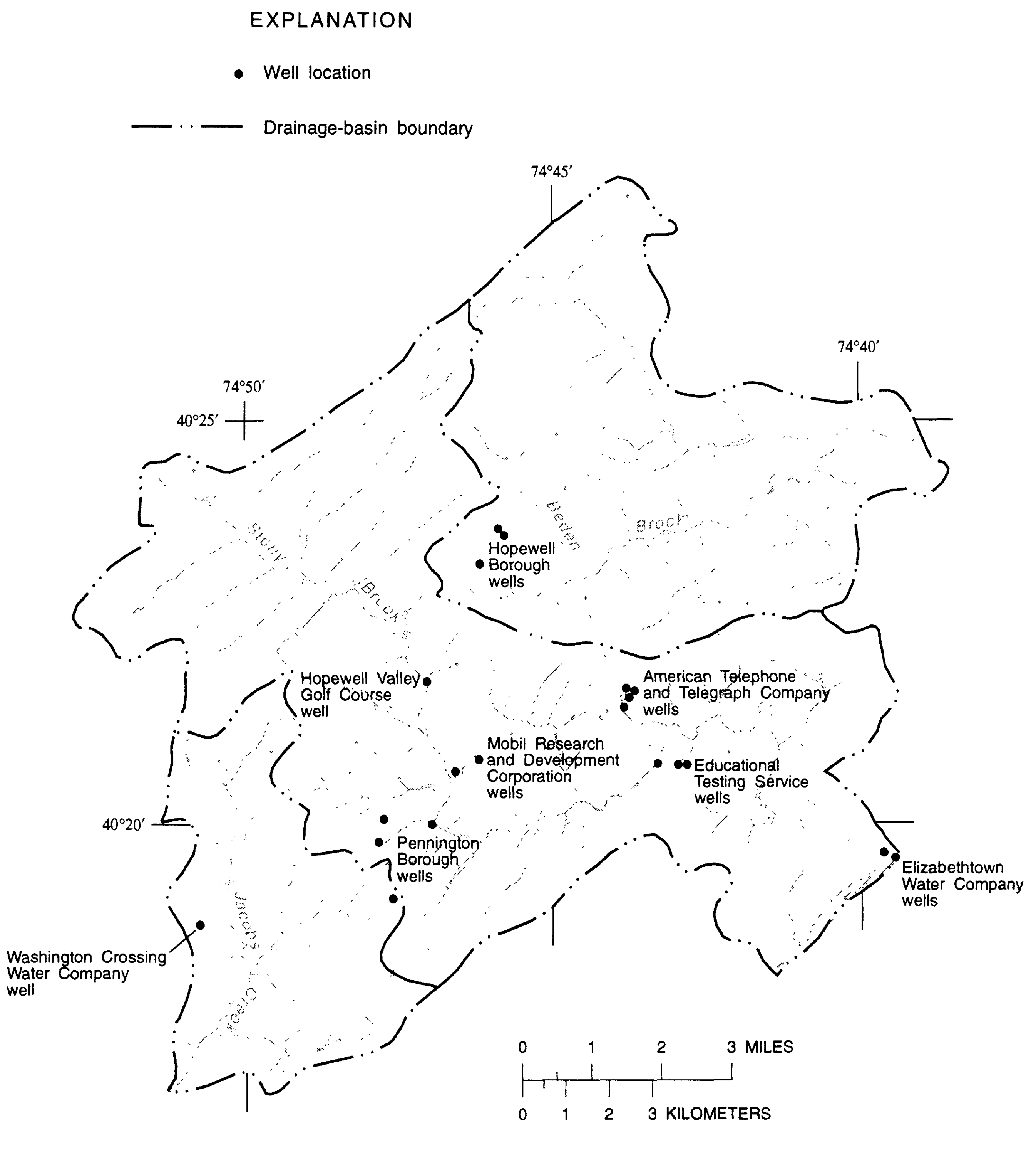

Figure 18. Public supply, industrial, and commerical wells in the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey.

Ground-water pumpage from the part of the Stony Brook drainage basin upstream from the streamflow-gaging station was 106.77 million gallons in 1987. This is equal to an average of 0.14 in/yr over the gaged part of the basin. This pumpage included all of the water withdrawn by Educational Testing Service, Mobil Research and Development Corporation, Hopewell Valley Golf Course, American Telephone and Telegraph Company, and three of the Pennington Borough wells. Wells owned by the Elizabethtown Water Company are in the part of the Stony Brook drainage basin downstream from the gaging station.

Ground-water pumpage from the Beden Brook drainage basin was 73.710 million gallons in 1987. This pumpage consists of water withdrawn from the Hopewell Borough wells and is equal to an average of 0.154 in/yr over the basin area.

Ground-water pumpage from the Jacobs Creek drainage basin was 42.70 million gallons in 1987. This pumpage consists of water withdrawn from the Washington Crossing Water Company well and one of the Pennington Borough wells and is equal to an average of 0.185 in/yr over the basin area.

Because average pumpage data are not available for the entire period 1954-91 for many of the purveyors, 1987 pumpage was added to the 1954-91 average-annual base flow to estimate prepumpage base flow. Average pumpage for 1954-91 is probably slightly lower than the 1987 pumpage; however, the 1987 pumpage is considered to be an adequate estimate of the average pumpage because the 1987 pumpage is low compared to the overall water budget. Therefore, an overestimate of pumpage would not significantly affect the overall water budget.

Ground-Water Flow to and from Adjoining Drainage Basins

Small amounts of ground water flow across the surface-water drainage divides along parts of the study-area boundary--near Baldpate and Sourland Mountains--and at drainage-basin divides within the study area. The amount of flow that crosses basin boundaries from outside the model area initially was estimated on the basis of the amount of recharge to and surface runoff from the source areas of these flows. The part of Sourland Mountain that is outside the study area is about 2 miles long and covers an area of about 1.2 mi^2. Recharge to that part of the mountain is estimated to be about 31,400 ft^3/d on the basis of the average recharge rate to diabase rocks. The digital model best simulated measured heads when the rate was adjusted to 27,300 ft^3/d. This water probably is derived in total or mostly from recharge to Sourland Mountain because a stream there probably captures any surface runoff.

The part of Baldpate Mountain that slopes eastward toward the study area consists of about 0.75 mi^2. Recharge to this part of the mountain is about 20,000 ft^3/d, on the basis of the average recharge rate to diabase rocks, and surface runoff is about 76,000 ft^3/d. Because no streams flow through the eastern part of Baldpate Mountain, all of the direct runoff from the mountain may infiltrate the more permeable Passaic Formation rocks adjacent to the mountain near the study-area boundary and flow into the study area along with the recharge to the eastern part of the mountain. Therefore, the initial estimate of flow crossing the model boundary in this area was 96,000 ft^3/d distributed over 10 model cells. During model calibration, this amount was increased to 104,000 ft^3/d.

Flow rates across drainage divides within the study area--between Jacobs Creek and Stony Brook and between Stony Brook and Beden Brook--were derived directly from the calibrated digital model. Flow from the Beden Brook drainage basin to the Stony Brook drainage basin amounts to 14,400 ft^3/d . Flow from the gaged part of the Stony Brook Basin consists of 4,750 ft^3/d to the Jacobs Creek Basin and 7,860 ft^3/d to the part of the Stony Brook Basin downstream from the streamflow-gaging station. Most of the flow (90 percent) between these adjoining basins occurs in model layer 1 along short flow paths in areas where ground-water divides are offset slightly from surface-water divides. The small amount of interbasin flow in layer 2 is deep flow from topographically high areas (such as areas underlain by diabase rocks) to lowlying streams, such as the downstream reaches of Jacobs Creek and Stony Brook. This deep flow is depicted in figure 10 by the long flow lines.

Areal Recharge

The average areal recharge rate for each drainage basin was estimated from base flow. The average rates were then adjusted to account for differences in recharge rates to the different rock types in the study area.

Initial estimates

Initial estimates of areal recharge were made by two methods. One estimate was made with the assumption that recharge equals base flow to streams. For the part of the Stony Brook drainage basin upstream from the streamflow-gaging station, the recharge rate estimated in this way is 8.06 in/yr. For the Beden Brook and Jacobs Creek drainage basins, the average areal recharge estimated in this way are 10.2 and 10.3 in/yr, respectively.

The second initial estimate of areal recharge was made with the assumption that base flow equals precipitation minus evapotranspiration and direct runoff. This estimate was made only for the Stony Brook drainage basin because estimates of direct runoff, which are based on continuous streamflow data, are available only for that basin.

Mean-annual precipitation in the study area during the 30-year period 1951-80 was 45.07 inches (table 7). Precipitation in the study area was estimated from the weighted average mean-monthly precipitation at the three weather stations nearest the study area. Weights assigned to each station were based on the part of the study area that is nearest the station--Lambertville, 0.403; Flemington, 0.348; and Hightstown, 0.248.

Mean-annual evapotranspiration was estimated with the method described by Thornthwaite and Mather (1955). This method incorporates mean-monthly air temperature and number of hours of sunlight. The method provides an estimate of potential evapotranspiration--the total amount of evaporation and transpiration that could occur if there were a constant supply of water in the soil. The estimated potential evapotranspiration in the study area is 27.28 in/yr. Mean-monthly estimates are listed in table 7. The Thornthwaite and Mather method does not take into account land use, soil type, or topography, all of which affect the ratio of direct runoff to precipitation. This ratio is relatively high in the study area--26 percent; consequently, the water available for evaporation and transpiration from the soil is relatively low. Therefore, the potential evapotranspiration rate estimated by using this method probably is higher than the actual evapotranspiration rate in the study area.

The estimated recharge rate for the Stony Brook Basin based on precipitation, potential evapotranspiration, and direct runoff is 5.98 in/yr, which is significantly lower than the estimate based on base flow. Because the evapotranspiration rate used in the second estimate probably was too high, the estimate based on base flow is considered to be the more accurate of the two estimates.

Table 7. Mean-monthly air temperature, potential evapotranspiration, and precipitation in the study area, Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

[Mean-monthly air temperature and precipitation are for the 30-year period 1951-80 (National Oceanic and Atmospheric Administration, 1990). Mean-monthly temperature and precipitation for the study area were estimated from the weighted average mean-monthly air temperature and precipitation for the three weather stations nearest the study area. Weights assigned to each station are based on the part of the study area that is nearest the station--Lambertville, 0.403; Flemington, 0.348; and Hightstown, 0.248]

Month	Mean-monthly air temperature (degrees Fahrenheit)	Mean-monthly evapotranspiration (inches)	Mean-monthly precipitation (inches)
January	29.5	0	3.47
February	31.3	0	3.01
March	40.0	.52	4.09
April	50.8	1.75	3.82
May	60.6	3.28	3.67
June	69.7	4.88	3.46
July	74.5	5.59	4.27
August	73.4	5.02	4.67
September	66.0	3.54	3.86
October	54.7	1.89	3.31
November	44.2	.76	3.69
December	33.6	.05	3.75
Total		27.28	45.07

The estimated recharge rates are average rates for each basin. Within each basin, the recharge rate varies areally as a result of the presence of geologic and topographic features such as diabase rocks and the Hopewell Fault. These features and their effects on areal-recharge rates are discussed in the following sections.

Effect of diabase rocks

Diabase rocks significantly affect the areal distribution of recharge. Conceptually, areas underlain by diabase rocks were hypothesized to receive less areal recharge than areas underlain by the more permeable sedimentary aquifers. Infiltration and percolation of precipitation is hindered in areas underlain by diabase because the slopes are steeper in these areas than in other parts of the study area.

A comparison of base-flow rates in streams draining areas underlain by diabase rocks with base-flow rates in streams draining areas underlain by sedimentary rocks supports this hypothesis. In August and November 1987, base flow was measured at several sites throughout the study area (Jacobsen and others, 1993, p. 63-66). In each of the three surface-water drainage basins, base flow was measured at one site whose drainage area is wholly or mostly underlain by diabase rocks. Ground-water-runoff rates (base flow divided by drainage area) at these three sites were compared to those at the furthest station downstream at which base flow was measured on the same day or, at one station, the previous day. The stations furthest downstream were selected with the assumption that base flow at these sites would be approximately equal to average base flow in the basin. The base-flow and runoff data for these stations indicate that the ratio of runoff in areas underlain by diabase to runoff in areas underlain by all rock types is approximately 0.375 (table 8). The locations of the base-flow-measurement sites used in this analysis are shown in figure 17.

Some of the precipitation that does not infiltrate into the diabase rocks was assumed to run over land surface or through the unsaturated zone and subsequently infiltrate downslope in areas underlain by the more permeable rocks near the borders of the diabase sills. The total amount of additional recharge received by these areas was assumed to be equal to the difference between the total amount of recharge that would have been applied to the diabase areas if they were underlain by other rocks and the actual amount of recharge applied to the diabase rocks. For each diabase sill, the total amount of additional recharge was distributed evenly among cells surrounding the sill. The additional recharge was applied one cell away from the edge of each diabase sill to account for the relatively impermeable hornfels rocks that surround each sill.

For example, the diabase rocks that comprise Pennington Mountain (fig. 4) occupy an area of about 34,500,000 ft^2. If this area were underlain by one of the sedimentary aquifers, it would receive recharge at a rate of 8.20 in/yr (64,600 ft^3/d) rather than 4.11 in/yr (32,400 ft^3). The difference--32,200 ft^3--was assumed to be the water that flows overland or in the unsaturated zone and then enters the ground-water system when it reaches the sedimentary rocks. The additional recharge was distributed evenly among the 45 model cells surrounding Pennington Mountain. Consequently, 12.5 in/yr of recharge was added to the 8.20 in/yr that this area is assumed to receive directly from precipitation for a total recharge rate of 20.7 in/yr to the cells surrounding Pennington Mountain.

Table 8. Ground-water-runoff rates in areas underlain by diabase rocks and in areas underlain by all rock types in the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

[mi^2, square miles; ft^3/s, cubic feet per second; in/yr, inches per year]

Date of measurement	Station number	Rock type	Drainage area (mi^2)	Discharge (ft^3/s)	Ground-water runoff (in/yr)	Ratio of runoff in areas underlain by diabase to runoff in areas underlain by all rock types
08/14/87	01400870	Diabase	2.60	0.25	1.31	0.336
08/13/87	01401000	All	44.5	12.8	3.90	
11/20/87	01400870	Diabase	2.60	1.25	6.53	.738
11/20/87	01401000	All	44.5	29.0	8.85	
08/13/87	01401540	Diabase	3.84	.07	.247	.043
08/13/87	01401600	All	27.6	11.8	5.80	
11/19/87	01401540	Diabase	3.84	.20	.707	.065
11/19/87	01401600	All	27.6	22.0	10.8	
08/13/87	01402730	Diabase	1.84	.31	2.29	.405
08/13/87	01402800	All	13.3	5.54	5.65	
11/19/87	01402730	Diabase	1.84	1.06	7.82	.663
11/20/87	01402800	All	13.3	11.6	11.8	
Average ratio of runoff in diabase to runoff in all rock types:						0.375

Effect of Hopewell Fault

The hydrologic system varies along the fault zone. The escarpment is steeper in the eastern part of the study area than in the western part, and a stream flows along the fault in the western part of the study area. These features affect the rate of recharge to the fault zone.

In the eastern part of the study area, the escarpment on the northwestern side of the Hopewell Fault was hypothesized to have a similar effect on recharge as the diabase rocks do, and the relatively permeable rocks in the fault zone enhance recharge. Recharge at the base of the escarpment is analogous to the flow of precipitation along a roof and into a drain along the side of a building. All of the direct runoff from precipitation that flows down the fault escarpment probably enters the ground-water system in the fault zone. This amounts to 162,000 ft^3/d (64.4 in/yr) distributed among 44 cells at the foot of the escarpment.

The digital model best simulated measured heads and base flow when recharge was applied at the foot of the fault escarpment at a rate of 95 in/yr. The additional 31 in/yr of recharge at the fault zone probably is derived from precipitation that falls directly on the fault zone. The high permeability of the rocks in the fault zone probably results in little or none of this precipitation being lost to direct runoff. Also, less water is lost to evapotranspiration in the fault zone than in other parts of the study area because vertical conductivity in the fault zone is sufficiently high to allow much of the precipitation to flow down past the root zone before it can be used by vegetation.

In the western part of the study area, where the fault escarpment is less steep than in the eastern part, less runoff reaches the fault zone. Runoff that does reach the fault zone probably is captured by the stream that runs along the escarpment. Therefore, no additional areal recharge was simulated in the model along this part of the fault zone.

Areal recharge rates in the digital model

In the digital model, rates of recharge to diabase rocks and non-diabase rocks were assumed to be constant throughout the study area, except in the fault zone. The rates applied to the diabase and non-diabase rocks were 4.11 and 8.20 in/yr, respectively. Because the total area underlain by diabase rocks and non-diabase rocks varies from basin to basin, and because the recharge rate in the fault zone varies, the overall average recharge rate is different for each basin. The average rates of areal recharge for the Stony Brook (above the streamflow-gaging station), Beden Brook, and Jacobs Creek Basins are 8.25, 9.11, and 8.11 in/yr, respectively, and the average rate over the entire study area is 8.58 in/yr.

Values of Hydraulic Conductivity and Conductance from Calibrated Digital Model

Hydraulic-conductivity zones in the model were established to coincide with the outcrops of geologic units (fig. 4) because lithology was found to be the major determinant of hydraulic conductivity. Simulated values of horizontal hydraulic conductivity, vertical conductance, and streambed conductance are listed in table 9.

The simulated values of horizontal hydraulic conductivity used in the model represent the hydraulic conductivity of each model layer as a whole rather than that of the individual water-bearing zones or confining units that comprise each model layer. Similarly, the vertical-conductance values used in the model and reported in table 9 are based on the vertical hydraulic conductivity of each entire model layer.

Table 9. Simulated values of horizontal hydraulic conductivity, vertical conductance, and streambed conductance factor in the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

[NA, not applicable; ft/d, feet per day; ft^{-1}, per foot]

Formation or zone	Horizontal hydraulic conductivity				Vertical conductance[1] (ft^{-1})	Streambed conductance factor[2] (ft/d)
	Layer 1		Layer 2			
	Strike direction (ft/d)	Dip direction (ft/d)	Strike direction (ft/d)	Dip Direction (ft/d)		
Diabase	0.1	0.1	0.001	0.001	7.00×10^{-5}	NA
Diabase--stream cells	1.00	1.00	.01	.01	7.00×10^{-4}	0.1
Passaic	50	25	.25	.025	3.74×10^{-4}	NA
Passaic--stream cells	500	250	2.5	.25	3.74×10^{-3}	1.5
Passaic--Lockatong-like strata	2	1	.01	.001	5.50×10^{-6}	NA
Passaic--Lockatong-like strata--stream cells	20	10	.1	.01	5.50×10^{-5}	1.5
Lockatong--northern zone	10	5	.05	.005	3.00×10^{-5}	NA
Lockatong--northern zone--stream cells	100	50	.5	.05	3.00×10^{-4}	1.5
Lockatong--southern zone	2	1	.01	.001	5.50×10^{-6}	NA
Lockatong--southern zone--stream cells	20	10	.1	.01	5.50×10^{-5}	1.5
Lockatong--Passaic-like strata	50	25	.25	.025	3.74×10^{-4}	NA
Lockatong-Passaic-like strata--stream cells	500	250	2.5	.25	3.74×10^{-3}	1.5
Stockton --northern zone	.50	.25	.0025	.00025	3.00×10^{-6}	NA
Stockton--northern zone--stream cells	5	2.5	.025	.0025	3.00×10^{-5}	.1
Stockton--southern zone	17.5	8.75	.0875	.00875	1.72×10^{-4}	NA
Stockton--southern zone stream cells	175	87.5	.875	.0875	1.72×10^{-3}	1.5
Fault zone	100	50	50	5	7.00×10^{-2}	1.5

1. Vertical conductance = $\dfrac{1}{\dfrac{m_1/2}{Kz_1} + \dfrac{m_2/2}{Kz_2}}$ where m_1 and m_2 = thickness of layers 1 and 2, respectively, and Kz_1 and Kz_2 = vertical hydraulic conductivity of layers 1 and 2, respectively.

2. Streambed-conductance factor = $\dfrac{K_s W}{m_s}$ where K_s = hydraulic conductivity of the streambed material, W = width of the stream, and m_s = thickness of the streambed.

Except at the fault, the contacts between geologic units dip at the same angle as the rock layers--12 to 15 degrees to the northwest. Therefore, the actual contacts span a distance of about 2,400 to 2,800 ft, or about four to six model cells, in the 500-ft thickness simulated by the model. For this reason, changes in conductivity at contacts were distributed over a four-cell width (two cells on each side of a contact) on a logarithmic scale. For example, at the contact between a zone in which the horizontal hydraulic conductivity in the strike direction is 175 ft/d and a zone in which the conductivity is 2 ft/d, the simulated hydraulic conductivities in the four cells nearest the contact are 175, 39, 9, and 2 ft/d.

Another reason for distributing the change in conductivity over a four-cell width at contacts is that all of the contacts are gradational rather than sharp. The contacts between the Stockton and Lockatong Formations and between the Lockatong and Passaic Formations represent gradual changes in lithology, whereas the contact formed by the Hopewell Fault is gradual because the extent of fracturing caused by faulting decreases with distance from the fault. Contacts at the edges of diabase sills are gradational because of the presence of altered rocks (hornfels) around the sills.

Horizontal Hydraulic Conductivity in the Direction of Strike

Horizontal hydraulic conductivity in the strike direction varies from 0.1 to 500 ft/d in layer 1 and from 0.001 to 50 ft/d in layer 2.

Diabase rocks

The simulated hydraulic conductivity of the diabase rocks in model layer 1 was 0.1 ft/d. This was the lowest value of hydraulic conductivity used in layer 1 and is consistent with the conceptual model of ground-water flow, in which the relatively impermeable diabase rocks impede ground-water flow.

The simulated hydraulic conductivity of the diabase rocks in layer 2 of the digital model, 0.001 ft/d, is lower than the conductivity in layer 1 by a factor of 100. This difference reflects the decrease in permeability and the density of fractures with depth below land surface as determined from specific-capacity values and the numbers of fractures in rock cores.

Stockton Formation

Two zones of different conductivity in the Stockton Formation in the digital model coincide with the two areas in which the formation crops out--at the southern border of the study area and on the northern side of the Hopewell Fault (fig. 4). The hydraulic conductivity used in layer 1 of the digital model for the Stockton Formation at the southern border of the study area (17.5 ft/d) is much higher than the value used for the area north of the fault (0.5 ft/d). The value used for the southern outcrop is more representative of the Stockton Formation than the one used for the northern outcrop because the Stockton Formation is reported to be the most permeable aquifer in the area. The low hydraulic conductivity of layer 1 in the northern outcrop of the Stockton Formation is a function of the depth below land surface (average 110 ft) of the bottom of layer 1 in this area. Consequently, model layer 1 in this area represents rocks that are, on average, less fractured and less permeable than the rocks in layer 1 elsewhere in the model.

In layer 2 of the digital model, the simulated hydraulic conductivity of the Stockton Formation was set lower than that of layer 1 by a factor of 200 to account for the decrease in permeability with depth.

Lockatong Formation

The Lockatong Formation was divided into thee zones of hydraulic conductivity in the digital model. Two of these zones coincide with the two areas in which the formation crops out--north of each of the two Stockton Formation outcrops (fig. 4). The third zone consists of the parts of the Lockatong Formation that are mapped as a separate geologic unit (Trlr) in figure 4. This zone was assumed to have the same hydraulic properties as the Passaic Formation and was therefore was assigned the same hydraulic conductivity.

The principal (strike-direction) hydraulic-conductivity values used for the Lockatong Formation in model layer 1 are 2.0 ft/d near the southern border of the study area and 10.0 ft/d for the area north of the fault. Initially, a value of 2.0 ft/d was assigned to both of these zones. During model calibration, however, a closer match between measured and simulated heads and base flow was achieved by increasing the value for the zone north of the fault to 10.0 ft/d. The difference in hydraulic conductivity in these two zones probably reflects a difference in lithology. The northern zone may include some thin, unmapped zones of Passaic Formation-like rocks (Trlr) similar to those mapped in the southern band, which would cause the overall conductivity of the northern band to be higher than that of the southern band.

Simulated hydraulic conductivity of the Lockatong Formation was lower in layer 2 of the digital model than in layer 1 by a factor of 200--the same ratio as that used for the Stockton Formation.

Passaic Formation

Two zones of hydraulic conductivity were used for the Passaic Formation in the digital model. One of these zones consists of the two areas where Passaic Formation crops out--the large area south of the Hopewell Fault and the small area in the northwestern part of the study area (fig. 4). The principal (strike-direction) conductivity value used for these areas in model layer 1 is 50.0 ft/d (table 9). The second zone consists of the parts of the Passaic Formation that are mapped as a separate geologic unit (Trpg) in figure 4. This zone was assumed to have the same hydraulic conductivity as the southern zone of the Lockatong Formation (2.0 ft/d).

Simulated hydraulic conductivity of the Passaic Formation was lower in layer 2 of the digital model than in layer 1 by a factor of 200--the same ratio as that used for the Stockton and Lockatong Formations.

Fault zone

The hydraulic conductivity of the fault zone was assumed to be higher than that of the surrounding rocks on the basis of reports of wells with high yields and high specific capacities in the fault zone. The fault zone consists of a 1,000-ft-wide (two-model-cell-wide) area that extends through the model area from southwest to northeast (fig. 4) and through both model layers. Simulated heads in the digital model were nearest to measured heads when conductivities of 100 ft/d and 50 ft/d were used for layer 1 and layer 2, respectively, of the fault zone.

Areas near streams

Streams in the study area generally follow the outcrops of water-bearing zones or joints. For this reason, the hydraulic conductivity of the aquifers was arbitrarily set higher in cells containing streams (fig. 12) than in other cells by a factor of 10 (table 9). Hydraulic conductivity in cells in layer 2 underlying streams also were increased by a factor of 10 because the water-bearing zone in layer 1 was assumed to continue into layer 2.

Horizontal Anisotropy Ratio

The ratio of hydraulic conductivity in the strike direction to hydraulic conductivity in the dip direction (the anisotropy ratio) used in the model was 2:1 in layer 1 and 10:1 in layer 2 for all of the sedimentary aquifers and for the fault zone. The lower ratio used for layer 1 is related to the higher density of fractures and greater effects of weathering in the shallow part of the aquifers compared to deeper part of the aquifers. Rock layers that act as confining units are much more fractured near land surface than at depth. Consequently, the confining effect of these layers is diminished near land surface and anisotropy also is diminished. In addition, intergranular porosity of some of the shallow rocks makes them more isotropic than the underlying, less weathered rocks.

The diabase rocks are assumed to be isotropic because they are not layered and because the fracture pattern in diabase rocks is more random than in the sedimentary rocks. Consequently, an aniostropy ratio of 1:1 was assigned to model cells representing diabase rocks.

Vertical Hydraulic Conductance

Vertical-hydraulic-conductance values used in the digital model are listed in table 9. McDonald and Harbaugh (1988, p. 5-13) define the vertical conductance between two model layers that represent two adjacent hydrogeologic units whose vertical conductivities differ according to the equation

$$\text{Vertical conductance} = \frac{1}{\frac{m1/2}{Kz1} + \frac{m2/2}{Kz2}},$$

where $m1$ and $m2$ = thicknesses of layers 1 and 2, respectively, and

$Kz1$ and $Kz2$ = vertical hydraulic conductivities of layers 1 and 2, respectively.

As a first approximation, the vertical conductivity of the sedimentary aquifers and the fault zone was estimated to be equal to the horizontal hydraulic conductivity in the dip direction. The saturated thicknesses of layers 1 and 2 were approximated at 50 ft and 425 ft, respectively. During model calibration, simulated heads were found to be highly sensitive to changes in vertical conductance. In the calibrated model, all initial estimates of vertical conductance were increased by factors ranging from 1.28 for the Passaic Formation to 4.17 for the southern zone of the Stockton Formation. The resulting calibrated conductance values indicate that the vertical hydraulic conductivity of the Stockton, Lockatong, and Passaic Formations is slightly higher than the dip-direction horizontal conductivity. The vertical conductance of cells containing streams and cells below streams in layer 2 was increased by a factor of 10 for the same reasons as those described for horizontal conductivity. The change in vertical conductance at geologic contacts was distributed over a four-cell width in the same way as was the change in horizontal hydraulic conductivity.

Streambed Hydraulic Conductance

In the digital model, all reaches of Stony Brook, Beden Brook, and Jacobs Creek except the uppermost reaches were simulated as head-dependent-flux boundaries by using the "River module" of the McDonald and Harbaugh (1988) flow model. The rate of flow between the streams and the aquifer is controlled by the head difference between the aquifer and the stream and by the hydraulic conductance of the stream-aquifer interconnection. McDonald and Harbaugh (1988, p. 6-5) define this hydraulic conductance according to the equation

$$CRIV = \frac{Ks\ L\ W}{ms},$$

where CRIV = the hydraulic conductance of the stream-aquifer interconnection,

Ks = the vertical hydraulic conductivity of the streambed material,

L = the length of the reach,

W = the width of the stream, and

ms = the thickness of the streambed.

Streambed material in the study area consists of clayey silt, silt, sandy silt, or fractured bedrock with one of these materials filling the fractures. As a first approximation, the hydraulic conductivity of the streambed material was assumed to be equal to the hydraulic conductivity of silt, about 0.1 ft/d (Heath, 1983, p. 13). The length of stream reach within each model cell was determined by digital scanning of topographic maps. The width of the three major streams was estimated at 20 ft in all reaches--the approximate average width of Stony Brook, Beden Brook, and Jacobs Creek at sites where stream discharge was measured. The thickness of the streambed was estimated to be 5 ft. Because the length of the stream within each model cell could be determined exactly, but the other parameters included in the conductance are estimates, the length of each reach was held constant during model calibration and a streambed conductance factor--the product of the other three parameters--was adjusted.

The initial estimate of streambed conductance factor was 0.4 ft/d. In the calibrated model, heads and base flow were best simulated when a streambed conductance factor of 0.1 ft/d was applied to stream reaches underlain by the diabase rocks and by the Stockton Formation outcrop north of the Hopewell Fault. The streambed conductance factor applied at all other stream reaches was 1.5 ft/d. The relatively low streambed conductance factor for the diabase probably results from the presence of a relatively high percentage of clay in the streambed material. Diabase rocks weather to a more clayey material than do other rocks in the study area. The relatively low hydraulic conductivity for the part of the Stockton Formation that crops out north of the Hopewell Fault probably is caused by the low conductivity of the rocks underlying the streambed. Streams in this area are very deeply incised, and the rocks at depth are less extensively fractured than shallower rocks. The rocks underlying the streambed probably are less permeable than the streambed, so the hydraulic connection between the stream and the aquifer is controlled by the conductivity of the bedrock rather than by the conductivity of the streambed.

Vertical Distribution of Ground-Water Flow

In the conceptual model ground-water flow was hypothesized to occur mostly in the shallow part of the system because the decrease in the density of fractures with depth restricts flow in the lower part of the system. In the calibrated digital model, 94 percent of the recharge to layer 1 remains in layer 1 and discharges to streams near the point of recharge. The other 6 percent of recharge flows downward from layer 1 to layer 2, flows a relatively long distance--up to a few miles--in layer 2, and then flows back into layer 1 and discharges to one of the major streams (Stony Brook, Beden Brook, or Jacobs Creek).

SUMMARY AND CONCLUSIONS

This study was undertaken as part of the Appalachian Valleys-Piedmont Regional Aquifer-Systems Analysis to characterize ground-water flow in the Mesozoic structural basins of the eastern United States. The study area consists of about 89 mi^2 in the Newark Basin of New Jersey. Ground-water flow in the Mesozoic-basin rocks is controlled by a complex hydrogeologic framework consisting of dipping beds of fractured sedimentary rocks, massive diabase rocks, and faults.

The study area is underlain by three sedimentary rock formations--the Stockton, Lockatong, and Passaic Formations--and by diabase sills. The sedimentary formations all contain fractured siltstone, shale, and sandstone; the Lockatong Formation also contains beds of massive, sparsely fractured argillite. The three formations are differentiated on the basis of the proportion of each rock type present. In these sedimentary formations, extensively fractured water-bearing units are interlayered with sparsely fractured confining units. The diabase rocks are massive and very impermeable relative to other rocks in the study area. All of the formations are thousands of feet thick in the study area. The density of fractures in all of the rocks decreases with depth and, in rocks more than about 500 ft below land surface, fractures are so sparse that ground-water flow is negligible.

The Hopewell Fault is a major, near-vertical fracture that extends vertically though all of the formations and trends northeast through the study area. Rocks on both sides of the fault are extensively fractured.

The beds of the sedimentary rocks dip about 12 to 15 degrees to the northwest. Therefore, within the study area, each water-bearing unit extends only from its outcrop area downdip to a depth of about 500 ft below land surface, where the permeability is negligible. Along strike, however, each water-bearing unit is extensive. Because the water-bearing units are much more extensive in the strike direction than in the dip direction, ground-water flow is anisotropic, and ground-water-flow directions are skewed toward the strike direction. This causes dip-aligned streams to receive more base flow and strike-aligned streams to receive less base flow than they would if the system were isotropic. Between land surface and about 50 to 150 ft below land surface, ground-water flow is unconfined because fractures are dense and interconnected. At greater depths, sparsely fractured beds impede flow enough to cause confined conditions.

The aquifers in the study area differ with respect to average specific capacity per foot of open hole. For the Stockton, Lockatong, and Passaic Formations and diabase rocks, the median specific capacity per foot of open hole is 0.00545, 0.00115, 0.00393, and 0.00143 ((gal/min)/ft)/ft, respectively. The decrease in the density of fractures with depth below land surface also is reflected in specific-capacity data. The mean specific capacities per foot of open hole of wells that are less than 76 ft deep are two to six times greater--depending on geologic formation--than those of wells 76 to 100 ft deep. Reported transmissivities range from 100 to 4,700 ft^2/d for the Stockton Formation and from 900 to 4,300 ft^2/d for the Passaic Formation. Storage coefficients estimated from results of aquifer tests range from 0.00001 to 0.367.

Water-level data for wells and streams in the study area indicate that ground-water divides generally coincide with surface-water divides and that most ground water discharges to streams near the point of recharge. Exceptions are found where water enters the ground-water system in topographically high areas underlain by diabase rocks and flows under one or more surface-water divides before discharging to a stream.

Because diabase rocks are very impermeable and resistant to erosion relative to other rocks in the study area, they form topographically high areas. The rate of areal recharge to these rocks is about one-half the rate of recharge to other rocks, and the surface-runoff rate is higher. Excess surface runoff flows downslope over land or in the unsaturated zone and enters the ground-water system where it encounters more permeable non-diabase rocks downslope.

Most ground-water flow in the study area occurs between the water table and 75 ft below land surface. When the system is unstressed, only about 6 percent of the recharge at land surface reaches depths greater than 75 ft below land surface.

Water that flows to pumped wells generally is derived mostly from the water-bearing units intersected by the well opening. Wells near surface-water bodies also derive a significant amount of water from the surface-water body by induced infiltration.

A three-dimensional finite-difference digital model of steady-state, prepumping ground-water flow in the study area was developed to test hypotheses concerning the hydrologic processes and geologic features that control ground-water flow. The decrease in hydraulic conductivity with depth was simulated by discretizing the model into two layers, with the conductivity of the upper layer much greater than that of the lower layer. The upper layer represents the unconfined part of the aquifer system and is generally less than 75 ft thick. The lower layer is generally 425 ft thick and represents the confined part of the system. Each model cell is 500 ft on each side. The lower boundary of the model and most of the lateral boundary were simulated as no-flow boundaries. Two small parts of the lateral boundary, where ground water flows into the model area from areas underlain by diabase rocks outside the model area, were simulated as specified-flux boundaries. The upper model boundary is the water table, which was represented as a free surface. Areal recharge to the water table was simulated as specified flux. The main stems of Stony Brook, Beden Brook, and Jacobs Creek were simulated as head-dependent-flux boundaries. Tributaries to these streams are simulated as specified-flux boundaries.

The model was calibrated by adjusting horizontal hydraulic conductivity, vertical conductance, horizontal anisotropy, and streambed conductance until simulated water levels and base flow most nearly matched measured water levels and base flow. So that simulated heads could be compared to composite measured heads, the model-generated heads for the two layers were converted to a single composite head at each model cell on the basis of the saturated thickness and hydraulic conductivity of each layer.

The digital model was divided into zones of different hydraulic conductivity on the basis of the outcrop areas of geologic units. Because all of the contacts between zones are gradational, the change in hydraulic conductivity and vertical conductance was distributed over a four-cell width at each contact. Horizontal hydraulic conductivities of layer 1 in the strike direction were 0.1 ft/d for the diabase rocks, 17.5 and 0.5 ft/d for the Stockton Formation, 2.0, 10.0, and 50.0 ft/d for the Lockatong Formation, 2.0 and 50.0 ft/d for the Passaic Formation, and 100 ft/d in the Hopewell Fault zone. The horizontal conductivity of layer 2 was lower than the conductivity of layer 1 by a factor of 200, except in the diabase rocks, where the difference was a factor of 100, and in the fault zone, where the difference was a factor of 2. The ratio of conductivity in the strike direction to the conductivity in the dip direction was 2:1 in layer 1 and 10:1 in layer 2, except in the diabase rocks, which were assumed to be isotropic. The vertical conductivity in all of the rock units was slightly higher than the dip-direction horizontal conductivity.

The quantity of water in the aquifers of the study area is small relative to other hydrogeologic terranes. Average precipitation in the study area is 45.07 in/yr. Average ground-water recharge rates to the Stony Brook, Beden Brook, and Jacobs Creek drainage basins are 8.25, 9.11, and 8.11 in/yr, respectively. Over the entire study area, the average recharge rate is 8.58 in/yr.

The digital model developed for this study can be used to analyze the effect of various controls on the ground-water system only when the area of analysis is relatively large--about 0.5 mi^2 or more. Because the model does not explicitly simulate individual water-bearing units, it cannot be used to analyze flow paths on a small or site-specific scale. Adequate analysis of ground-water flow on a local scale would require development of a ground-water-flow model that simulates flow in each water-bearing unit and consideration of additional geologic complexities in the study area, such as the dip of the water-bearing units and the discontinuity of water-bearing and confining units in the dip direction.

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Table 4a. Records obtained from U.S. Geological Survey Ground-Water Site Inventory data base for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

[Altitudes in feet above sea level, rounded to nearest foot; top and bottom of open interval and depth to water rounded to nearest foot; diameter of open interval rounded to nearest inch; --, no data available; depth to water is depth reported at time of well construction; USGS, U.S. Geological Survey.

Geologic-unit codes: PSSC--Passaic Formation; LCKG--Lockatong Formation; SCKN--Stockton Formation; DIBS--Diabase rocks.

Use-of-water codes: C--Commercial; H--Domestic; I--Irrigation; N--Industrial; P--Public supply; R--Recreation; T--Institutional; U--Unused; Z--Other]

USGS well number	Use of water	Owner	Local well number or name	Diameter of open interval (inches)	Year of construction	Open interval (feet below land surface) Top	Open interval (feet below land surface) Bottom	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water level (feet)
190045	H	EHRET, DONALD	EHRET 1	6	1978	50	160	LCKG	402530	744909	290	65	225
190050	H	HORSMAN, KEN	REPLACEMENT-81	6	1981	50	350	LCKG	402633	744711	305	60	245
190059	I	CARNAVALE CONSTRUCTION	2-NURSERY	6	1965	21	200	LCKG	402150	745218	385	21	364
190060	I	CARNAVALE CONSTRUCTION	1-GREENHOUSE	--	1965	30	405	LCKG	402148	745220	385	30	355
190080	H	BRITTON, CHARLES	BRITTON 1	6	1959	20	200	LCKG	402153	745204	370	15	355
190233	C	ARGUS INTERNATIONAL	1	6	1968	30	100	PSSC	402351	745056	370	2	368
190234	H	PISARCIK, D	PISARCIK	6	1978	51	100	LCKG	402446	744908	470	15	455
190239	H	WASABAUGH, F	WASABAUGH DOM	--	1969	25	42	DIBS	402407	740005	385	11	374
190240	H	BLOMQUIST, ALBERT E	BLOMQUIST DOM	6	1951	22	146	DIBS	402426	744939	439	12	427
190241	H	COLONIAL SPORTSMENS CLUB	COLONIAL SM DOM&POOL	6	1957	22	192	LCKG	402343	744918	309	12	297
190242	H	HELEWA, JOSEPH	HELEWA 1	6	1966	31	400	PSSC	402335	745014	305	25	280
190244	H	ANKNER, JOAN	ANKNER DOM	6	1985	50	300	PSSC	402232	745239	440	10	430
190250	U	US GEOLOGICAL SURVEY	W AMWELL TB2 OBS 3	3	1989	12	428	PSSC	402146	745351	445	36	409
190251	U	US GEOLOGICAL SURVEY	CORSALO RD TB1 OBS	4	1989	22	299	PSSC	402151	745253	405	--	--
190258	H	GRIFFITHS, BRIAN	GRIFFITHS DOM	6	1985	50	250	PSSC	402247	745215	420	5	415
190267	H	KOEPKE, HILBERT	KOEPKE 1	6	1971	40	310	PSSC	402220	745303	450	50	400
190269	H	CARRIER, WILLIAM	CARRIER 1	6	1965	23	122	PSSC	402140	745223	365	25	340
190278	H	CARRIER, RONALD	CARRIER DOM	6	1982	50	350	LCKG	402132	745221	280	20	260
190282	H	LEWIS, FRANK J	LEWIS DOM	6	1966	23	60	LCKG	402157	745203	370	15	355
210028	U	STATE OF NJ	CIVIL DEFENSE	6	1964	33	300	LCKG	401553	745012	123	20	103
210087	P	HOPEWELL BORO W	3-1965	8	1965	60	237	SCKN	402335	744547	200	146	54
210088	U	US GEOLOGICAL SURVEY	HONEY BRANCH 10	6	1967	20	150	PSSC	402128	744613	179	25	154
210090	P	PENNINGTON WD	PWD 5D		1967	--	400	SCKN	402000	744658	140	29	111
210132	N	BELL TELE CO	BELL LAB 4	8	1968	42	200	PSSC	401935	743836	108	18	90
210136	P	WILDERSMITH, J	WEST WINDSOR TWP	8	1960	48	252	SCKN	401935	743821	100	20	80

Table 4a. Records obtained from U.S. Geological Survey Ground-Water Site Inventory data base for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

USGS well number	Use of water	Owner	Local well number or name	Diameter of open interval (inches)	Year of construction	Open interval (feet below land surface) Top	Open interval (feet below land surface) Bottom	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water level (feet)
210189	P	HOPEWELL BORO WC	WELL 1	--	1914	--	250	SCKN	402340	744553	220	--	--
210196	P	ELIZABETHTOWN WC	2/STONY BROOK	6	1938	54	306	SCKN	401935	743926	110	--	--
210242	N	MOBIL RESEARCH LAB	MOBIL RESEARCH 2	6	1980	50	600	PSSC	402040	744635	157	20	137
210244	P	HOPEWELL TWP MUA	WASH CROSSING EST	8	1966	105	235	PSSC	401846	745046	210	90	120
210245	S	AMERICAN CYANAMID CO	CYANAMID D-1959	12	1959	34	169	SCKN	401756	744022	85	7	78
210250	C	WESTERN ELECTRIC CO INC	RESEARCH LAB 3	--	1960	31	400	PSSC	402142	744348	205	20	185
210251	C	EDUCATIONAL TESTING SERV	ETS 2-NEW ETS 1	--	1956	35	223	LCKG	402045	744248	125	5	120
210252	H	AMER. LEGION POST #339	1-LEGION HALL	6	1982	60	400	DIBS	402252	744650	260	40	220
210253	H	STEFFANELLI, A	REPLACEMENT-81	6	1981	63	250	PSSC	402024	745103	285	19	266
210256	C	HOPEWELL VAL. GOLF CLUB	4-HAND PUMP	6	1981	31	100	PSSC	402156	744700	160	3	157
210257	C	HOPEWELL VAL. GOLF CLUB	1-STONY BROOK	6	1967	22	200	PSSC	402147	744703	160	16	144
210258	H	ROGASKI, BRIAN	ROGASKI 1	6	1982	42	350	PSSC	402244	744642	280	50	230
210259	H	MAZIARZ, STAN	MAZIARZ 1	6	1982	50	250	LCKG	402412	744758	400	20	380
210260	H	CHYUN, YONG-CHOL	CHYUN 1	6	1982	50	500	LCKG	402355	744726	360	20	340
210261	H	RULE, MARVIN	RULE 1	6	1977	47	277	PSSC	402406	744548	405	60	345
210262	H	GURKA, JOHN	GURKA 1	6	1957	22	135	PSSC	402358	744550	400	28	372
210263	H	HOLCOMBE, JR, RUSSELL	HOLCOMBE 1	6	1977	51	120	PSSC	402406	744415	200	18	182
210264	H	OLSWFSKI, ANTHONY	OLSWFSKI 1	6	1974	51	285	PSSC	402243	744758	240	75	165
210265	H	ANDERSON, THOMAS	ANDERSON FARM-1981	6	1981	50	275	SCKN	402418	744520	355	50	305
210266	T	ST PETERS CHURCH	CHURCH 1	6	1981	31	100	LCKG	402217	745050	340	12	328
210267	C	AT&T TECHNOLOGIES	RESEARCH LAB 1	--	1960	38	400	PSSC	402140	744340	214	17	197
210268	H	SINCLAIR, PAUL	SINCLAIR 1	6	1980	50	150	SCKN	402135	744940	400	60	340
210269	P	PENNINGTON BORO	PENNINGTON WD 6	--	1957	43	273	PSSC	401947	744750	200	83	117
210270	C	EDUCATIONAL TESTING SERV	ETS 3	--	1956	32	282	PSSC	402045	744257	160	13	147
210274	H	ELLIS, WILLIAM	ELLIS-1960	6	1960	28	90	LCKG	401938	744300	200	10	190
210275	P	PENNINGTON BORO	WD 7	10	1963	81	300	PSSC	401905	744736	200	10	190
210276	H	VAN NOTE, SHEILA	1-1985	6	1985	50	233	PSSC	401835	744604	215	12	203
210277	P	HOPEWELL BORO	4-LOUELLEN ST	8	1968	50	380	PSSC	402314	744611	200	--	190
210281	H	POTTS, JAMES	RESIDENCE-1986	6	1986	50	425	LCKG	402042	745200	210	30	180
210283	T	N.J. HIGHFIELDS CENTER	LINDBERGH-1931	6	1931	33	350	LCKG	402451	744610	400	--	369
210288	P	ELIZABETHTOWN WATER CO	STONY BROOK 3	10	1913	20	353	SCKN	401939	743937	60	--	
210289	U	BRISTOL-MYERS SQUIBB CO	100 OBS	8	1955	12	300	LCKG	401753	744835	215	17	198
210290	Z	US GEOLOGICAL SURVEY	CORE HOLE B	3	1986	20	187	PSSC	401753	744823	215	--	
210291	H	ASTALOSH, FRANK	ASTALOSH	6	1979	41	200	PSSC	401910	745001	210	50	160
210292	H	COLIVITA, SAM	COLIVITA	6	1980	50	175	LCKG	402208	745050	310	15	295

Table 4a. Records obtained from U.S. Geological Survey Ground-Water Site Inventory data base for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

USGS well number	Use of water	Owner	Local well number or name	Diameter of open interval (inches)	Year of construction	Open interval (feet below land surface) Top	Open interval (feet below land surface) Bottom	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water level (feet)
210293	T	INST. FOR ADVANCED STUDY	1	10	1963	45	305	SCKN	401951	744011	110	22	88
210294	H	KIEFER	KEIFER	6	1978	50	220	DIBS	402215	744138	270	25	245
210295	H	LEICHT	LEICHT	6	1979	40	130	PSSC	402123	744521	140	12	128
210296	H	MCALINDEN, MERRITT	MCALINDEN	6	1978	50	250	LCKG	402430	744640	430	40	390
210297	H	MITCHELL, N	MITCHELL	6	1978	50	205	PSSC	401819	745028	150	35	115
210298	H	SLATER	SLATER	6	1983	50	175	PSSC	402359	744512	186	25	161
210299	H	STANIAR, H B	STANIAR	6	1980	62	215	PSSC	402149	744810	250	15	235
210301	H	STONE	STONE	6	1984	56	200	PSSC	402023	744508	170	50	120
210302	H	WECHSLER	WECHSLER	6	1969	42	290	DIBS	402207	744342	343	10	333
210303	H	WEINROTH, R	WEINROTH	6	1979	30	115	SCKN	402128	744945	350	10	340
210304	H	WOODWARD, DON	WOODWARD DOMESTIC	6	1985	50	120	PSSC	402147	744841	340	35	305
210305	I	KALES NURSERY	KALE IRRIGATION	8	1986	59	260	LCKG	401940	744308	200	20	180
210306	H	MOUNT, GARY	MOUNT DOMESTIC	6	1965	51	98	LCKG	401955	744330	190	15	175
210308	C	EDUCATIONAL TESTING SERV	ETS 4-NEW ETS 2	8	1957	30	248	LCKG	402045	744257	160	13	147
210309	C	EDUCATIONAL TESTING SERV	NEW ETS 3R	8	1964	51	303	LCKG	402046	744317	130	--	
210310	T	PRINCETON UNIVERSITY	GUYOT HALL 1	6	1961	33	150	SCKN	402044	743916	140	8	132
210312	H	ROBERTSON, TOM	ROBERTSON DOM	6	1972	30	118	LCKG	402110	745109	329	20	309
210313	H	RILEY, D	RILEY DOM 1	6	1970	40	160	LCKG	402147	745053	318	40	278
210314	H	MOORE, S W	MOORE DOM	6	1980	50	165	DIBS	402228	744654	237	30	207
210315	H	COHEN	COHEN DOM	6	1981	40	300	DIBS	402219	744506	344	30	314
210316	H	GUNN, ROBERT W	GUNN DOM	6	1983	50	240	SCKN	402440	744504	407	80	327
210317	I	HENDERSON, JOHN	HENDERSON FARM	6	1985	51	140	PSSC	402312	744357	136	20	116
210318	H	FINE, SIDNEY	FINE 2	6	1966	30	247	DIBS	402003	745225	430	30	400
210319	I	DILWORTH, J R	DILWORTH 1	6	1955	28	130	LCKG	402059	744025	190	22	168
210321	H	KENNEDY, W	KENNEDY DOM	6	1983	52	150	PSSC	402043	744459	142	8	134
210322	H	SELTER, E	SELTER 1	6	1966	30	248	LCKG	401655	745112	124	20	104
210323	H	JONES, RONALD	JONES DOM	6	1984	52	150	LCKG	401704	745119	116	37	79
210324	H	KLEEPER, WILLIAM	KLEEPEN DOM	6	1972	30	135	LCKG	401707	745049	119	38	81
210325	C	SUSSMAN REALTY CO	PARSONS BLDG	6	1984	52	190	LCKG	401755	744710	214	24	190
210326	H	MILEWSKI, JOHN P	MILEWSKI 1	6	1978	52	300	PSSC	401817	745036	164	20	144
210327	H	STILSON, E	STILSON DOM	6	1983	50	160	PSSC	401824	745019	143	42	101
210328	H	REINECKE, GEORGE A	REINECKE 1	6	1972	53	118	PSSC	401827	745021	156	30	126
210329	H	MALEC, M	MALEC DOM	6	1984	52	150	PSSC	401844	744703	190	27	163
210330	C	ROBEX CORP	ROBEX CORP 3	6	1975	50	190	PSSC	401915	744755	223	54	169
210331	H	PELIKAN HOUSING INC	PELIKAN HOUSING	8	1974	31	200	LCKG	401932	744542	184	30	154

Table 4a. Records obtained from U.S. Geological Survey Ground-Water Site Inventory data base for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

USGS well number	Use of water	Owner	Local well number or name	Diameter of open interval (inches)	Year of construction	Open interval (feet below land surface) Top	Open interval (feet below land surface) Bottom	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water level (feet)
210332	H	MORRISON, R	MORRISON DOM	6	1962	24	142	PSSC	401949	744943	188	30	158
210333	H	TOWBIN, J	TOWBIN 1	6	1972	36	80	PSSC	402011	745056	256	8	248
210334	H	MATHER, SAMUEL II	MATHER DOM	6	1976	95	170	DIBS	402025	744956	295	40	255
210335	H	RALPH, ELIZABETH K	RALPH 1	6	1976	38	250	DIBS	402035	744943	311	20	291
210336	H	JACOBELLI, CARL	JACOBELLI DOM	6	1984	52	164	PSSC	402037	744528	182	40	142
210337	H	GRAVEN, R	GRAVEN DOM	6	1979	51	200	PSSC	402041	744528	198	50	148
210338	H	BACON, WESLEY	BACON DOM	6	1978	75	270	DIBS	402045	744919	300	50	250
210339	H	NELSON, J	NELSON DOM	6	1974	30	120	PSSC	402055	744502	174	33	141
210340	H	SCOZZARI, VINCENT	SCOZZARI DOM	6	1979	51	200	PSSC	402057	744522	206	50	156
210341	C	HOPEWELL VAL. RAQUETBALL	H VALLEY RAQUETBALL	6	1978	42	175	PSSC	402058	744741	203	11	192
210342	H	EDGE, L	EDGE 1	6	1969	40	460	PSSC	402113	744402	218	50	168
210344	H	FAHERTY, J	FAHERTY DOM	6	1972	44	225	SCKN	402136	744942	384	40	344
210345	H	MAYER, RUDY	MAYER DOM	6	1980	61	200	DIBS	402210	744428	310	35	275
210346	H	LEWELLEN, W S	LEWELLEN DOM	6	1973	50	265	DIBS	402228	744550	310	40	270
210347	H	O'NEILL, B	O NEILL DOM	6	1973	52	125	LCKG	402001	744315	196	15	181
210349	C	SUSSMAN REALTY	ANDREWS BLDG	6	1979	31	150	LCKG	401757	744711	210	15	195
210350	H	GRIFFIS, EARL	GRIFFIS DOM	6	1979	40	100	LCKG	401801	744729	198	20	178
210352	H	ALECH, BUD	ALECH DOM	6	1982	52	162	PSSC	401935	744919	238	82	156
210353	C	STAGE DEPOT MOTEL	STAGE DEPOT DOM	10	1970	20	100	PSSC	402137	744755	203	8	195
210354	H	GILLESPIE, RICHARD	GILLESPIE DOM	6	1980	31	140	PSSC	401940	744623	176	40	136
210355	H	OLMLAND, L	OLMLAND DOM	6	1972	31	125	PSSC	402121	744522	161	10	151
210356	H	YU, Y S	YU DOM	6	1979	50	300	LCKG	402014	744222	175	40	135
210357	H	JAFFIN, CHARLES	JAFFIN DOM	6	1981	50	250	LCKG	402044	744106	167	40	127
210358	U	US GEOLOGICAL SURVEY	PRNCTN 1-BRICK RD OB	4	1989	24	305	SCKN	402023	743919	100	41	59
210359	U	US GEOLOGICAL SURVEY	PRNCTN 2-CHILL PL OB	4	1989	28	439	SCKN	402032	743925	120	10	110
210360	H	DUPEE, SAMUEL JR	DUPEE 1	6	1970	40	173	PSSC	402242	745006	300	20	280
210365	U	AT&T	AT&T NORTH OBS	6	--	--	99	PSSC	402138	744358	232	15	217
210366	U	STATE OF NJ - NJGS	WASH CRS PRK 14 OBS	6	1989	50	225	PSSC	401837	745115	150	65	85
210367	H	HOROWITZ, MILTON	HOROWITZ DOM	6	1957	51	70	SCKN	401809	744022	80	17	63
210368	H	BIRCH	BIRCH DOM	6	1948	22	131	SCKN	401957	744053	100	55	45
210369	H	POLANA, JASNA	BOMB SHELTER	6	1984	40	300	LCKG	402003	744136	130	40	90
210370	H	WANG, SHU-SHENG	WANG DOM	6	1957	24	60	SCKN	402017	743801	70	18	52
210371	H	CIGNARELLA, RICHARD	CIGNARELLA DOM	6	1988	59	360	LCKG	402220	744927	410	50	360
210373	H	PENNINGTON WATER DEPT	PENNINGTON WD 8	10	1965	61	300	PSSC	402004	744745	195	37	158
210374	U	MOBIL RESEARCH & DEV.	MW 2	6	1989	70	600	PSSC	402027	744632	158	24	134

Table 4a. Records obtained from U.S. Geological Survey Ground-Water Site Inventory data base for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

USGS well number	Use of water	Owner	Local well number or name	Diameter of open interval (inches)	Year of construction	Open interval (feet below land surface) Top	Bottom	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Depth to water (feet below land surface)	Altitude of water level (feet)
210375	U	MOBIL RESEARCH & DEV.	MW 1	6	1989	32	600	PSSC	402047	744553	216	50	166
210376	N	SOCONY MOBIL OIL COMPANY	1	10	1962	30	426	PSSC	402049	744612	202	52	150
210377	U	MOBIL TECHNICAL CENTER	MW 3	6	1989	20	600	PSSC	402052	744637	176	35	141
210381	R	HOPEWELL VAL. GOLF CLUB	HVGC RESTROOM 2	--	1959	25	180	PSSC	402139	744651	170	8	162
210382	H	HOPEWELL VAL. GOLF CLUB	HVGC CLUBHOUSE 1	--	1959	30	400	PSSC	402146	744714	180	12	168
210408	N	AT&T TECHNOLOGIES	AT&T FILM CENTER	6	1948	12	185	PSSC	402128	744350	180	14	166
210409	N	AT&T TECHNOLOGIES	AT&T WELL 2	8	1960	35	300	PSSC	402135	744345	200	22	178
350016	U	NJ NEUROPSYCHIATRIC	EIGHT	10	1963	42	300	SCKN	402509	744142	105	25	80
350025	H	GILLICO, CARMEN	GILLICO 1	6	1961	20	160	LCKG	402516	744436	370	20	350
350026	H	BALDINO, JOHN	BALDINO 1	6	1984	50	200	PSSC	402438	744314	160	40	120
350028	U	N.J. NEUROPSYCHIATRIC	SEVEN	8	1958	33	303	PSSC	402510	744116	115	35	80
350040	H	SMITH, WILLIAM L	SOMERVILLE POULTRY	6	1970	52	155	PSSC	402545	744200	120	15	105
350041	H	DEMUND, WINIFRED	DEMUND 1	6	1978	52	200	LCKG	402556	744430	357	20	337
350043	H	JAMES, LEONARD P	DOMESTIC 1	6	1965	21	117	PSSC	402601	744246	200	12	188
350047	H	KRIK, GEORGE	KIRK DOM	6	1983	60	145	SCKN	402520	744323	159	27	132
350048	H	RYAN, GEOFFREY T	RYAN DOM	6	1985	32	165	LCKG	402539	744500	434	20	414
350049	H	FRENCH	FRENCH 1	6	1977	51	180	PSSC	402403	744216	128	20	108
350050	H	HAGGON, WILLIAM	HAGGON DOM & OFC	6	1986	52	260	PSSC	402443	744112	102	20	82
350051	H	MARTIN	MARTIN DOM	6	1984	50	300	LCKG	402620	744409	348	20	328
350052	H	HYDAHL	HYLDAHL DOM	6	1986	50	175	PSSC	402342	744345	115	20	95
350053	H	MCBRIDE, GREGORY	MCBRIDE DOM	6	1985	50	200	PSSC	402423	744357	174	25	149
350054	H	MCNALLY	MCNALLY DOM	6	1984	60	160	PSSC	402450	744313	131	40	91
350055	H	FELMEISTER	FELMEISTER DOM	6	1983	52	275	PSSC	402406	744057	104	60	44
350056	H	DILLIVIO	DILLIVIO DOM 1	6	1980	31	200	LCKG	402559	744457	412	15	397
350057	H	KEIFER, DAVID	KEIFER DOM	6	1984	50	250	PSSC	402417	744356	164	45	119
350058	H	DUDEK, LARRY	DUDEK DOM	6	1984	50	180	PSSC	402438	744357	196	20	176
350059	H	VOORHEES, WILLIAM	VOORHEES 762	6	1984	50	420	PSSC	402421	744059	74	10	64
350060	H	BERGMAN, JAMES	BERGMAN DOM	6	1987	63	200	LCKG	402259	744250	199	25	174
350061	H	BUCCI, EDWARD	BUCCI DOM	6	1985	50	230	LCKG	402253	744150	271	35	236
350062	H	HOISINGTON, ELEANOR M	HOISINGTON DOM	6	1984	50	225	LCKG	402302	744110	250	35	215

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey

[Altitudes in feet above sea level, rounded to nearest foot; --, no data available; casing lengths and well depths rounded to nearest foot.

Geologic-unit codes: PSSC--Passaic Formation; LCKG--Lockatong Formation; SCKN--Stockton Formation; DIBS--Diabase rocks.

Use-of-water codes: H--domestic; I--industrial.

Well number identifies the reference from which the well data were obtained:

For well data obtained from Kasabach (1966):
The first digit in the well number is 8.
The second and third digits indicate the Township in which the well is located: 05--East Amwell, 14--West Amwell.
The fourth, fifth, and sixth digits are the well number as listed in the cited report.

For well data obtained from Vecchioli and Palmer (1962):
The first three digits are 900.
The fourth, fifth, and sixth digits are the well number as listed in the cited report.

For well data obtained from Widmer (1965):
First digit is 7.
The second and third digits indicate the Township in which the well is located: 05--West Windsor, 06--Princeton, 07--Lawrence, 08--Ewing, 09--Hopewell.
The fourth, fifth, and sixth digits are the well number as listed in the cited report.]

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County							
705001	H	Design for Living	6	1957	22	82	SCKN	401808	744019	80	15	65
705003	I	American Cyanamid #3	8	1958	--	300	SCKN	401743	744024	81	26	55
705007	H	Public Service	6	1959	30	67	SCKN	401956	743830	100	28	72
705009	I	Springdale Warehouse Corp.	6	1959	37	200	SCKN	401928	743827	80	11	69
705010	I	Paradise Pool	8 & 6	1954	37	320	SCKN	401824	743952	60	2	58
705040	I	Princeton Water Co. B-4	13.5 & 10	1930	--	302	SCKN	402019	743806	74	4	70
705048	H	Boyd	6	1928	--	84	SCKN	401842	743948	78	4	74
205056	I	Heyden Chemical Company #1	12	1943	--	300	SCKN	401937	743824	100	7	93
705059	I	Wildermuth #1	--	1926	--	135	SCKN	401942	743812	100	1	99
705066	H	Levine	--	1930	--	80	SCKN	401827	744007	60	10	50

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County--Continued							
705072	H	Amabile	6	1950	45	86	SCKN	401829	743919	60	18	42
706001	H	Chin	6	1958	--	85	DIBS	402260	744022	230	12	218
706004	H	Italian Amer. Sportsmans Club	6	1953	20	400	LCKG	402208	743910	149	16	133
706005	H	Italian Amer. Sportsmans Club	6	1953	24	115	LCKG	402210	743919	184	8	176
706007	H	Humphreys	6	1957	27	163	LCKG	402225	743836	137	10	127
706008	H	Lambert #5	8	1955	32	452	LCKG	402029	744205	160	12	148
706011	H	Fox	8	1957	29	77	LCKG	402047	744100	165	3	162
706012	H	Institute for Advanced Study	6	1956	22	150	SCKN	401952	744004	103	18	85
706013	H	Cashvan	6	1959	23	110	SCKN	401917	744124	97	23	74
706014	H	Miller	6	1959	23	100	SCKN	401906	744125	84	23	61
706015	H	Miller	6	1959	23	85	SCKN	401916	744112	73	18	55
706016	I	Princeton Water Company	12	1958	36	403	PSSC	402149	743946	176	13	163
706018	H	Harris	6	1959	24	108	LCKG	402117	743824	126	15	111
706019	H	Snedaker & Son	6	1954	24	175	PSSC	402041	744214	190	7	183
706020	H	Vancleve	6	1952	18	95	LCKG	402132	744205	165	10	155
706021	H	Hall	6	1951	--	100	DIBS	402223	744256	330	20	310
706022	H	Flag	6	1952	15	97	LCKG	402004	744158	126	18	108
706023	H	Endersky	6	1952	23	137	LCKG	402050	744215	203	18	185
706024	H	Schluter	6	1949	28	155	LCKG	402046	744218	187	6	181
706028	H	Cresswell	6	1925	41	167	DIBS	402246	744154	269	10	259
706030	H	Sayer	8	1951	53	174	DIBS	402221	744133	295	8	287
706033	H	Stokes	6	1941	25	107	SCKN	401937	744143	163	8	155
706034	H	Princeton Quaker Meeting	6	1953	21	91	SCKN	401935	744042	88	26	62
706035	H	Eno	8	1943	30	190	SCKN	401922	744041	81	17	64
706036	H	Lauck	--	1947	--	158	SCKN	401927	744129	149	50	99
706037	I	Princeton Shopping Center	10	1952	38	393	PSSC	402154	743907	137	1	136
706039	H	Lambert #1	6	1949	27	378	LCKG	402025	744153	95	32	63
706040	H	Behrens	6	1929	--	70	DIBS	402207	744019	229	12	217
706042	H	Zullig	6	1954	23	70	DIBS	402222	744018	321	6	315
706043	H	Geherty	6	1952	52	75	DIBS	402314	743903	161	7	154
706044	H	Cook	6	1952	57	270	DIBS	402242	743959	285	18	267
706046	I	Rockwood Dairy	6	1938	--	85	LCKG	402123	743954	145	10	135
706049	H	Tuska	6	1948	8	109	SCKN	401958	744035	133	20	113
706051	H	Swan	6	1948	23	182	LCKG	402013	744155	144	19	125

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
						Mercer County--Continued						
706054	H	Funkhouser	6	1952	23	141	LCKG	402210	743834	103	14	89
706055	I	Princeton Water Company	10	1915	--	304	SCKN	401934	743934	60	13	47
706058	H	Salzman	6	1947	25	87	DIBS	402216	744008	310	22	288
706059	H	Pretty Brk. Corporation Lot A	6	1928	24	140	LCKG	402149	744131	203	19	184
706060	H	Parker	6	1910	--	186	LCKG	402113	743832	133	8	125
706061	H	Bower	6	1952	34	156	LCKG	402214	743836	115	6	109
706062	H	Howell	6	1938	33	181	PSSC	402150	743837	138	28	110
706064	H	Davidson	6	1951	--	92	PSSC	402144	743833	121	25	96
706066	H	Cramer & Bogert	6	1947	--	50	DIBS	402315	743932	174	15	159
706067	H	Bond	6	1948	22	202	LCKG	402213	743829	125	16	109
706071	H	Lambert #4	8	1949	--	267	LCKG	402015	744150	140	23	117
706072	H	Lambert #3	8	1948	22	396	LCKG	402017	744160	140	10	130
706073	H	Lambert #2	6	1949	27	287	LCKG	402019	744152	144	23	121
706074	H	Yates	6	1926	15	160	LCKG	402150	744125	200	4	196
706075	H	Kilgore	6	1953	30	252	PSSC	402141	743844	136	30	106
707001	I	Education Testing Service	12 & 8	1957	45	248	LCKG	402112	744303	101	13	88
707004	I	Education Testing Service	12 & 8	1956	50	223	LCKG	402105	744310	98	5	93
707005	H	Woods	8 & 6	1956	21	350	LCKG	401945	744351	212	6	206
707007	H	Thompson	8 & 6	1954	18	100	LCKG	401846	744242	100	22	78
707008	H	Rusling	8 & 6	1954	28	169	LCKG	401831	744310	161	22	139
707010	H	Cashvan	6	1959	38	146	SCKN	401853	744129	81	20	61
707015	H	Campbell	6	1956	32	80	SCKN	401749	744232	60	9	51
707025	H	LaPlaca	8 & 6	1951	21	80	LCKG	402025	744302	195	5	190
707026	H	Schleuter	8	1951	24	337	LCKG	402036	744247	203	4	199
707027	H	Goldstine	6	1950	22	103	LCKG	401954	744332	193	10	183
707028	H	Beacraft	8 & 6	1951	22	130	LCKG	402021	744250	180	5	175
707029	H	Hannah	6	1929	21	130	LCKG	402053	744232	200	10	190
707030	H	Cowan	6	1929	24	119	LCKG	402038	744222	203	9	194
707031	H	Katzenbach	6	1941	24	199	LCKG	401952	744205	145	15	130
707032	H	Batton	--	1930	--	201	LCKG	402042	744232	204	18	186
707034	H	Goodridge	--	1938	--	185	LCKG	402014	744215	162	11	151
707041	H	Newman	6	1947	28	90	LCKG	401828	744436	184	5	179
707048	H	Raymond	6	1953	44	106	LCKG	401845	744236	122	25	97
707049	H	Penrose	6	1953	35	100	LCKG	401854	744223	144	28	116
707050	H	Buxton's Dairy	8	1948	26	250	LCKG	401805	744452	180	3	177

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
						Mercer County--Continued						
707057	H	Lauck	6	1950	23	198	LCKG	401904	744214	154	22	132
707058	H	Luccarelli	6	1952	17	115	SCKN	401913	744154	162	45	117
707059	H	Prickett	4	1934	--	204	PSSC	402041	744328	105	35	70
707060	H	Hazeltine	6	1949	28	105	LCKG	401942	744235	187	3	184
707061	H	LaPlaca	6	1951	--	76	LCKG	402018	744303	196	4	192
707062	H	Kelly	6	1952	18	131	PSSC	402059	744234	171	12	159
707065	H	Hutchinson	6	1952	24	149	LCKG	401903	744248	163	18	145
707066	H	Houghton	6	1953	31	125	LCKG	401849	744230	122	26	96
707067	H	Mitchell	6	1950	22	160	LCKG	401858	744249	148	10	138
707072	H	Houghton	6	1934	--	123	LCKG	401854	744341	182	20	162
707080	I	Clarksville Diner	8	1960	41	85	SCKN	401750	744102	78	17	61
707081	H	Nadi	6	1929	--	73	SCKN	401725	744129	69	3	66
707091	H	Fackler	6	1935	40	104	SCKN	401833	744224	100	20	80
707096	H	Maruca	6	1961	23	100	LCKG	402006	744206	119	8	111
707097	H	Lonska	6	1961	22	95	LCKG	401837	744417	168	18	150
707099	H	Lovero	6	1962	26	145	LCKG	401801	744513	180	20	160
708001	H	Penlee	6	1956	22	133	LCKG	401643	745044	190	2	188
708002	H	Nortorion	6	1954	6	177	LCKG	401714	745016	151	37	114
708003	H	Jacobella	6	1954	21	125	LCKG	401639	745057	144	27	117
708005	H	Barber	8 & 6	1949	21	176	LCKG	401623	745109	59	55	4
708006	H	Fraulino	10,8 & 6	1954	22	113	LCKG	401629	745060	102	25	77
708007	H	Dowdell	10 & 8	1955	23	120	LCKG	401633	745050	144	50	94
708008	H	Walker	8 & 6	1954	20	156	LCKG	401603	745044	115	40	75
708009	H	Duralski	6	1956	45	100	LCKG	401629	745032	207	15	192
708010	I	Hampton Hill WC	8	1955	35	250	SCKN	401647	744644	164	19	145
708016	H	George Brewster, Inc.	8 & 6	1959	25	90	LCKG	401614	744923	138	17	121
708030	H	Lambert	6	1948	20	111	LCKG	401551	745032	112	28	84
708033	H	Dowdell	6	19--	23	84	SCKN	401632	745105	102	20	82
708035	H	Huff	6	1951	21	72	SCKN	401650	744822	187	8	179
708037	I	Mercer County Airport	8	1943	--	232	SCKN	401700	744853	207	9	198
708038	I	US Navy - Air Testing Station	8	1943	--	603	SCKN	401609	744830	154	11	143
708040	H	Scott	6	1954	--	92	SCKN	401640	744654	161	29	132
708041	H	Van Horn	6	1951	27	85	SCKN	401636	744710	157	24	133
708043	H	Kittell	6	1951	60	90	SCKN	401647	744655	184	42	142
708050	H	Jackson	6	1940	--	67	SCKN	401643	744716	180	50	130

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County--Continued							
708064	H	Buck	6	1956	34	95	SCKN	401549	744934	157	15	142
708073	H	Kreiguer	6	1952	--	104	LCKG	401622	745054	118	40	78
708075	H	Holmes	6	1951	--	62	LCKG	401646	745037	184	15	169
708087	H	Peterson	6	1953	22	123	LCKG	401636	745105	108	30	78
708093	I	State Hospital Dairy Farm	12 & 8	1944	30	436	LCKG	401612	744933	138	17	121
708094	H	Harmon	6	1948	21	105	LCKG	401660	745007	197	20	177
708095	H	Klim	6	1948	29	110	SCKN	401550	744913	167	19	148
708100	H	McElwee	6	1951	16	142	LCKG	401649	745030	187	15	172
708101	H	Trinity Church, Trenton	--	1921	--	123	LCKG	401635	745059	131	24	107
708102	H	Russo	6	1956	20	153	LCKG	401633	745039	157	8	149
708103	H	Landwehr Restaurant	6	1952	--	140	LCKG	401648	745048	161	10	151
708106	H	Calvanelli	6	1951	--	72	LCKG	401658	745014	187	15	172
708107	H	Kotovach	6	1952	22	80	LCKG	401650	745014	200	19	181
708108	H	Perline	6	1952	22	81	LCKG	401648	745007	207	12	195
708111	H	Brophy	8 & 6	1957	23	90	SCKN	401710	744659	167	4	163
708112	H	Lentini	8 & 6	1958	21	70	SCKN	401703	744653	167	8	159
708115	H	Tren-Deli Con	6	1958	22	200	LCKG	401616	745031	125	20	105
708116	H	McLaughlin	8 & 6	1957	--	95	LCKG	401624	744925	180	18	162
708118	H	Lentini & Grice	6	1956	26	90	SCKN	401651	744707	184	25	159
708120	H	Genecey Company	6	1956	21	135	LCKG	401708	745013	180	40	140
708121	H	Genecey Company	6	1956	21	148	LCKG	401651	745014	203	32	171
708123	H	Statler Buildings	6	1957	22	115	LCKG	401624	745047	134	18	116
708124	H	Jacobelli	6	1957	33	110	LCKG	401616	745037	148	14	134
708125	H	Statler Buildings	6	1957	21	110	LCKG	401712	745023	161	14	147
709001	H	Lake	8 & 6	1954	46	90	DIBS	402411	744821	407	12	395
709002	H	McKelvy	6	1956	27	153	SCKN	402238	744744	216	27	189
709003	H	Hodnett	8 & 6	1955	55	67	DIBS	402240	744619	315	16	299
709004	H	Newbanks, Inc.	8	1960	--	85	SCKN	402215	744759	305	12	293
709005	H	Hodson Hart	10 & 6	1954	23	173	DIBS	402003	745132	364	35	329
709006	H	Harbourton Cemetery	6	1960	25	85	LCKG	402101	745105	298	10	288
709007	H	Pennington Builders #2	8 & 6	1960	24	100	LCKG	402049	744816	197	26	171
709008	H	Pennington Builders #1	8 & 6	1954	23	108	LCKG	402049	744806	207	12	195
709011	H	Nickerson	8 & 6	1954	21	184	LCKG	401912	745123	266	60	206
709013	H	Yazujian	6	1955	24	404	DIBS	401952	745215	436	96	340
709014	H	Doll	6	1955	20	175	DIBS	401958	745214	420	20	400

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
						Mercer County--Continued						
709015	H	Grove	8 & 6	1957	21	190	LCKG	401913	745148	194	43	151
709016	H	Whyte	8 & 6	1955	30	262	LCKG	401905	745137	246	33	213
709017	H	Anderson	8 & 6	1960	24	60	PSSC	401924	744857	216	18	198
709019	H	Hill	6	1958	22	300	LCKG	401708	745126	105	60	45
709020	H	Hill	6	1958	22	380	LCKG	401708	745126	105	60	45
709025	I	Anderson	6	1955	30	138	PSSC	402035	744544	180	50	130
709026	H	Raswieler	8 & 6	1955	24	124	PSSC	402019	744615	174	18	156
709027	H	MacDonald	8 & 6	1957	21	112	PSSC	401932	744603	180	24	156
709028	H	Ogden Nursing Home	6	1961	24	200	LCKG	401728	745138	118	20	98
709029	H	Howe Nurseries	8 & 6	1957	22	205	PSSC	401915	744710	190	30	160
709030	H	Young	8 & 6	1955	23	240	PSSC	401907	744652	180	23	157
709032	I	Howe Nurseries	8 & 6	1957	23	228	PSSC	401913	744635	174	6	168
709033	H	Himes	6	1954	23	230	PSSC	401907	744704	203	31	172
709034	H	Doherty	8 & 6	1954	23	142	LCKG	401825	744742	220	12	208
709035	H	Barbour	8	1961	32	150	LCKG	401704	745124	102	28	74
709036	H	Trenton Banking Company	8 & 6	1958	21	147	LCKG	401825	744717	200	19	181
709037	H	Vickers	6	1955	21	80	LCKG	401741	744626	164	9	155
709038	H	Blue Ribbon, Inc.	8 & 6	1957	23	100	LCKG	401743	744647	210	16	194
709039	H	Toten	4 & 6	1954	80	202	LCKG	401737	744648	203	37	166
709040	I	Blue Ribbon Water Company	10 & 8	1956	35	159	SCKN	401724	744622	148	17	131
709041	H	Badinski #2	6	1961	24	92	LCKG	402008	744904	213	25	188
709042	H	Shauer	8 & 6	1954	23	150	LCKG	402419	744528	331	30	301
709043	H	Brookstone Builders	10 & 6	1960	63	91	DIBS	402221	744455	304	12	292
709044	H	Pomeroy	6	1957	36	211	SCKN	402429	744456	394	18	376
709046	H	Philco Company	8 & 6	1957	33	100	DIBS	402212	744315	357	22	335
709047	H	Queenston Builders	6	1960	24	100	PSSC	402156	744554	180	22	158
709048	H	Queenston Builders	6	1960	27	125	PSSC	402156	744547	180	18	162
709049	H	Queenston Builders	6	1960	24	185	PSSC	402154	744542	184	24	160
709050	H	Queenston Builders	6	1960	24	116	PSSC	402147	744546	177	12	165
709051	H	Lane Farms, Inc.	8	1961	46	373	LCKG	402202	744942	364	5	359
709052	H	Hutchinson	6	1956	22	85	LCKG	401825	744529	220	25	195
709053	H	Potts	6	1962	29	89	LCKG	402227	745022	295	12	283
709054	H	Toten	6	1962	21	125	LCKG	401705	745107	148	23	125
709055	H	Blackwell	6	1962	34	350	LCKG	401701	745112	141	12	129
709057	H	Carom	6	1951	15	130	PSSC	402234	744413	256	23	233

Table 4b. **Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued**

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County--Continued							
709058	H	Voorhees	6	1948	23	155	PSSC	402344	744410	141	16	125
709059	H	Collins	8	1953	21	208	SCKN	402438	744447	420	18	402
709060	H	Badinski #3	6	1961	24	100	LCKG	402014	744905	220	18	202
709064	H	Barna	6	1949	53	93	DIBS	402247	744637	285	27	258
709065	H	Udy	6	1958	24	110	SCKN	402418	744448	295	19	276
709066	H	Scarpati	6	1948	20	282	DIBS	402454	744710	440	16	424
709067	H	Pierson	6	1952	20	81	SCKN	402313	744711	364	15	349
709068	H	Snyder	6	1952	10	82	LCKG	402418	744617	335	15	320
709069	H	VanSant	6	1952	21	139	PSSC	402352	744426	184	17	167
709070	H	LaCross	6	1961	26	100	PSSC	401841	744609	203	10	193
709071	H	Basil DiGuiseppe	6	1961	24	163	PSSC	401841	744842	187	50	137
709072	H	Stover - now Wierdsma	8	1941	32	168	SCKN	402246	744723	236	25	211
709073	H	Mulford	6	1951	--	75	DIBS	402235	744634	259	20	239
709074	H	Wombwell	6	1951	22	114	LCKG	402423	744531	246	10	236
709075	H	Bellot	6	1950	26	140	SCKN	402350	744554	358	6	352
709076	H	Chorley	6	1951	--	118	PSSC	402343	744450	164	18	146
709077	H	Conoven	6	1951	--	76	LCKG	402460	744511	315	4	311
709078	H	Cole	6	1950	31	271	SCKN	402327	744653	390	19	371
709079	H	Chafey	6	1949	32	75	SCKN	402408	744519	282	29	253
709080	H	Capner	6	1948	18	140	PSSC	402346	744441	167	17	150
709081	H	Novohilsky	--	1949	--	119	LCKG	402427	744627	374	19	355
709082	H	VanSant	6	1949	53	79	DIBS	402238	744639	259	22	237
709083	H	Basil DiGuiseppe	6	1961	25	100	PSSC	401836	744841	161	50	111
709084	H	Valents	6	1949	34	75	DIBS	402256	744642	246	13	233
709086	H	Denaci	6	1949	22	214	LCKG	402439	744632	426	7	419
709087	H	Brooks	6	1948	23	129	SCKN	402434	744430	305	16	289
709088	H	Totten, Robert	6	1961	25	124	LCKG	401825	744725	207	12	195
709089	H	Swick	6	1948	40	190	DIBS	402227	744654	236	19	217
709093	H	Kostar	6	1950	20	151	LCKG	401727	744911	157	35	122
709094	H	Wood	6	1951	20	130	LCKG	401727	744903	187	40	147
709095	I	National Dairy Products Co.	8	1929	42	188	PSSC	401806	744808	226	19	207
709104	H	Panacek	6	1955	20	110	SCKN	402105	745022	384	16	368
709105	H	Fernwood Mercer	6	1953	24	62	LCKG	401731	744654	197	9	188
709106	H	Backus	6	1953	66	85	LCKG	401659	745120	105	19	86
709107	H	Seckle - now Anderson	6	1956	--	150	LCKG	402424	744519	387	70	317

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County--Continued							
709108	H	Bard	6	1950	22	145	PSSC	401747	744848	223	28	195
709109	H	NJCED (Bear Tavern)	6	1950	30	165	LCKG	401834	745050	194	25	169
709111	H	NJCED (Washington Grove)	6	1929	40	144	PSSC	401749	745207	39	27	12
709113	H	Postley	8	1953	32	397	PSSC	401732	745056	171	25	146
709114	H	Cioppi	6	1956	20	68	LCKG	402053	745107	292	15	277
709115	H	Lake	6	1957	43	66	DIBS	402414	744813	397	12	385
709117	H	Holcomb	6	1958	27	65	LCKG	402256	744940	289	8	281
709118	H	Schire Deer Club	6	1959	20	65	DIBS	402452	744700	449	8	441
709119	H	Hunt, Jr.	6	1960	25	250	LCKG	402234	745008	289	35	254
709120	H	Engle	6	1956	24	173	LCKG	402035	744416	173	20	153
709121	H	Meredith	6	1956	23	150	PSSC	402019	744529	164	27	137
709122	H	City Service Oil Company	6	1957	26	140	PSSC	401817	744659	200	10	190
709123	H	Culten	6	1949	24	135	PSSC	401804	745130	115	51	64
709124	H	Keffer	6	1949	42	215	LCKG	401734	745141	121	69	52
709125	H	Beemen	6	1948	21	165	LCKG	401825	745028	154	45	109
709126	H	Hilbert	6	1956	21	124	LCKG	402243	745046	348	13	335
709127	H	Lauter	6	1950	22	160	LCKG	401826	745042	180	24	156
709129	H	Cooley	--	1909	--	121	PSSC	401747	745152	112	20	92
709130	H	Ehret	6	1951	--	150	LCKG	401651	745114	92	15	77
709131	H	Hayes	6	1948	20	181	LCKG	401828	745032	187	40	147
709132	H	Jury	6	1948	22	143	LCKG	401827	745101	187	16	171
709133	H	Illian	6	1948	21	121	PSSC	401808	745124	131	32	99
709134	H	Antrobus	6	1958	22	200	DIBS	401950	745136	397	20	377
709136	H	Bueschel	6	1959	20	170	DIBS	402013	745227	348	30	318
709137	H	Banacei	6	1953	22	110	LCKG	401655	745118	102	31	71
709138	H	Winkler	6	1952	23	204	PSSC	401849	744716	200	20	180
709139	H	Wilson	6	1951	43	119	PSSC	401934	744805	207	37	170
709140	H	Hoffman	6	1950	21	110	PSSC	401901	744812	190	18	172
709142	H	Van Dyke	6	1950	26	50	DIBS	402028	744932	285	8	277
709143	H	Kettenberg & son	6	1961	25	100	DIBS	402217	744702	226	20	206
709144	H	Kettenberg & Son	6	1961	20	100	LCKG	402212	744702	220	20	200
709145	H	Tizik	6	1948	24	104	PSSC	401836	744725	207	18	189
709149	H	Dayizak	6	1959	23	90	SCKN	401717	744635	144	17	127
709150	H	Pierson	6	1956	46	52	SCKN	402313	744654	292	25	267
709151	H	Katzenback	6	1956	28	115	SCKN	402318	744718	338	12	326

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County--Continued							
709152	H	Salnaggio	6	1948	41	126	PSSC	401837	744731	213	16	197
709153	H	Comstock Architect	6	1956	22	137	SCKN	402301	744736	351	43	308
709154	H	Prozeralick	6	1955	31	32	DIBS	402406	744819	394	13	381
709155	H	Perry Preckwinkle	6	1956	20	120	SCKN	402204	744855	384	18	366
709156	H	Rockwell	6	1938	31	127	PSSC	401951	744653	184	32	152
709163	H	Reed, Jr.	6	1949	31	171	DIBS	402058	744919	417	44	373
709164	H	Pennington Quarry Company	6	1951	39	45	PSSC	402102	744805	233	16	217
709165	H	Oldis	6	1949	22	250	PSSC	401821	744914	177	22	155
709166	H	Palmer Nurseries	6	1929	130	225	PSSC	402112	744535	157	6	151
709167	H	Holler	6	1942	30	256	PSSC	402022	744501	161	19	142
709168	H	Himmekbock	6	1953	21	100	PSSC	401840	744716	197	9	188
709169	H	Herpers	6	1951	20	109	PSSC	402012	744749	190	12	178
709170	H	Hoagland	6	1950	20	128	LCKG	402044	744753	197	12	185
709172	I	Pennington Boro #1 Penn. Mt.	6	1907	--	186	PSSC	402046	744847	236	8	228
709173	I	Pennington Boro #2 Penn. Mt.	6	1907	--	159	PSSC	402046	744847	236	8	228
709174	I	Pennington Boro #3 Del Ave	10	1927	57	657	PSSC	401944	744751	194	38	156
709179	I	Pennington Boro #8 Del. Ave.	10	1954	43	178	PSSC	402003	744702	141	19	122
709188	H	Brookside Inn	6	1931	--	96	LCKG	402259	744913	233	5	228
709191	H	Kurylo	6	1951	--	100	LCKG	402208	745102	344	9	335
709194	H	Burd	6	1953	40	70	DIBS	402039	744935	367	10	357
709195	H	Klein	6	1953	22	150	DIBS	401958	745119	384	10	374
709196	H	Betjemann	6	1953	14	150	DIBS	401958	745204	413	30	383
709197	H	Kessler	6	1936	--	112	PSSC	402006	745021	210	20	190
709198	H	Czaiko	6	1950	22	126	LCKG	402133	745100	289	9	280
709199	H	Wilson	6	1936	--	249	LCKG	402046	745113	282	10	272
709200	H	Maddox	6	1932	37	180	LCKG	402056	745122	282	6	276
709201	H	Rose	6	--	116	LCKG	402121	745132	236	14	222	
709203	H	Holden	6	1948	64	110	PSSC	402032	745134	253	8	245
709204	H	Roebling	6	1950	23	262	LCKG	402113	745129	338	3	335
709206	I	Penn Brook Club	8	1957	26	250	PSSC	402005	744729	184	17	167
709207	I	Western Electric Company	8	1960	35	300	PSSC	402138	744343	200	22	178
709208	I	Western Electric Company	8	1957	42	501	PSSC	402136	744330	208	27	181
709210	H	Fauseet	6	24	150	SCKN	402245	744756	246	40	206	
709211	H	Pennington Grance	6	1956	22	126	PSSC	402052	744741	177	9	168
709212	H	Bruce, Jr.	6	1955	22	120	PSSC	401945	744552	164	18	146

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
						Mercer County--Continued						
709213	H	Nelson	6	1955	21	115	PSSC	402007	744537	138	25	113
709214	H	Nelson	6	1955	22	131	PSSC	402009	744526	141	30	111
709215	H	Knowlton	6	1955	32	150	PSSC	402012	744514	138	32	106
709218	I	Smith Machine Company	6	1939	--	150	PSSC	402340	744523	190	5	185
709221	H	Martin	6	1951	39	148	LCKG	402226	744912	282	10	272
709222	H	Tobiason	6	1949	34	184	LCKG	402049	744759	207	12	195
709223	H	Burton	6	1950	21	85	LCKG	402227	744938	249	2	247
709227	H	Schometzer	6	1950	22	120	LCKG	401957	744758	220	50	170
709229	H	VonSchmidt	6	1951	--	71	PSSC	401807	744732	210	15	195
709230	H	Bolz	6	1947	30	133	LCKG	401743	745136	161	28	133
709243	H	Haldeman	6	1951	27	91	LCKG	402058	744755	207	17	190
709244	H	Fabian	6	1952	21	95	PSSC	401824	744621	203	13	190
709245	H	Funeisn	6	1950	21	130	PSSC	401854	744856	144	35	109
709246	H	DiGaetano	8	1952	28	114	PSSC	401849	744726	213	15	198
709247	H	Appelgate	6	1951	21	135	PSSC	401941	744909	223	22	201
709248	H	Anderson	6	1961	30	250	DIBS	402018	745301	225	3	222
709249	H	DiCocco, Honey Brook Drive	6	1961	22	148	PSSC	402040	744436	140	30	110
709253	H	Dolphin Shores	6	1962	25	124	PSSC	401832	744603	216	15	201
709263	H	Narozniak	6	1949	34	111	PSSC	401806	744724	210	14	196
709289	I	Washington Cross. Park Est.	6	1961	31	500	PSSC	401839	745034	157	35	122
709290	H	Pierson	6	1951	20	143	PSSC	401902	745118	243	60	183
709293	H	VanKmanvich	6	1951	--	130	PSSC	401944	744852	216	18	198
709295	H	Balain	6	1950	22	132	PSSC	401908	744712	207	45	162
709296	H	Panecek	6	1955	20	110	SCKN	402113	745006	410	24	386
709297	H	Roman	6	1956	23	125	LCKG	401914	745134	239	43	196
709302	H	Utt	6	1960	22	118	DIBS	401955	745128	420	18	402
709303	H	Expanded Living Search Avenue	6	1961	31	140	PSSC	401835	744738	220	40	180
709304	H	McVeigh, Joseph	6	1961	12	200	DIBS	401951	745159	390	35	355
709334	H	Wilson	6	1949	22	125	LCKG	401826	745015	134	28	106
709339	H	Atlantic Gas Station	6	1939	--	105	LCKG	401831	744720	200	30	170
709341	H	Murray	6	1949	43	115	DIBS	402007	745112	312	5	307
709342	H	Neiderer	8	1954	25	85	DIBS	401958	745147	354	32	322
709345	H	Shestko	6	1961	28	130	LCKG	401826	745109	187	50	137
709346	H	Niewojna	6	1961	22	93	LCKG	401948	744928	207	38	169
709348	H	Fosbrook	6	1961	26	300	LCKG	401901	745218	197	8	189

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County--Continued							
709349	H	Potts (Howe Tract)	6	1961	26	108	PSSC	401916	744649	177	18	159
709350	H	Bayard	6	1961	30	165	PSSC	402058	744647	164	37	127
709351	H	Zigleniski	6	1961	21	111	PSSC	401947	744638	167	22	145
709352	H	Kiefer	6	1957	76	95	DIBS	402213	744421	307	18	289
709353	H	Koppach	6	1959	22	90	PSSC	402222	744420	272	15	257
709354	H	Poleski	6	1957	32	70	DIBS	402215	744427	318	12	306
709355	H	Whitcraft	6	1956	24	82	LCKG	402437	744510	384	0	384
709356	H	Princeton Manor Construction	6	1959	20	175	PSSC	402220	744332	303	5	298
709357	H	Thompson	6	1956	24	80	PSSC	402256	744529	161	16	145
709358	H	Hunt - Builder	6	1957	21	63	DIBS	402230	744536	285	30	255
709360	H	Bonano	6	1957	21	130	LCKG	402308	744738	318	30	288
709361	H	Lord	6	1961	23	85	LCKG	402253	744952	289	20	269
709362	H	Maul	6	1961	23	100	LCKG	402242	745009	302	15	287
709363	H	Mudge	6	1960	20	49	LCKG	402228	745007	279	15	264
709364	H	Mudge	6	1961	20	48	LCKG	402222	745006	262	8	254
709365	H	Maul	6	1961	21	287	PSSC	401918	745221	118	60	58
709366	H	Donigan, Jr.	6	1957	22	90	LCKG	401751	744639	203	20	183
709367	H	Kerr	6	1958	34	150	PSSC	401906	744658	197	32	165
709368	H	Moticha	6	1961	25	222	LCKG	402212	744955	279	10	269
709369	H	Perlee - Orchard Avenue	6	1956	20	101	LCKG	401741	744635	184	10	174
709373	H	Weitzman	6	1958	21	135	LCKG	401726	744643	180	12	168
709375	H	DiCocco	6	1960	24	122	PSSC	402101	744541	200	21	179
709376	I	Hopewell Borough Water Co.	6	1908	30	362	SCKN	402349	744544	276	42	234
709378	H	Colonial Construction Company	6	1958	24	100	PSSC	402152	744535	184	16	168
709379	H	Colonial Construction Company	6	1958	24	130	PSSC	402150	744526	184	20	164
709380	H	Colonial Construction Company	6	1958	23	80	PSSC	402150	744517	180	5	175
709381	H	Strano	6	1961	27	140	LCKG	401728	744849	210	12	198
900004	H	Power	6	1953	24	160	PSSC	401913	745127	269	58	211
900005	H	Hinkle	6	1957	22	103	PSSC	401860	745220	194	25	169
900006	H	Majeski	6	1953	22	138	PSSC	401820	745113	177	40	137
900009	H	Bear	6	1952	22	95	PSSC	402020	745113	285	4	281
900010	H	Hansen	6	1954	29	100	DIBS	402113	744927	289	8	281
900011	H	Arch	6	1952	22	60	LCKG	402220	745140	371	3	368
900012	H	Sheridan, Jr.	6	1954	25	95	LCKG	402220	745047	331	8	323
900025	H	Sutphen	6	1953	37	59	DIBS	402233	744327	289	8	281

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
					Mercer County--Continued							
900028	H	Kianka	6	1953	23	100	PSSC	402153	744540	184	8	176
900030	H	Western Electric Co., Inc.	6	1948	12	185	PSSC	402127	744353	180	14	166
900032	H	Gulf Oil Company	6	1958	35	150	PSSC	402127	744753	194	18	176
900033	H	Wicoff	6	1953	22	94	PSSC	402047	744807	203	30	173
900036	H	Smith	6	1956	32	105	PSSC	401953	744940	200	10	190
900044	H	Mraz	6	1954	22	125	PSSC	401927	744540	197	29	168
900045	H	Kuller	6	1953	22	135	PSSC	402020	744540	154	23	131
900066	I	Princeton Water Company	12	1945	69	300	SCKN	402020	743807	75	5	70
900106	H	Reside	6	1957	23	100	PSSC	401807	744753	223	22	201
900108	H	Underwood	6	1950	22	133	LCKG	401727	744900	200	25	175
900109	H	Smith	6	1952	20	220	LCKG	401713	745020	157	8	149
900112	H	Martin	6	1952	24	80	LCKG	401713	744647	148	5	143
					Hunterdon County							
805004	H	Parrenzan	6	1948	34	154	LCKG	402551	744820	302	23	279
805012	H	Allen, Jr.	6	1951	32	226	PSSC	402614	744806	282	25	257
805014	H	Marino	6	1950	37	351	DIBS	402516	744728	472	14	458
805031	H	Franke	6	1948	25	100	PSSC	402522	745121	197	6	191
805034	H	Halychyn	6	1950	28	99	PSSC	402407	745107	377	21	356
805035	H	Burton	6	1954	40	48	DIBS	402348	744917	387	7	380
805036	H	Hoffman	6	1952	15	100	DIBS	402358	744941	403	3	400
805038	H	Hoffman	6	1947	13	42	DIBS	402401	744934	426	12	414
805039	H	Blomquist	6	1947	20	119	DIBS	402427	744942	453	20	433
805045	H	Denmon	6	1954	18	55	DIBS	402435	745112	403	15	388
805046	H	Smith	6	1957	14	103	DIBS	402423	744833	436	19	417
805049	H	Palmatier	6	1954	24	88	LCKG	402552	744746	400	7	393
805062	H	Ostrowski	6	1961	23	202	DIBS	402427	745125	413	20	393
805063	H	Hannah	6	1962	22	90	PSSC	402411	745119	380	30	350
805064	H	LaRowe	6	1961	23	102	DIBS	402424	745121	426	10	416
805065	H	Adams	6	1962	23	93	LCKG	402534	744859	253	15	238
805066	H	Cvetan	6	1962	23	305	LCKG	402538	744844	285	40	245
805067	H	Siolli	6	1962	43	58	LCKG	402358	744840	380	15	365
805069	H	Hart	6	1963	20	193	LCKG	402318	744934	256	18	238
805071	H	Kresmer	6	1961	12	112	LCKG	402539	744732	489	6	483

Table 4b. Records obtained from published reports for selected wells in and near the Stony Brook, Beden Brook, and Jacobs Creek drainage basins, west-central New Jersey--Continued

Well number	Use of water	Owner	Diameter of casing (inches)	Year of construction	Casing length (feet)	Depth of well (feet)	Geologic-unit code	Latitude (degrees)	Longitude (degrees)	Altitude of land surface (feet)	Static water level (feet below land surface)	Altitude of static water level (feet)
				Hunterdon County--Continued								
814030	H	Roebling	6	1932	--	127	LCKG	402119	745151	213	6	207
814034	H	Yard	6	1949	32	129	PSSC	402247	745201	410	8	402
814035	H	Gayda	6	1949	60	70	PSSC	402452	745144	344	18	326
814036	H	Skibinsky	6	1932	--	108	PSSC	402404	745119	394	10	384
814042	H	S. Hunterdon Regional H.S.	6	1958	26	250	PSSC	402316	745331	390	21	369
814043	H	Kollmer, Jr.	6	1954	19	97	DIBS	402304	745254	456	19	437
814044	H	Steinmetz	6	1957	22	200	DIBS	402257	745252	455	10	445
814061	H	Pawljuch	6	1951	20	100	PSSC	402341	745047	380	15	365
814070	H	Arico	6	1961	23	100	DIBS	402321	745307	390	18	372
814071	H	Hanley	6	1962	18	94	DIBS	402330	745257	423	18	405
814072	H	Holcombe No. 1	6	1962	30	105	DIBS	402356	745203	361	15	346
814074	H	Cripps	6	1962	18	110	DIBS	402301	745259	450	22	428
814075	H	Mahan	6	1962	24	48	DIBS	402248	745228	449	20	429
814076	H	Stoy	6	1962	21	125	PSSC	402242	745222	426	15	411
814077	H	Kurylo	6	1954	24	71	DIBS	402405	745151	384	10	374
814083	H	Marino	6	1962	22	97	LCKG	402153	745212	377	15	362