GEOHYDROLOGY AND SIMULATION OF GROUND-WATER FLOW IN THE RED CLAY CREEK BASIN, CHESTER COUNTY, PENNSYLVANIA, AND NEW CASTLE COUNTY, DELAWARE

By Karen L. Vogel and Andrew G. Reif

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Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.000063	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second
inch per year (in/yr)	25.4	millimeter per year
	Specific capacity	
gallon per minute per foot [(gal/min)/ft]	0.000207	cubic meter per second per meter
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day
	Temperature	
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius (°C)

Other Abbreviations

milligrams per liter (mg/L)
micrograms per liter (µg/L)
micrograms per kilogram (µg/kg)
picocuries per liter (pCi/L)

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

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ABSTRACT

The 54-square-mile Red Clay Creek Basin, located in the lower Delaware River Basin, is underlain primarily by metamorphic rocks that range from Precambrian to Lower Paleozoic in age. Ground water flows through secondary openings in fractured crystalline rock and through primary openings below the water table in the overlying saprolite. Secondary porosity and permeability vary with hydrogeologic unit, topographic setting, and depth. Thirty-nine percent of the water-bearing zones are encountered within 100 feet of the land surface, and 79 percent are within 200 feet.

The fractured crystalline rock and overlying saprolite act as a single aquifer under unconfined conditions. The water table is a subdued replica of the land surface. Local ground-water-flow systems predominate in the basin, and natural ground-water discharge is to streams, comprising 62 to 71 percent of streamflow.

Water budgets for 1988-90 for the 45-square-mile effective drainage area above the Wooddale, Del., streamflow-measurement station show that annual precipitation ranged from 43.59 to 59.14 inches and averaged 49.81 inches, annual streamflow ranged from 15.35 to 26.33 inches and averaged 20.24 inches, and annual evapotranspiration ranged from 27.87 to 30.43 inches and averaged 28.98 inches.

The crystalline rocks of the Red Clay Creek Basin were simulated two-dimensionally as a single aquifer under unconfined conditions. The model was calibrated for short-term steady-state conditions on November 2, 1990. Recharge was 8.32 inches per year. Values of aquifer hydraulic conductivity in hillside topographic settings ranged from 0.07 to 2.60 feet per day. Values of streambed hydraulic conductivity ranged from 0.08 to 26.0 feet per day.

Prior to simulations where ground-water development was increased, the calibrated steady-state model was modified to approximate long-term average conditions in the basin. Base flow of 11.98 inches per year and a ground-water evapotranspiration rate of 2.17 inches per year were simulated by the model.

Different combinations of ground-water supply and wastewater-disposal plans were simulated to assess their effects on the stream-aquifer system. Six of the simulations represent an increase in population of 14,283 and water use of 1.07 million gallons per day. One simulation represents an increase in population of 28,566 and water use of 2.14 million gallons per day. Reduction of average base flow is greatest for development plans with wastewater removed from the basin through sewers and is proportional to the amount of water removed from the basin. The development plan that had the least effect on water levels and base flow included on-lot wells and on-lot septic systems.

Five organochlorine insecticides--lindane, DDT, dieldrin, heptachlor, and methoxychlor--were detected in ground water. Four organophosphorus insecticides--malathion, parathion, diazinon, and phorate--were detected in ground water. Four volatile organic compounds--benzene, toluene, tetrachloroethylene, and trichloroethylene--were detected in ground water. Phenol was detected at concentrations up to 8 micrograms per liter in water from 50 percent of 14 wells sampled. The concentration of dissolved nitrate in water from 18 percent of wells sampled exceeded 10 milligrams per liter as nitrogen; concentrations of nitrate were as high as 19 milligrams per liter. PCB was detected in the bottom material of West Branch Red Clay Creek at Kennett Square at concentrations up to 5,600 micrograms per kilogram.

INTRODUCTION

The demand for water in the Red Clay Creek Basin, located near the urbanized areas of Philadelphia and Wilmington (fig. 1), has increased as a result of rapid residential and commercial development. Because that development commonly is outside the service areas of public-water-supply systems, new developments rely on on-site wells for water supply. In addition, the Borough of Kennett Square obtains approximately 50 percent of its water from a well drilled in the Cockeysville Marble in the basin. Most of the basin is underlain by low-yielding crystalline rocks, and local government agencies are concerned about the capability of the ground-water system to meet the water demands of an increasing population. The U.S. Geological Survey (USGS), in cooperation with the Chester County Water Resources Authority and the Delaware Geological Survey (DGS), completed this study to evaluate the ground-water resources of the Red Clay Creek Basin.

Purpose and Scope

This report describes the geohydrology of the aquifer in the Red Clay Creek Basin in Pennsylvania and Delaware and the simulation of ground-water flow in the basin and summarizes water-quality data. This report specifically presents a description of the physical characteristics and hydrologic properties of the aquifers, ground-water/surface-water relations, water budgets, a summary of water-quality data, results of simulations by use of a digital ground-water flow model, and the effects of different ground-water development plans on the hydrologic system.

Water levels, precipitation, and streamflow were measured to quantify the components of the hydrologic budget and to construct and calibrate a digital ground-water flow model. Water levels were measured once at 351 wells (June 1989 through March 1990) and monthly at 10 wells (January 1988 through December 1990). Continuous water-level recorders were maintained at five wells; in addition, a continuous water-level recorder was maintained by the DGS. Daily precipitation was measured by volunteers at nine sites (January 1988 through December 1990) in the basin. A streamflow-measurement station was installed below the confluence of the East and West Branches of Red Clay Creek. Streamflow records also were available for two other continuous-record streamflow-measurement stations in the basin. Base-flow measurements were made once at 88 sites in the basin (pl. 1). The location of sites for monthly and continuous records of water levels, daily precipitation, and continuous-record streamflow-measurement stations is shown in figure 2.

Information from drillers completion reports and previous studies was used to determine the physical characteristics and hydrologic properties of the aquifer. Results of chemical analyses of water samples collected for other studies from 54 wells and 2 surface-water sites in Chester County are summarized.

Description of Study Area

The Red Clay Creek Basin drains 54 mi^2 of the lower Delaware River Basin (fig. 1) in Chester County, Pa., and New Castle County, Del. The headwaters of the Red Clay Creek, the East and West Branches and their tributaries, are in southeastern Chester County. The East and West Branches are confluent 0.75 mi north of the Pennsylvania-Delaware State line. The Red Clay Creek flows southeast to the White Clay Creek just south of Stanton, Del. White Clay Creek is a tributary to the Christina River, which flows into the Delaware River near Wilmington, Del.

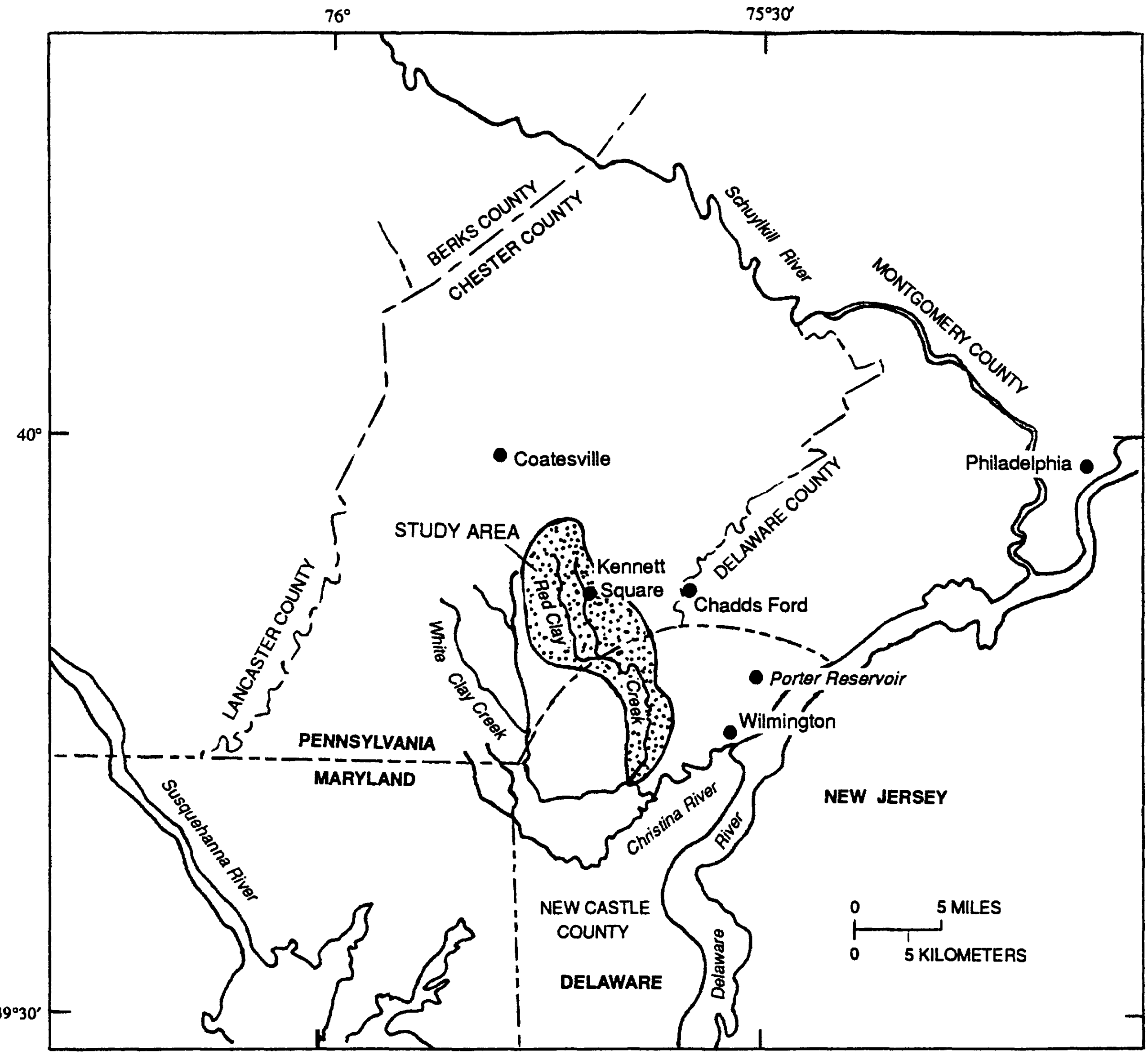

Figure 1.--Location of Red Clay Creek Basin, Pennsylvania and Delaware.

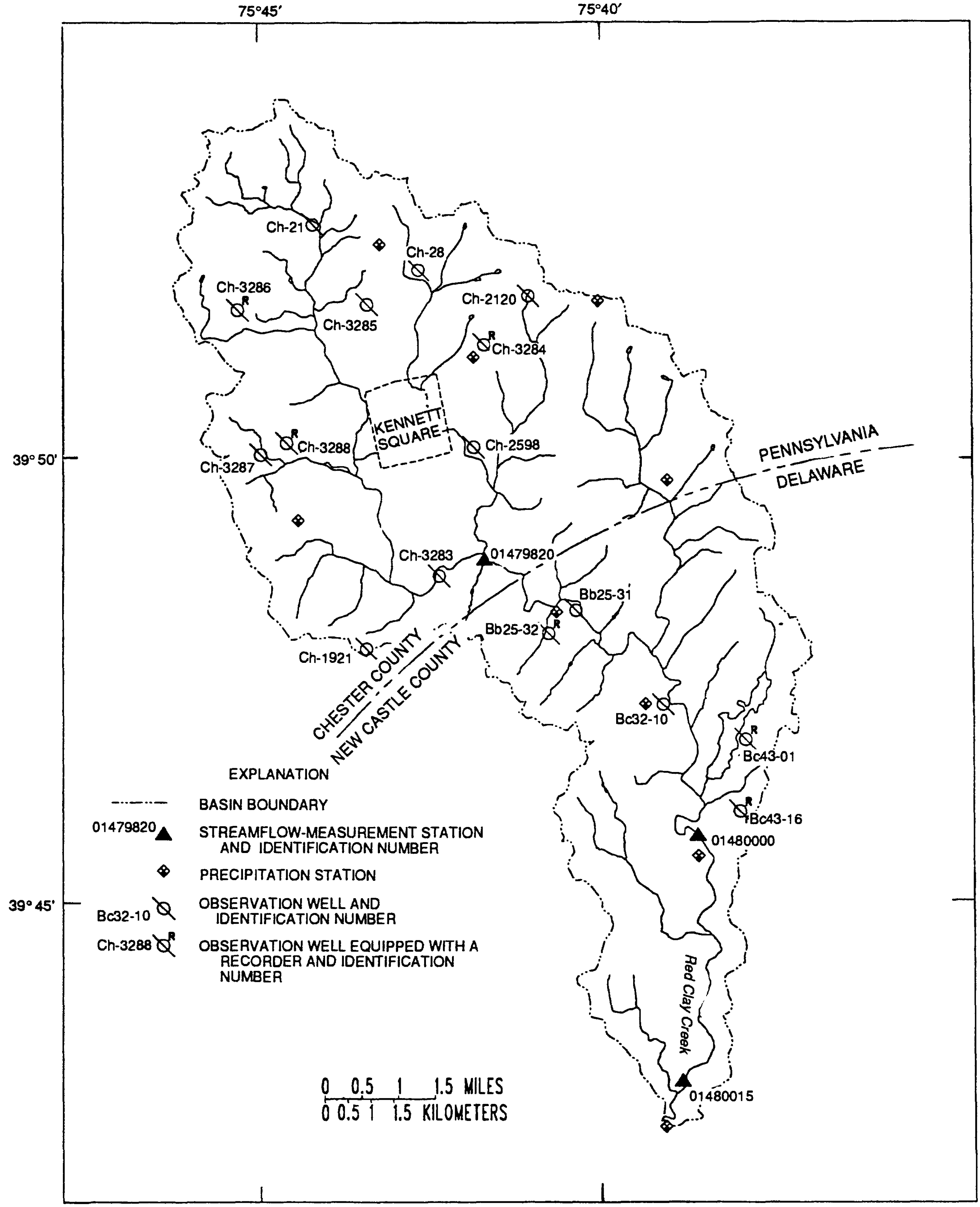

Figure 2.--Hydrologic-data-collection sites in the Red Clay Creek Basin, Pennsylvania and Delaware.

Physical and Cultural Setting

The Red Clay Creek Basin lies in the Piedmont and Atlantic Coastal Plain Physiographic Provinces. The two physiographic provinces are distinguished by differences in geology and topography. Because the transition area between the two provinces commonly is marked by waterfalls and rapids on most streams crossing it, the term Fall Line is used to describe the transition. In the study area, the Fall Line generally coincides with the Baltimore and Ohio Railroad tracks north of Stanton, Del. (pl. 1). The Piedmont part (52.8 mi^2) of the study area is underlain predominantly by metamorphic rocks that range from Precambrian to Lower Paleozoic in age. The Atlantic Coastal Plain part (1.2 mi^2) of the study area is underlain by unconsolidated sediments that range from Cretaceous to Holocene in age. The topography of the Piedmont Physiographic Province is characterized by gently rolling uplands dissected by narrow valleys. North of the Fall Line, the upland slopes gently to the southeast. South of the Fall Line, the slope flattens to form the broad plains of the Atlantic Coastal Plain Physiographic Province. Elevation in the Piedmont uplands ranges from 557 ft above sea level at the Red and White Clay Creek drainage divide near Upland, Pa., to 70 ft above sea level at the Fall Line. The elevation at the confluence of the Red and White Clay Creeks in the Coastal Plain is 10 ft above sea level.

The Red Clay Creek Basin is rural with residential, commercial, and industrial development concentrated in the Borough of Kennett Square, along U.S. Route 1 in Pennsylvania, and south of Faulkland Road (State Route 34) in Delaware (pl. 1). Land use in the basin is predominantly agricultural, and the area surrounding the Borough of Kennett Square is the largest mushroom-producing region in the nation. Population of the basin in 1980 was about 39,600 (Martin Wollaston, New Castle County Water Resources Agency, oral commun., 1992; David Yaeck, Chester County Water Resources Agency, oral commun., 1991). Projected increases in population for 1980-2000 are 23 and 11 percent for the Pennsylvania and Delaware parts of the basin, respectively (Roy F. Weston, Inc., 1988, p. 2-17).

The Borough of Kennett Square and the area south of Faulkland Road are supplied by public water, the majority of which is imported from outside the Red Clay Creek Basin. In Pennsylvania, wastewater is treated and returned to Red Clay Creek; in Delaware, wastewater is exported to a sewage treatment plant outside the basin. Water from Hoopes Reservoir is not released to Red Clay Creek (William Turner, Commissioner of Public Works, City of Wilmington, oral commun., 1991). Water is pumped from Brandywine Creek into the Hoopes Reservoir (pl. 1), where it is stored as an emergency water supply; it can be delivered from the reservoir to the City of Wilmington by pipeline. In the rest of the basin, the sole source of water for domestic and agricultural use is on-site wells or springs. An estimated 90 percent of pumpage from on-site wells is returned to the aquifer through on-lot septic systems; consumptive loss is estimated to be 10 percent (Loper and others, 1989, p. 10). Some pumpage is returned to streams by sewage treatment plants. Several industries in the basin withdraw water from the Red Clay Creek for process cooling systems and return it directly to the creek.

Climate and Precipitation

The Red Clay Creek Basin has a modified humid continental climate. Winters are mild to moderately cold and summers are warm and humid. Normal mean annual air temperatures at National Oceanic and Atmospheric Administration (NOAA) weather stations in Coatesville, Pa., and Porter Reservoir near Wilmington, Del. (fig. 1), for the period 1951-80 are 51.5°F and 53.3°F, respectively. Normal mean temperatures for the period 1951-80 for January, the coldest month, are 28.6°F and 30.8°F for the Coatesville and Porter Reservoir stations, respectively. Normal mean temperatures for July, the warmest month, for the period 1951-80, are 73.6°F and 74.9°F for the Coatesville and Porter Reservoir stations, respectively (National Oceanic and Atmospheric Administration, 1982a, b).

Normal mean annual precipitation for the period 1951-80 is 45.59 in. at Coatesville and 44.90 in. at Porter Reservoir. Precipitation is distributed fairly evenly throughout the year.

Previous Investigations

Water-bearing characteristics of the crystalline rocks that underlie the Red Clay Creek Basin in Pennsylvania are described in several published reports. Hall (1934) described the water-bearing properties of the geologic formations in southeastern Pennsylvania. Poth (1968) described the hydrology of the metamorphic and igneous rocks of central Chester County. McGreevy and Sloto (1977) and Sloto (1994) described the ground-water resources of Chester County. Sloto (1989) presented ground-water data for Chester County. An inventory of the water resources and a water-supply budget were completed by Reith and others (1979).

Water resources of the Delaware part of the Red Clay Creek Basin were described by Marine and Rasmussen (1955), Rasmussen and others (1957), Baker and others (1966), and Sundstrom and Pickett (1971). Hydrologic data for the Potomac Formation in New Castle County were presented by Martin and Denver (1982). Martin (1984) simulated ground-water flow in aquifers in the Potomac Formation in New Castle County. A basin-wide discussion of water resources was presented by Parker and others (1964) for the Delaware River Basin.

The geology of the area was mapped and described by Bascom and Miller (1920) and Bascom and Stose (1932). The Pennsylvania Geologic Survey (PAGS) published geologic quadrangle maps (Berg and Dodge, 1981) for the Pennsylvania part of the Red Clay Creek Basin, and the PAGS recompiled the geology of Chester County (Sloto, 1994). The DGS published geological quadrangle maps for the Delaware part of the basin (Woodruff and Thompson, 1972, 1975; Woodruff, 1977, 1981).

Well-Numbering System

The method of assigning local well numbers used in this report is different for each state. In Pennsylvania, the local well number consists of (1) a two-letter abbreviation that identifies the county in which the well is located and (2) a sequentially assigned number. All Pennsylvania wells in this report are in Chester County and are identified by the prefix "CH." Delaware is divided into 5-minute quadrangles of latitude and longitude. The quadrangles are lettered north to south with capital letters and west to east with lower case letters. Each 5-minute quadrangle is further subdivided into 25 1-minute-square blocks that are numbered from north to south in series of tens from 10 to 50 and numbered from west to east in units from 1 to 5 (fig. 3). Wells within 1-minute-square blocks are sequentially assigned a number. Thus, a local well number in Delaware consists of a sequence number prefixed with an upper and lower case letter designating the 5-minute-square block and followed by two numbers designating the 1-minute-square block in which the well is located. For example, well number Gd34-2 is the second well to be scheduled in the 1-minute-square block that has the coordinates Gd-34 (fig. 3). Locations of selected wells are shown on plate 1. Records of wells listed by local number are in table 25 for Pennsylvania and table 26 for Delaware.

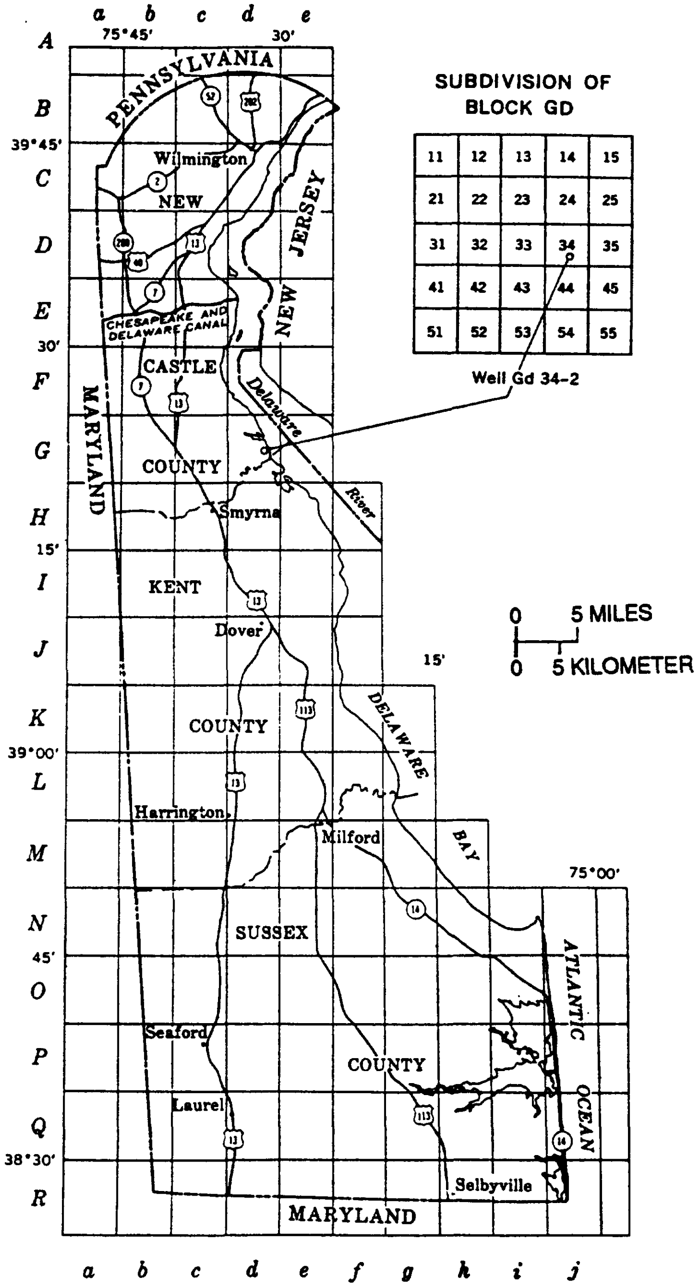

Figure 3.--Coordinates for the State of Delaware well-numbering system. (From Rima and others, 1964, p. 6)

Acknowledgments

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Hydrologic data essential for this study were provided by many individuals who deserve credit for their effort. The following volunteers recorded daily observations of precipitation: Robert Way, William Zimmerman of Wilmington Suburban Water Corp., Jeff Lynch of Longwood Gardens, C. Minor Barringer, Frank Riggins, Tom Kelleher of Hercules Inc., Carroll Pratt, Gregory Adsit of NVF Corp., Edwin Allen of Mt. Cuba Center, and Ed Caudill of East Marlborough Township.

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The authors thank the Pennsylvania Geological Survey, Delaware Geological Survey, and the Delaware Department of Natural Resources and Environmental Control for providing information on wells completed in the Red Clay Creek Basin. The Delaware Geological Survey also provided aquifer-test and water-level data.

GEOHYDROLOGY

Ground water flows through interconnected openings below the water table in the crystalline rocks and sediments of the Red Clay Creek Basin. The type of openings (porosity) and degree of interconnection (permeability) depend on the mineral composition and structure of the rocks. The geology of the basin is described here to provide a basis for understanding the occurrence and movement of ground water in the basin.

Geology

The geologic map of the study area (pl. 1) is a composite of the mapped geology for Pennsylvania (Sloto, 1994) and Delaware (Woodruff and Thompson, 1972, 1975). Much of the original mapping of Bascom and Stose (1932) is retained, although the mapping of Bascom and Miller (1920) has been revised. The age, origin, and tectonic history of the mapped units has undergone much revision since Bascom and Stose's interpretation (1932) and is still being debated. For this report, the stratigraphic nomenclature of the PAGS (Sloto, 1994) is used; the stratigraphic nomenclature of the DGS is used for units that crop out only in the Delaware part of the study area. Stratigraphic nomenclature and descriptions of the geologic units shown on plate 1 are listed in table 1 for Pennsylvania and table 2 for Delaware.

Table 1. --Description of geologic units within the study area in Pennsylvania

Age [1]		Geologic unit	Lithologic description[1]
Quarternary		alluvium	Fine- to medium-grained unconsolidated material deposited in and along stream valleys consisting mostly of silt and sand with some admixture of pebbles and locally derived cobbles.
Early Jurassic		diabase	Dark-gray, fine-grained rock consisting mainly of plagioclase and pyroxene.
Early-Middle Ordovician	Glenarm Group	Wissahickon Formation	Light- to medium-gray, quartzo-aluminous schist and gneiss. Composition ranges from quartz-orthoclase-biotite and orthoclase-quartz-muscovite schist to quartz-biotite-plagioclase and quartz-plagioclase-biotite schistose gneiss. Moderately high metamorphic grade, mostly in the amphibolite facies.
Cambrian	Glenarm Group	Cockeysville Marble	White, medium- to coarse-grained, saccharoidal marble and light-gray, fine-grained, banded marble. Commonly contains scattered golden-brown phlogopite.
Late Precambrian	Glenarm Group	Setters Formation	White to light-gray quartzite, quartzose schist, and potassic-feldspar-quartz-biotite-muscovite schist. A lower part is a darker biotite-quartz-orthoclase(?)-muscovite schist.
Precambrian		pegmatite	Light-colored, very-coarse- to coarse-grained dikes of granitic rock, containing mostly alkali feldspars and quartz with subordinate amounts of muscovite or biotite.
		mafic gneiss, amphibolite facies	Very-dark-gray, medium- to coarse-grained amphibolite, interlayered with some felsic laminae and layers.
		felsic gneiss, amphibolite facies[2]	Light- to medium-gray, medium-grained, finely to coarsely layered quartz-plagioclase-biotite-potassium-feldspar-garnet +/- hornblende gneiss.
		felsic gneiss, granulite facies[2]	Rather variable composition; plagioclase-quartz-orthoclase-garnet-biotite-hypersthene/clinopyroxene gneiss (strongly lineated) to light-gray, fine- to medium-grained quartz-mesoperthite-garnet +/- biotite +/- hypersthene gneiss. Quartz-kyanite and quartz-garnet +/- kyanite rocks are present locally.

[1] Sloto (1994).

[2] Baltimore Gneiss of Bascom and Stose (1932).

Table 2.--Description of geologic units within the study area in Delaware

Age [1]	Geologic unit	Lithologic description [2]
Quarternary	Holocene sediments and Columbia Formation	Sediments in present-day stream valleys and marshes are Holocene age fine sands, silts, and clay including fresh, poorly sorted, micaceous sands and gravels in and near the Piedmont, derived mainly from underlying or nearby crystalline rocks. Columbia Formation (Pleistocene age) includes gravelly coarse and medium sands with some interbedded silts. Thickness of the Columbia Formation and Holocene sediments mapped in the Red Clay Creek Basin is up to 10 feet.
Early to Late Cretaceous	Potomac Formation	Variegated red, gray, purple, yellow, and white, commonly lignitic silts and clays containing interbedded white, gray, and rust-brown quartz sands and some gravel. Individual beds usually laterally restricted.
Cambrian-Ordovician?	serpentinite	Massive antigorite, chromite, and talc with minor vermiculite.
	pegmatite	Quartz-microcline-muscovite-albite lenses and dikes, both concordant and discordant. Usually present in Wissahickon Formation.
Glenarm Group	Wissahickon Formation	Metagraywacke facies: interbedded felsic, unfoliated quartz-oligoclase-hornblende-almandine gneiss and foliated quartz-biotite-oligoclase-almandine schist. Gneisses commonly contain nonparallel foliations suggesting primary sedimentary structures. Usually finely phaneritic. Pelitic facies: felsic, biotite-oligoclase-quartz-almandine-microcline schist and occasional gneiss. Usually coarsely phaneritic and strongly foliated. Contains numerous small pegmatities.
Glenarm Group	Cockeysville Formation	Marble, predominantly calcitic with some dolomitic marble. Coarsely phaneritic and weakly foliated with small scale folding.
Precambrian?	felsic and mafic gneiss [3] (Wilmington Complex)	Felsic and mafic gneiss and minor schist. Felsic gneiss is a quartz-oligoclase to andesine-microcline-hornblende-hypersthene gneiss. Mafic gneiss is a quartz-andesine to labradorite-augite-hypersthene +/- hornblende gneiss. Strongly to weakly foliated, coarsely to finely phaneritic.

[1] Woodruff and Thompson (1975).
[2] Woodruff and Thompson (1972).
[3] James Run Formation of Hager (1976) and Thompson (1979).

Two Precambrian felsic gneiss belts crop out in the Red Clay Creek Basin in Pennsylvania. The northern gneiss belt is mapped as granulite-facies felsic gneiss by the PAGS and forms the core of the Woodville Dome (pl. 1). The southern gneiss belt consists of amphibolite-facies felsic and intermediate gneiss and forms the core of the Avondale Anticline (pl. 1). Although the PAGS maps the northern gneiss belt as granulite-facies gneiss, Wagner and Crawford (1975) and Crawford and Crawford (1980) map the northern gneiss belt as amphibolite-facies gneiss. Both gneiss belts originally were mapped as Baltimore Gneiss by Bascom and Stose (1932) because their stratigraphic relations and petrographic character are similar to the Baltimore Gneiss domes in Maryland.

Higgins and others (1973) used aeromagnetic data and field relations to roughly locate a previously unmapped dome of Baltimore Gneiss in Delaware that extends into Pennsylvania, north of Hockessin, Del. The DGS is presently mapping the Baltimore Gneiss in the Yorklyn, Del., area (K. D. Woodruff, Delaware Geological Survey, oral commun., 1990). Because mapping of the Baltimore Gneiss in this area is not complete, it is not shown on plate 1.

The felsic gneiss is unconformably overlain by a metasedimentary sequence of rocks of the Glenarm Group. The age of the Glenarm Group rocks has been interpreted as late Precambrian to Cambrian and possibly Ordovician.

A belt of Precambrian to early Paleozoic granulite-facies felsic and mafic gneisses of the Wilmington Complex lies southeast of the Wissahickon Formation. The felsic and mafic gneisses are in fault contact with the Wissahickon Formation (Woodruff and Thompson, 1975; Hager, 1976, p. 65; Wagner and Srogi, 1987, p. 121). The gneisses of the Wilmington Complex are interpreted to be metavolcanic units and metamorphosed volcaniclastic sediments (Hager, 1976, p. 60; Thompson, 1979, p. 120; Crawford and Crawford, 1980, p. 319).

The Glenarm Group consists of the Setters Formation, Cockeysville Marble, and Wissahickon Formation. The Setters Formation and Cockeysville Marble crop out along the flanks of the felsic gneiss. In some areas, the Setters Formation and marble are missing, and the felsic gneiss is in direct contact with the Wissahickon Formation. The Setters Formation and Cockeysville Marble are approximately 1,000 and 200 ft thick, respectively (Bascom and Stose, 1932). The Cockeysville Marble is overlain by the Wissahickon Formation. The Wissahickon Formation in southeastern Pennsylvania and northern Delaware is 5,000-8,000 ft thick (Bascom and Stose, 1932) and includes rocks probably deposited in several different tectonic environments (Wagner and Srogi, 1987, p. 115). The Glenarm Group rocks were deposited in a basin that developed on the southeastern edge of the continental margin. The Wissahickon Formation was originally deposited as deep-water clastic sediments. The Setters Formation and Cockeysville Marble were deposited near the continental margin as a thin basal clastic sequence and a carbonate bank, respectively (Rodgers, 1968).

Several small elongated bodies of mafic gneiss that trend northeast are found within the Wissahickon Formation. Pegmatite bodies trending northeast crop out within the Wissahickon Formation in Pennsylvania and in the Cockeysville Formation in Delaware. A small body of serpentinite is found within the Wissahickon Formation just north of Hoopes Reservoir in Delaware (pl. 1).

Unconsolidated sediments of the Potomac Formation of Cretaceous age unconformably overlie the crystalline basement in the southern part of the study area. The Potomac Formation crops out south of the Fall Line, increases in thickness to the southeast of the Fall Line, and is 100 ft thick near the mouth of the Red Clay Creek (Martin, 1984, p. 13). The strike of the Potomac Formation is to the northeast, and it dips to the southeast. The sediments were deposited in a deltaic environment (Spoljaric, 1979, p. 92).

The surficial deposits of the Columbia Formation of Pleistocene age unconformably overlie the Potomac Formation. The Columbia deposits are up to 20 ft thick in the study area. Holocene sediments are found in stream valleys and marshes (Woodruff and Thompson, 1972).

Evidence of three metamorphic events are present in the Piedmont rocks of southeastern Pennsylvania and northern Delaware (Crawford and Crawford, 1980). The first event was a high pressure granulite-facies episode of Grenville age. Crawford and Crawford (1980) believe it affected the felsic gneisses northeast of the study area. Wagner and Srogi (1987) believe it also affected the felsic and intermediate gneisses exposed in the study area. The felsic and intermediate gneisses were later overprinted by a Taconic age amphibolite-facies metamorphic event. Two high-grade metamorphic events took place during the Taconic orogeny; the Wilmington Complex was metamorphosed at moderate pressure and high temperature to granulite facies, and the felsic and intermediate gneisses and Glenarm Group rocks were metamorphosed to amphibolite facies during a regional metamorphic event. The regional metamorphic grade is highest (second sillimanite isograd) adjacent to the Wilmington Complex (Wagner and Srogi, 1987).

Wagner and Srogi (1987) and Crawford and Crawford (1980) have interpreted the southeastern Pennsylvania and northern Delaware Piedmont Physiographic Province as the site of a collision between a magmatic arc and the North American continent. The Wilmington Complex was the infrastructure of the magmatic arc. Gneisses to the northeast of the study area were the continental margin. Between these two plates are nappes of allochthonous remobilized basement (Woodville Dome and Avondale Anticline) and highly deformed basin sediments. The nappes and thrust faults trend northeast.

Hager (1976, p. 42-44) identified two types of faults that cut across the Wissahickon Formation in the Hoopes Reservoir area. Medium-angle reverse faults parallel northeast-trending structures in the area. High-angle normal or reverse faults trend northwest and affect both Wissahickon Formation and Wilmington Complex rocks. Stream valleys follow both types of faults in the study area.

Hydrology

Ground water flows through secondary openings in fractured crystalline rock and through primary openings below the water table in the overlying saprolite. Saprolite is derived from the in-place chemical weathering of the underlying crystalline rock; generally, it is composed of rock fragments and sandy clay. The saprolite has high primary porosity, and ground water occupies the pore spaces between the unconsolidated weathered grains in the saturated part of the saprolite. The crystalline rock has low primary porosity, but secondary porosity in the form of fractures, cleavage planes, joints, and faults is prevalent. In the Cockeysville Marble, secondary openings may be enlarged by solution. Because of the greater porosity of the saprolite (fig. 4), water stored in the saprolite is slowly transmitted to the fracture system of the underlying crystalline bedrock. The degree of interconnection of the pores determines the permeability (ability to transmit water) of the rock. The greater the density and interconnection of the secondary openings, the greater the permeability of the crystalline rock. Most saprolite has low permeability because of the abundance of clay material. Saprolite associated with the Cockeysville Marble commonly is very sandy and has a high permeability.

The fractured crystalline bedrock and overlying saprolite act as a single aquifer under unconfined conditions. In an unconfined aquifer, the upper surface of the zone of saturation or water table is under atmospheric pressure. In the Red Clay Creek Basin, the water table commonly is within the saprolite, especially in topographically low areas, such as valleys (fig. 5). The water table is within the crystalline bedrock in topographically high areas, such as hilltops. The bottom of the zone of saturation is coincident with the bottom of the open-fracture system, which is not a distinct surface, but rather a gradual transition from open fractures near the surface to closed fractures at depth (fig. 5). Locally, ground water in deep fractures in the crystalline bedrock can be under hydrostatic pressure (under confining conditions), especially in areas where the fracture system is poorly connected with the overlying saprolite. Nutter and Otton (1969, p. 13) state that the line of demarcation between confined and unconfined conditions is not sharp, and it can be difficult to determine which conditions exist at a given well. Regionally, fracture density and the connection between the fractured crystalline bedrock and saprolite is sufficient so that the bedrock and overlying saprolite behave as a single aquifer under unconfined conditions.

Ground water flows through primary openings in Coastal Plain sediments. Coarse sediments have a higher porosity and higher permeability than fine sediments. Ground-water flow is impeded by clay and silt lenses and layers. The unconsolidated sediments of the Coastal Plain behave as a single aquifer under unconfined conditions.

The water table is a subdued replica of the land surface in the study area, and ground water flows from areas of high water-table altitude to areas of low water-table altitude. In the Red Clay Creek Basin, there are numerous local ground-water-flow systems with short flow paths from hilltops to nearby stream valleys. Although determination of ground-water-flow directions from water-level maps (Vogel and others, 1991) in the basin may indicate a direct flow path from hilltops to valley, the actual flow path can be a circuitous route along intersecting fractures (fig. 5). Vertical flow in hilltop areas results where the head gradient is downward and in valley areas where the head gradient is upward. Ground-water flow between hilltop and valley areas is nearly horizontal.

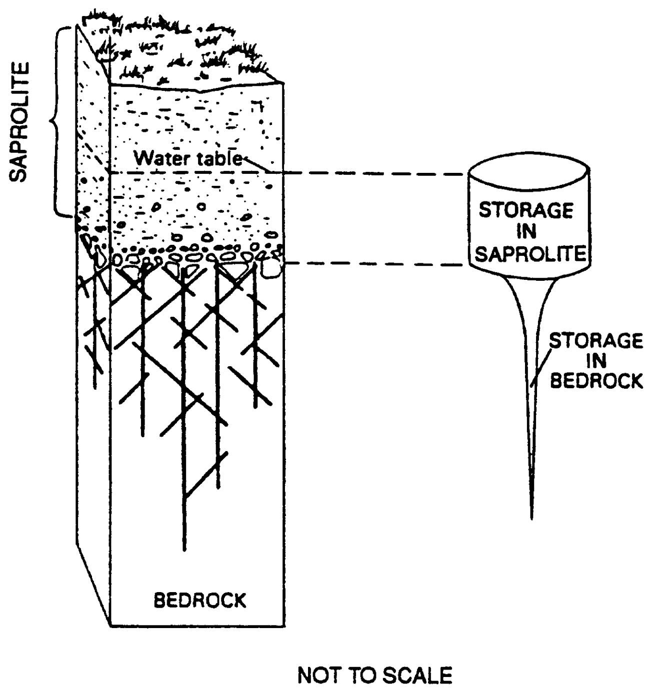

Figure 4.--Comparison of storage capacity of the saprolite and fractured crystalline bedrock. (Modified from Heath, 1984, p. 47.)

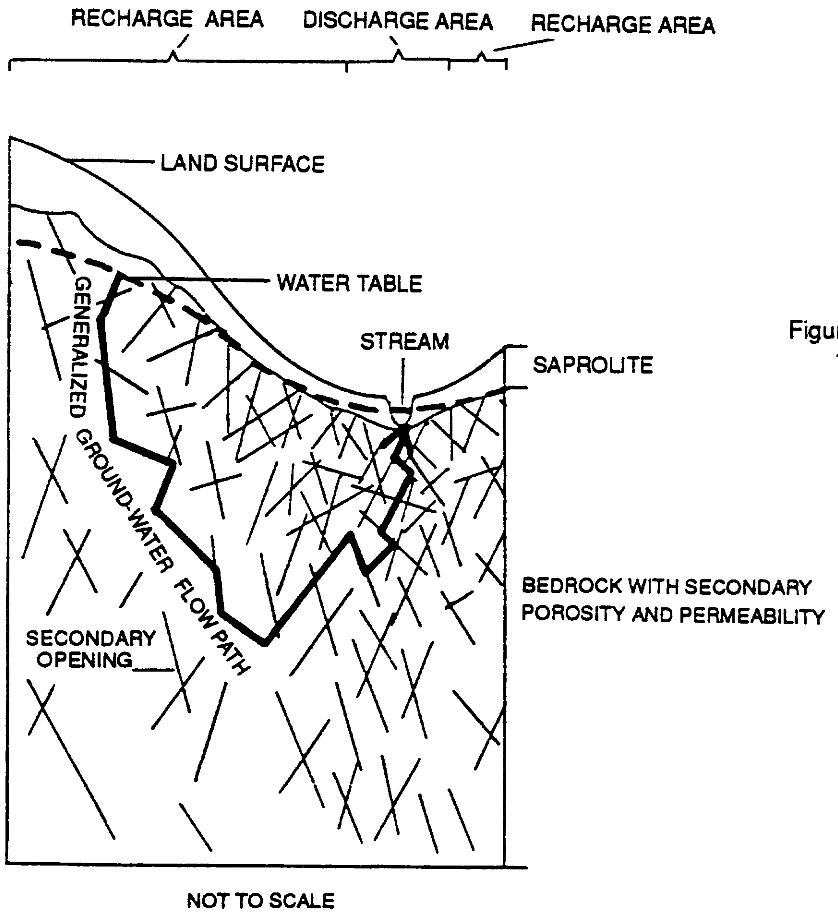

Figure 5.--Generalized cross-section of the ground-water-flow system in the Red Clay Creek Basin. (Modified from Gerhart and Lazorchick, 1984, p. 12)

Natural recharge to and discharge from the ground-water system predominantly are precipitation and ground-water discharge to streams, respectively. Recharge, as precipitation that percolates through the saprolite to the water table, occurs everywhere in the basin except in flood plains and streams where ground water discharges (fig. 5). Minor amounts of recharge to the aquifer result when withdrawals of ground water by wells are returned to the aquifer by spray-irrigation and septic systems. Ground-water discharge to streams sustains the base flow of Red Clay Creek. Minor amounts of ground water discharge through ground-water evapotranspiration and pumping of wells.

The water table fluctuates in response to recharge and discharge. Although water-table gradients commonly remain the same, the water table fluctuates seasonally in response to changes in precipitation, evapotranspiration, and ground-water discharge to streams. The water table can have a long-term rise or fall of a year or more because of above- or below-normal precipitation throughout the year. Locally, the water table may be lowered by ground-water withdrawals.

Water-Bearing Zones

The size, number, and interconnection of water-bearing secondary openings differs with depth and topographic setting. The increase in pressure from the overlying rock tends to decrease the size and number of fractures with depth. Intensely fractured bedrock is less resistant to erosion than unfractured rock. Thus, valleys and draws generally indicate areas underlain by intensely fractured bedrock. Hilltops generally indicate areas underlain by less fractured bedrock. Thus, permeability decreases with depth and differs with topographic setting. Permeability generally is high under valleys and draws and low under hilltops.

Table 3 shows the distribution of water-bearing zones with depth, expressed as number of water-bearing zones per 100 ft for 50-ft intervals, for hydrogeologic units in the study area with sufficient data for analysis. Data on water-bearing zones were reported by drillers for 148 wells in the Red Clay Creek Basin. For the 148 wells analyzed, 39 percent of the water-bearing zones were encountered within 100 ft of the land surface, and 79 percent of the water-bearing zones were encountered within 200 ft of the land surface.

Specific Capacity and Well Yield

Data from wells in the Red Clay Creek Basin and from wells in areas bordering the basin were used to compare the specific capacities and well yields of the hydrogeologic units underlying the basin. Wells from areas bordering the basin underlain by the same hydrogeologic units were included to enlarge the sample size, especially for nondomestic (public supply, industrial, and institutional) wells. Specific-capacity data were available for 144 wells; well-yield data were available for 335 wells. Most of the specific-capacity data presented in this report are based on aquifer-test results reported by drillers and consultants. Several tests were performed by the DGS.

Specific capacity is calculated by dividing the pumping rate of a well by the drawdown. Specific capacity for a well pumped at a constant yield decreases with time. The specific capacity of nondomestic [1] wells provides a better estimate of maximum aquifer productivity than does the specific capacity of domestic wells. Nondomestic wells generally are deeper, penetrate more water-bearing zones, and have larger diameters than domestic wells. Nondomestic wells commonly are drilled for maximum yield; domestic wells commonly are drilled only until an adequate yield for domestic use is obtained. Also, nondomestic wells commonly are located in valleys, and wells located in valleys generally have higher specific capacities than those in other topographic settings (LeGrand, 1967; Nutter and Otton, 1969, p. 21; Daniel, 1987; Knopman, 1990, p. 16).

Specific-capacity data for domestic and nondomestic wells are summarized in table 4. The specific capacity of nondomestic wells in the Cockeysville Marble is higher than the specific capacity of domestic wells in the Cockeysville Marble. Too few data are available to draw a similar conclusion about the other

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[1] Nondomestic wells include public supply and industrial wells. Wells used by small business and commercial establishments are considered to be domestic wells.

Table 3.--Distribution of water-bearing zones with depth in the Red Clay Creek Basin, Pennsylvania and Delaware [1]

[Number of water-bearing zones per 100 feet of borehole given for 50-foot intervals. Footage drilled in each interval does not include cased and unsaturated parts of borehole. ft, feet; --, no data; **, data not analyzed]

Interval (ft)	Wissahickon Formation (72 wells)			Cockeysville Marble (7 wells)			Setters Formation (11 wells)			Felsic gneiss (43 wells)			Mafic gneiss (15 wells)		
	Number of water-bearing zones			Number of water-bearing zones			Number of water-bearing zones			Number of water-bearing zones			Number of water-bearing zones		
	Penetrated	Per 100 ft of borehole	Footage drilled (ft)	Penetrated	Per 100 ft of borehole	Footage drilled (ft)	Penetrated	Per 100 ft of borehole	Footage drilled (ft)	Penetrated	Per 100 ft of borehole	Footage drilled (ft)	Penetrated	Per 100 ft of borehole	Footage drilled (ft)
0-50	10	2.34	428	1	1.14	88	5	3.60	139	13	4.23	307	0	0	101
51-100	52	2.05	2,537	7	2.51	279	8	2.85	281	36	2.07	1,738	15	2.62	573
101-150	42	1.54	2,734	2	1.32	151	10	2.84	352	20	1.25	1,594	13	2.54	511
151-200	29	1.53	1,898	3	2.04	147	3	1.02	295	20	1.87	1,070	10	4.10	244
201-250	14	.96	1,454	0	0	55	2	1.04	192	10	1.34	744	2	** [2]	20
251-300	12	1.06	1,135	0	** [2]	12	0	0	116	5	1.09	459	--	--	--
301-350	6	.90	667	--	--	--	0	** [2]	36	5	2.04	245	--	--	--
351-400	10	1.98	505	--	--	--	--	--	--	0	0	115	--	--	--
401-450	3	1.01	297	--	--	--	--	--	--	0	0	55	--	--	--
451-500	6	2.40	250	--	--	--	--	--	--	1	2.00	50	--	--	--
501-600	1	.83	121	--	--	--	--	--	--	1	1.33	75	--	--	--
Total	185		12,026	13		732	28		1,411	111		6,452	40		1,449
Average		1.54			1.78			1.98			1.72			2.76	

[1] Based on data reported by drillers. Depths below land surface are given in 50-foot increments to 500 feet. None of the wells analyzed were deeper than 600 feet.

[2] If footage of hole sampled is less than 50 feet, then number of water-bearing zones per specified footage sampled was not determined.

wells in the Cockeysville Marble. Too few data are available to draw a similar conclusion about the other hydrogeologic units in the basin. The Cockeysville Marble has the highest specific capacity of the hydrogeologic units in the study area (table 4).

Reported yields of domestic and nondomestic wells are summarized in table 5. The yield of a well depends on the size and number of water-bearing zones that the well intersects. Reported yields of nondomestic wells completed in the Wissahickon Formation, Cockeysville Marble, and Setters Formation are greater than the reported yields of domestic wells in the same units. Too few data are available to draw a similar conclusion about the other hydrogeologic units in the basin.

Water-Level Fluctuations

Water levels for 1988-90 for seven observation wells in the basin are shown in figure 6. Although the wells are completed in different hydrogeologic units, the hydrographs generally are similar. The amplitude of the water-level fluctuation is dampened as depth to water increases, possibly as a function of the time for recharge to reach the water table.

Hydrographs are similar for shallow dug wells and deep drilled wells. Two wells (CH-3287 and CH-3286) completed in the Setters Formation show similar water-level fluctuations. Well CH-3287 is a 36-ft deep dug well. Well CH-3286 is a 336-ft deep drilled well with 90 ft of casing; water-bearing zones were penetrated between 100-213 ft below land surface.

Water levels fluctuate seasonally in response to changes in recharge and discharge. During the winter months, plants are dormant and temperatures are cooler. Discharge by evapotranspiration is low and water levels rise as recharge from precipitation reaches the water table. During the summer months, discharge by evapotranspiration increases as temperatures increase and the growing season progresses. Recharge from precipitation may not satisfy the soil moisture deficit and may not reach the water table; thus, water levels decline. The seasonal change in water levels is shown for 1988-90 in figure 6. Figure 6 shows that the annual rise in water levels continued into July 1989 when precipitation was 13.20 in., which is 8.89 in. above the July normal for the period 1951-80 at the Chadds Ford, Pa., NOAA station located near the eastern basin boundary. Because precipitation during the early summer months exceeded the potential evaporation in 1989, water levels continued to rise into the mid-summer months.

Water levels are affected by above- and below-normal precipitation. For example, the 1989 average precipitation measured at the nine precipitation gages in the basin was 59.90 in., which is 14.38 in. above the normal for the period 1951-80 for the Chadds Ford NOAA station. The average precipitation in 1988 was 43.59 in., which is 1.82 in. below the normal for the period 1951-80 for the Chadds Ford station. Generally, monthly water levels in 1989 were higher than monthly water levels in 1988 (fig. 6).

Table 4.--Specific capacities of domestic and nondomestic wells in the Red Clay Creek Basin, Pennsylvania and Delaware

[(gal/min)/ft, gallons per minute per foot of drawdown; --, too few data to compute statistic]

	Domestic wells [1]						Nondomestic wells [2]					
		Specific capacity [(gal/min)/ft] exceeded by indicated percentage of wells						Specific capacity [(gal/min)/ft] exceeded by indicated percentage of wells				
Geologic unit	Number of wells	10 percent	25 percent	50 percent (median)	75 percent	90 percent	Number of wells	10 percent	25 percent	50 percent (median)	75 percent	90 percent
Wissahickon Formation	71	0.76	0.30	0.15	0.04	0.01	4	--	--	0.25	--	--
Cockeysville Marble	15	10	5	1	.21	.08	9	200	25	10	3.8	1
Setters Formation	9	10	1.8	.36	.08	.01	1	--	--	1.5	--	--
Mafic gneiss	7	--	--	.21	--	--	--	--	--	--	--	--
Felsic gneiss	26	1.4	.5	.12	.05	.02	1	--	--	2.4	--	--

[1] Also includes commercial wells.

[2] Includes public supply, industrial, irrigation, and institutional wells.

Table 5.--Reported yields of domestic and nondomestic wells in the Red Clay Creek Basin, Pennsylvania and Delaware

[--, too few data to compute statistic]

	Domestic wells [1]						Nondomestic wells [2]					
		Yield (gallons per minute) exceeded by indicated percentage of wells						Yield (gallons per minute) exceeded by indicated percentage of wells				
Hydrogeologic unit	Number of wells	10 percent	25 percent	50 percent (median)	75 percent	90 percent	Number of wells	10 percent	25 percent	50 percent (median)	75 percent	90 percent
Felsic and mafic gneiss	4	--	--	8	--	--	--	--	--	--	--	--
Wissahickon Formation	147	30	20	10	6	3	13	74	52	25	14	10
Cockeysville Marble	29	140	40	20	10	6	32	405	200	105	76	30
Setters Formation	21	50	22	15	6.5	2.2	12	117	108	68	14	2.9
Mafic gneiss	15	30	20	12	8	7.6	2	--	--	32	--	--
Felsic gneiss	56	43	25	14	6	2	4	--	--	28	--	--

[1] Also includes commercial wells.

[2] Includes public supply, industrial, irrigation, and institutional wells.

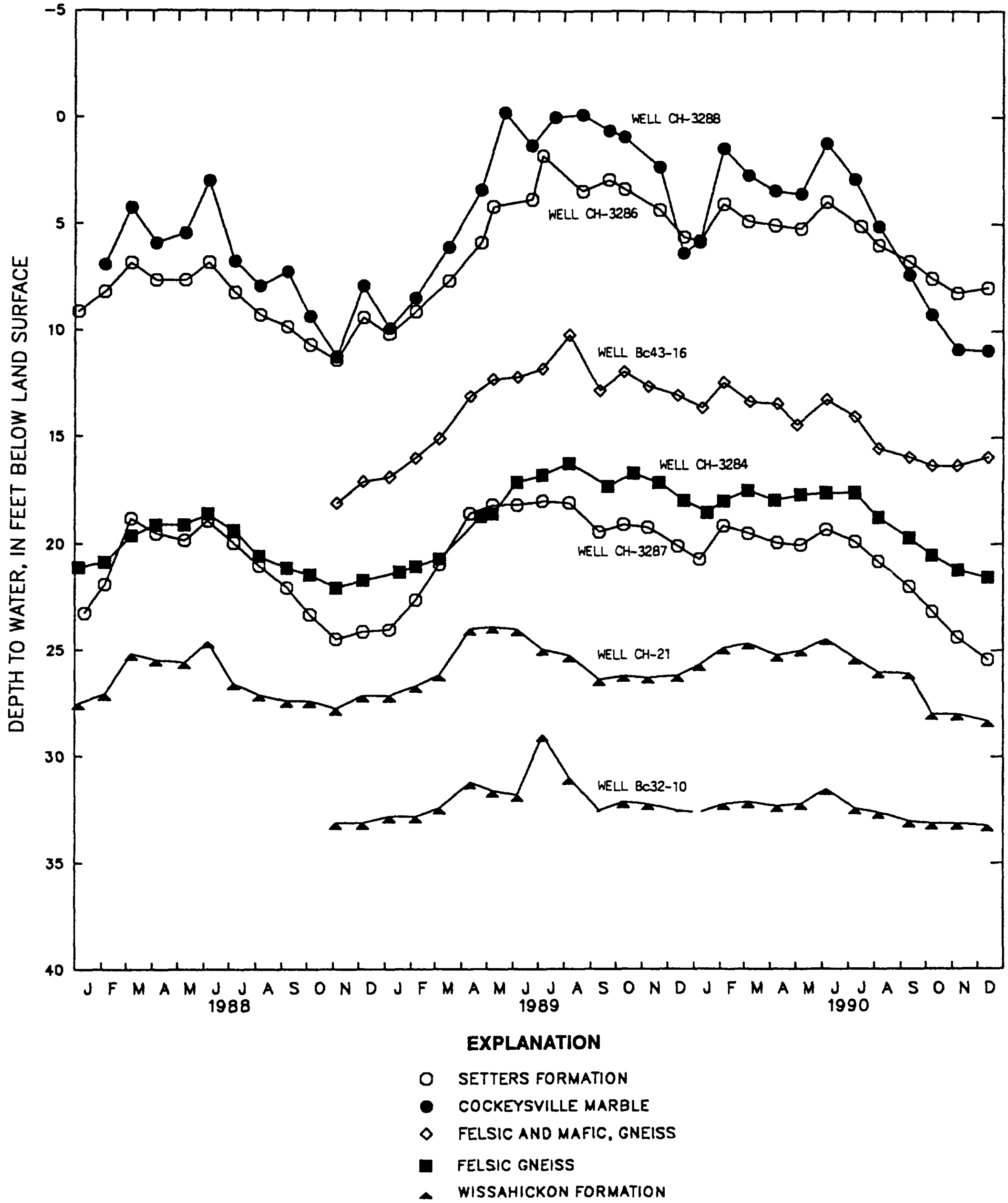

Figure 6.--Hydrographs of seven observation wells in the Red Clay Creek Basin, 1988-90.

Ground-Water/Surface-Water Relations

In the Red Clay Creek Basin, ground water from the crystalline-rock aquifers primarily is discharged to streams. Thus, the stream system acts as a local drain or sink for the aquifer. Ground-water discharge to streams is base flow. The base-flow component of streamflow was estimated from hydrographs of Red Clay Creek at three streamflow-measurement stations (table 6). The streamflow hydrograph was separated into overland runoff and base-flow components with a computer program developed by Sloto (1991); the local minimum hydrograph-separation technique was used. Base flow comprised 62 to 71 percent of streamflow and ranged from 10.43 in. in 1988 to 17.08 in. in 1989. This is similar to calculations at other streamflow-measurement stations in Chester County where the ground-water discharge to streams ranges from 45.2 to 77.7 percent with a long-term mean annual ground-water discharge of 57.2 to 65.6 percent (Sloto, 1994).

Table 6.--Streamflow and base flow of Red Clay Creek, 1988-90
[Streamflow-measurement station locations are shown on figure 2. mi2, square miles; in., inches; --, no data]

	Kennett Square, Pa. (Station 01479820) (28.3 mi^2)			Wooddale, Del. (Station 01480000) (45.0 mi^2) [1]			Stanton, Del. (Station 01480015) (50.4 mi^2) [1]		
		Base flow			Base flow			Base flow	
Year	Streamflow (in.)	(in.)	Percent of streamflow	Streamflow (in.)	(in.)	Percent of streamflow	Streamflow (in.)	(in.)	Percent of streamflow
1988	16.29	11.08	68	15.35	10.43	68	-- [2]	--	--
1989	24.34	15.59	64	26.33	17.08	65	27.48	16.91	62
1990	19.74	13.66	69	19.05	13.56	71	19.34	13.38	69

[1] Effective drainage area. Hoopes Reservoir drainage area (2 mi^2) not included because no water is released from the reservoir to Red Clay Creek.
[2] Continuous record started October 1988.

Base-flow discharge to streams is controlled, in part, by the hydraulic gradient toward the stream. Olmsted and Hely (1962) found a direct, linear relation between the monthly average ground-water level in wells and the base flow of Brandywine Creek during the winter months. As ground-water levels rise, the hydraulic gradient and ground-water discharge to streams increases; as ground-water levels decline, the hydraulic gradient and ground-water discharge to streams decreases. Thus, low base flows commonly occur in late summer when water levels have declined in response to low ground-water recharge rates. Figure 7 shows streamflow and base flow of Red Clay Creek near Kennett Square, Pa., for 1988-90. Low base-flow periods were in September of these years.

Base flow was measured at 88 sites on Red Clay Creek and its tributaries during October 31-November 2, 1990, as part of a seepage investigation (pl. 1 and table 27). Base-flow measurements were used in calibration of the ground-water-flow model, as well as to determine gaining and losing stream reaches. Streams gain water when the altitude of the local water table is higher than the elevation of the stream surface. In areas where the local water table is below the altitude of the stream surface, the stream will lose water to the aquifer. Streamflow lost to the aquifer eventually returns to the stream as ground-water discharge to gaining reaches downstream of the losing reach. The reach for the seepage investigation is 21 mi long and extends from the headwaters of the West Branch Red Clay Creek to the confluence with White Clay Creek at Stanton, Del. The measurements were made during a period of constant base flow. Tributary inflow and industrial and sewage treatment plant discharges were considered a contribution to the overall flow and not a gain to the streams from ground-water discharge. Diversions were not considered losses. Measurement errors of 2 to 8 percent may be included in indicated gains or losses. Generally, Red Clay Creek is a gaining stream.

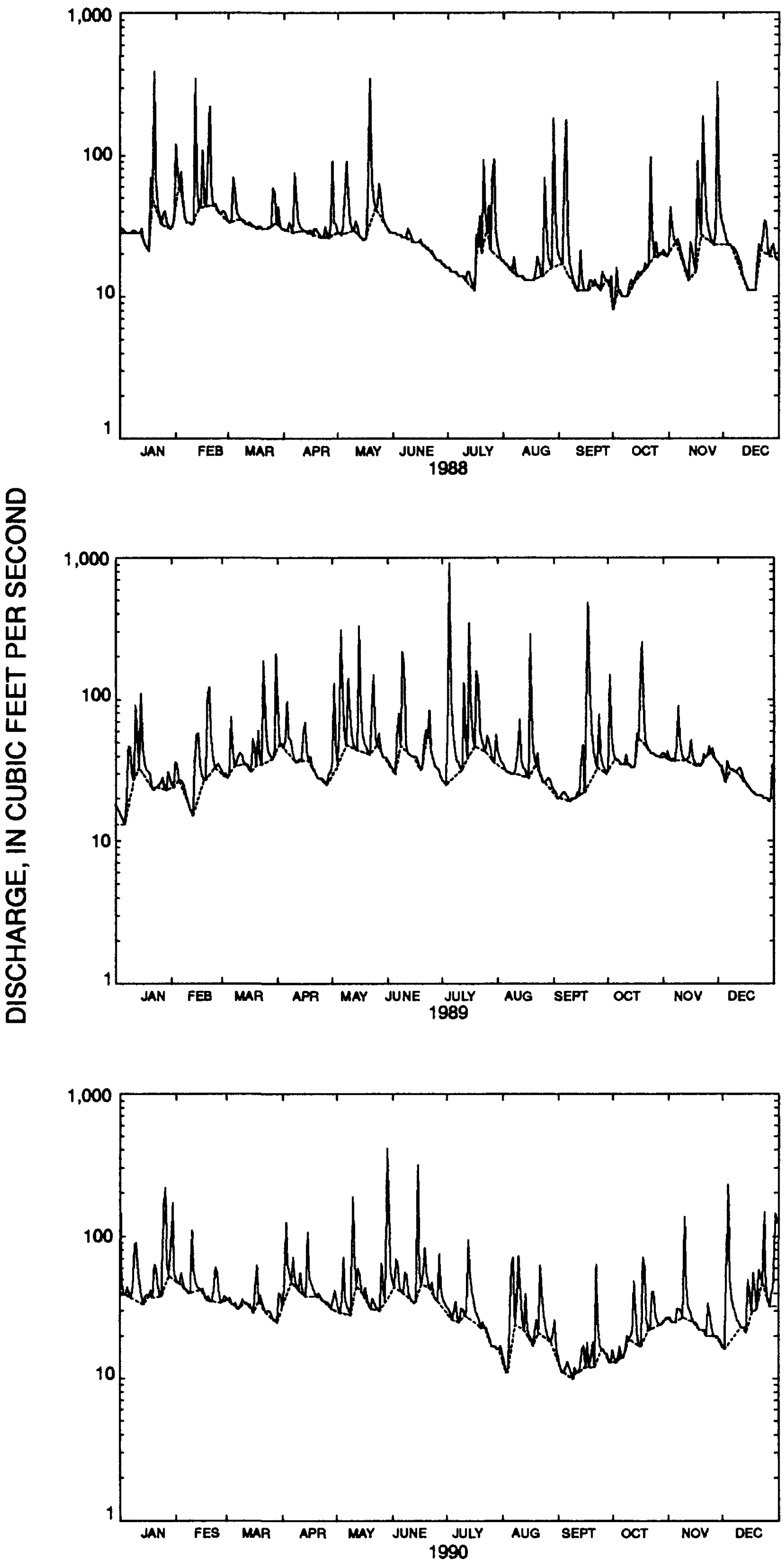

Figure 7.--Streamflow and base-flow hydrographs of Red Clay Creek near Kennett Square, Pa. (01479820), 1988-90.

Significant losses, defined as a loss greater than 10 percent of measured streamflow, were measured at two sites. The first losing reach is between measurement sites 6 and 7 where the West Branch of Red Clay Creek flows over the contact between the Setters Formation and the Cockeysville Marble (pl. 1). A loss of 0.78 ft^3/s occurs here; this is 27 percent of the streamflow measured at site 7. The water-level gradient of the ground-water system changes from a sloping gradient in the Setters Formation to a nearly flat surface in the Cockeysville Marble in the area of sites 6 and 7 (Vogel and others, 1991). The flatter hydraulic gradient indicates that the Cockeysville Marble has greater permeability than the Setters Formation, and water levels are probably lower in the Cockeysville Marble in the vicinity of site 7. Thus, the stream surface is higher than the water table, and the stream loses water to the aquifer.

The second losing reach is between sites 80 and 86 where the stream flows over the Wissahickon Formation. A loss of 2.79 ft^3/s was determined; this is 11 percent of the streamflow measured at site 86. Because the percentage of streamflow lost is close to the total measurement error of 10 percent for sites 80 and 86, additional base-flow measurements need to be made at sites 80 and 86 to confirm that this is a losing reach.

Water Budget

A water budget quantifies the components of the hydrologic cycle for a given area over a given period of time. The general water-budget equation is inflow equals outflow plus or minus change in storage. In the Red Clay Creek Basin, the ground-water and surface-water divides coincide. Calculations for the water budget begin and end in the winter when soil moisture is generally at field capacity and, therefore, the change in soil moisture storage is zero. Surface storage is negligible. The water-budget equation used in this study is

$$P = SF + GS + EX + ET, \quad (1)$$

where P is precipitation,
SF is streamflow,
GS is change in ground-water storage,
EX is net import or export of water from the basin, and
ET is evapotranspiration.

Precipitation, streamflow, and water imports and exports are measured directly. Change in ground-water storage is calculated from measured water-level changes and aquifer specific yield. The equation is solved for evapotranspiration.

The water-budget equation was used to calculate annual water budgets for 1988-90 for the area above the Wooddale, Del., streamflow-measurement station (01480000). Regional ground-water inflow and outflow in the crystalline rocks is considered negligible (Olmsted and Hely, 1962, p. 8), and the water-level map of the Red Clay Creek Basin (Vogel and others, 1991) indicates that the ground-water and surface-water divides coincide. Because water is not released from Hoopes Reservoir to Red Clay Creek, the 2-mi^2 reservoir drainage area is excluded from the drainage area above the Wooddale streamflow-measurement station. The average precipitation was calculated from the seven precipitation stations located north of Wooddale (fig. 2). The quantity of water leaving the basin as streamflow was measured at the streamflow-measurement station at Wooddale. Water-level records for 14 observation wells in the basin were used to calculate the annual change in ground-water storage. The quantity of water imported into the basin for the Borough of Kennett Square Water System was obtained from the Chester County Health Department. The quantity of surface-water withdrawn and exported from the basin as wastewater was obtained from the National Vulcanized Fiber Company (NVF). The quantity of ground water withdrawn by Hercules Research Center and exported from the basin as wastewater was obtained from the Delaware Department of Natural Resources and Environmental Control.

The annual change in ground-water storage was calculated by averaging the annual water-level change measured in 14 observation wells and multiplying by the specific yield of the zone of water-table fluctuation. A specific yield of 0.08 was used on the basis of Olmsted and Hely's calculated specific yields of 0.07-0.10 (Olmsted and Hely, 1962, p. 16-17) for the zone of water-table fluctuation in the adjacent Brandywine Creek Basin. Nutter and Otton calculated a specific yield of 0.08 (1969, p. 28) for an area in Maryland underlain by the Wissahickon Formation.

Water budgets for 1988-90 for the 45-mi^2 area above the Wooddale streamflow-measurement station are given in table 7. The water-budget equation was solved for evapotranspiration, which ranges from 27.87 in. to 30.43 in.; the average evapotranspiration was 28.98 in. for the 3-year period. Olmsted and Hely (1962, p. 8) calculated a 4-year average annual evapotranspiration of 28.09 in. for the adjacent Brandywine Creek Basin.

Table 7.--Annual water budgets for the Red Clay Creek Basin above the Wooddale, Del., streamflow-measurement station (0148000), 1988-90

[Values are in inches per year. Negative values indicate a decrease in ground-water storage. Positive values indicate an increase in ground-water storage. To convert inches to million gallons per day per square mile ($Mgal/d/mi^2$), multiply inches by 0.048.]

Year	Precipitation	Streamflow	Change in ground-water storage	Net exported water [1]	Evapotranspiration
1988	43.59	15.35	-0.69	0.28	28.65
1989	59.14	26.33	+2.13	.25	30.43
1990	46.71	19.05	- .46	.25	27.87
Average	49.81	20.24	+ .33	.26	28.98

[1] Net exported water is equal to ground-water and surface-water withdrawals exported out of the basin minus water imported into the basin.

Water Quality

The effects of human activity and the introduction of manmade organic compounds into ground water and surface water have created serious water-quality problems in ground water and stream sediment in the Red Clay Creek Basin. Water quality in the Red Clay Creek Basin has been affected by the use of fertilizers and pesticides in agriculture and the mushroom industry and by the use of volatile organic compounds (VOC's) in industry. Water-quality data presented below are for the Pennsylvania part of the Red Clay Creek Basin.

Ground water

The USGS collected 69 ground-water samples from 54 wells in the Pennsylvania part of the Red Clay Creek Basin during 1925 through 1990. Sampling sites during 1980-90 were chosen to investigate known or suspected areas of contamination and to determine concentrations of naturally occurring radionuclides in ground water. Because sampling for organic compounds was biased towards wells that were likely to be contaminated, the percentage of wells reported contaminated by organic chemicals does not reflect the percentage of wells in the basin contaminated by organic chemicals. Ground-water sampling was not done as part of this study, but results from other studies are summarized in this report.

Chemical analyses of ground water are given for organochlorine and organophosphorus insecticides, polychlorinated biphenols (PCB), and polychlorinated napthalenes (PCN) in table 28. Chemical analysis for VOC's, base-neutral organic compounds and phenol are given in table 29; nutrients in table 30; metals and trace constituents in table 31; and physical properties, selected ions, and radionuclides in table 32.

Insecticides commonly are used in the Red Clay Creek Basin in both rural and urban areas to control household pests and insect damage in agriculture. Organochlorine insecticides are water-insoluble compounds that are persistent in the environment, highly toxic, and strongly bioaccumulate in some organisms. The U.S. Environmental Protection Agency (USEPA) has restricted or banned the use of many of the organochlorine insecticides. All uses of DDD, DDE, and DDT were banned in 1972, and the use of dieldrin was banned in 1973. Heptachlor and chlordane were restricted to use in termite control in 1974 and were banned in 1989. All uses of aldrin were banned in 1975. The use of methoxychlor, endosulfan, lindane, mirex, and endrin are restricted but still permitted (U.S. Environmental Protection Agency, 1990). Lindane and methoxychlor commonly are used in the mushroom industry. Methoxychlor also is widely used on crops and for home and garden use.

Thirty-eight water samples from 31 wells were analyzed for organochlorine insecticides. A summary of the compounds analyzed for and detected and a range of concentrations is given in table 8. Of the 15 organochlorine insecticides analyzed for, five compounds--lindane, DDT, dieldrin, heptachlor, and methoxychlor--were detected. Organochlorine insecticides were found in 29 percent of the wells sampled. Lindane was the most frequently detected organochlorine insecticide; it was detected in 23 percent of the wells sampled. DDT, dieldrin, and methoxychlor were detected in 7 percent of the wells sampled. Heptachlor was detected in one sample. The USEPA has set a maximum contaminant level (MCL) of 4 μg/L for lindane and 100 μg/L for methoxychlor (U.S. Environmental Protection Agency, 1991); these MCL's were not exceeded.

Because organophosphorus insecticides are less persistent and less likely to bioaccumulate than organochlorine insecticides, they have been substituted for some of the banned organochlorine insecticides. Organophosphorus insecticides are used for insect control in agriculture, homes, and gardens. Diazinon is widely used to control household pests and insect damage in agriculture. Twenty-one water samples from 20 wells were analyzed for organophosphorus insecticides. A summary of the compounds analyzed for and detected and range of concentrations is given in table 9. Of the 12 organophosphorus insecticides analyzed for, 4 compounds--malathion, parathion, diazinon, and phorate--were found in concentrations above the detection limit. The USEPA does not set MCL's for these compounds. Organophosphorus insecticides were found in 30 percent of the wells sampled. Diazinon was the most frequently detected organophosphorus insecticide; it was detected in 20 percent of the wells sampled. The median concentration of diazinon was 0.01 μg/L. Malathion, parathion, and phorate each were detected in one sample.

Table 8.--Organochlorine insecticides detected in ground water in the Red Clay Creek Basin in Pennsylvania
[--, compound not detected; µg/L, micrograms per liter]

Compound	Number of wells sampled	Number of wells where the compound was detected	Concentration or range of concentrations (µg/L)
Aldrin	31	0	--
Chlordane	30	0	--
DDD	31	0	--
DDE	31	0	--
DDT	30	2	0.02-.04
Dieldrin	30	2	.01-.02
Endosulfan	30	0	--
Endrin	30	0	--
Heptachlor	31	1	.01
Heptachlor epoxide	30	0	--
Lindane	30	7	.01-.03
Methoxychlor	30	2	.01-.11
Mirex	31	0	--
Perthane	30	0	--
Toxaphene	31	0	--

Table 9.--Organophosphorus insecticides detected in ground water in the Red Clay Creek Basin in Pennsylvania
[--, compound not detected; µg/L, micrograms per liter]

Compound	Number of wells sampled	Number of wells where the compound was detected	Concentration or range of concentrations (µg/L)
Chlorphrifos	3	0	--
DEF	15	0	--
Diazinon	20	4	0.01-2.6
Disyston	15	0	--
Ethion	20	0	--
Fonofos	3	0	--
Malathion	20	1	.01
Methyl parathion	20	0	--
Methyl trithon	20	0	--
Parathion	20	1	.01
Phorate	15	1	.02
Trithion	20	0	--

Triazine herbicides are moderately water-soluble compounds that are used for weed control on corn and other crops. Alachlor is an aetonilide herbicide used for weed control in agriculture. Water samples from two wells were analyzed for the triazine herbicides ametryne, atrazine, cyanazine, metolachlor, metribuzin, prometone, prometryne, propazine, simazine, simetryne, and trifluralin. Water samples from two wells were analyzed for alachlor. None of the triazine herbicides or alachlor were detected.

VOC's are manmade compounds that commonly are used in industrial, commercial, and residential areas as degreasers and solvents. Many VOC's are suspected or confirmed carcinogens (Council on Environmental Quality, 1981, p. 64). Eighteen water samples from 13 wells were analyzed for VOC's (table 29). Of the 41 VOC's analyzed for, 4 were detected. Benzene at a concentration of 3 µg/L was detected in water from one well. The USEPA MCL for benzene is 5 µg/L. Toluene at a concentration of 7 µg/L was detected in water from one well. The USEPA MCL for toluene is 1,000 µg/L. Tetrachloroethylene (PCE) at concentrations up to 400 µg/L and trichloroethylene (TCE) at concentrations up to 8 µg/L were detected in water from one well. The USEPA MCL for both PCE and TCE is 5 µg/L. TCE at a concentration of 1 µg/L was detected in water from one well. Benzene and toluene are components of refined oil products and are used as industrial solvents and in the manufacture of medicinal and organic chemicals. PCE and TCE commonly are used as degreasers of metals and in the dry cleaning industry. TCE also is used as a solvent for paints, varnishes, and other organic compounds and in the manufacture of pharmaceuticals and organic chemicals (Windholz and others, 1976).

Thirty-eight water samples from 31 wells were analyzed for total PCB and total PCN (table 28). PCB and PCN were not detected in any of the samples. Eighteen water samples from 14 wells were analyzed for total phenols (table 28). Phenol was detected in water from 50 percent of the wells sampled; concentrations of phenol ranged from 1 to 8 µg/L. Phenol is used as a disinfectant and in the manufacture of medical and industrial organic compounds (Windholz and others, 1976).

Nitrate usually is the most abundant nitrogen species in ground water. The major sources of nitrate in ground water are industrial and municipal wastewater, septic systems, and agriculture. High intakes of nitrate are dangerous to warmblooded animals because nitrate is reduced to nitrite in the gastrointestinal tract and can enter the bloodstream and react with hemoglobin to impair oxygen transport. The reaction of nitrite with hemoglobin can be serious or fatal in infants under 3 months of age (U.S. Environmental Protection Agency, 1986). Sixty-two water samples from 51 wells were analyzed for nitrate as nitrogen (table 32). The concentration of dissolved nitrate as nitrogen in water samples from 9 wells (18 percent of wells sampled) exceeded the USEPA MCL of 10 mg/L nitrate as nitrogen. Concentrations of nitrate as nitrogen ranged from 0.07 to 19 mg/L.

Ground-water samples were analyzed for arsenic, barium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, zinc, aluminum, lithium, selenium, and mercury (table 31). Most metals and other trace constituents in natural ground water are found in low concentrations, commonly below the detection limit of the analytical instruments. Some constituents, such as iron and manganese, are naturally occurring and commonly are detected in ground water. The USEPA secondary maximum contaminant levels (SMCL's) for iron and manganese are 300 µg/L and 50 µg/L, respectively (U.S. Environmental Protection Agency, 1991). The USEPA SMCL's are set to avoid objectionable taste and staining in laundry and not for health reasons. Concentrations of manganese in water from 17 percent of the 29 wells sampled and concentrations of iron in water from 6 percent of the 32 wells sampled exceeded the USEPA SMCL's. No other metals or trace constituents analyzed for were detected in concentrations above the USEPA MCL's or SMCL's.

Radon-222 is a naturally occurring radionuclide commonly found in ground water. Radon-222 is a decay product of radium-226 and is soluble in water. Radon in drinking water is considered a health risk only when it is released from water and contributes to airborne radon-222. The progeny of radon-222 are known to cause lung cancer when inhaled (Lowry and Lowry, 1988). Activities of radon-222 ranged from 97 to 4,200 pCi/L ; the median was 590 pCi/L (table 32).

Surface water

Surface-water, biological, and stream-bottom-material samples were collected at two sites in the Red Clay Creek Basin as part of an on-going USGS water-quality monitoring program operated in cooperation with the Chester County Water Resources Authority. Chemical and biological samples are collected annually from the East and West Branches of Red Clay Creek. Samples for chemical analysis were collected by use of techniques described by Brown and others (1970, p. 5). Chemical data from the monitoring program, beginning in 1973, is published annually in the USGS Water Resources Data reports for Pennsylvania (U.S. Geological Survey, 1974-92).

Surface-water samples for chemical analysis were collected at two sites, East Branch Red Clay Creek near Five Point (01479800) and West Branch Red Clay Creek at Kennett Square (01479680) (pl. 1). Water samples were analyzed for determinations of alkalinity, total dissolved solids, and major nutrients (nitrite, nitrate, ammonia, organic nitrogen, total phosphorus and orthophosphate), major ions (calcium, potassium, sodium, magnesium, chloride, fluoride, sulfate, and silica), and trace metals (cadmium, chromium, cobalt, copper, lithium, lead, iron, manganese, nickel, and zinc).

Concentrations of lead exceeded 1 μg/L in six samples; the maximum concentration was 6 μg/L. The concentration of mercury exceeded 0.2 μg/L in three samples; the maximum concentration was 1.8 μg/L. The concentration of manganese exceeded 50 μg/L in two samples from the West Branch Red Clay Creek at Kennett Square; the maximum concentration was 130 μg/L. Concentrations of metals, trace constituents, and inorganic constituents did not indicate a water-quality problem in samples from the East Branch Red Clay Creek near Five Point.

Four bottom-material samples, two from the East Branch Red Clay Creek near Five Point and two from the West Branch Red Clay Creek at Kennett Square, were analyzed for insecticides, PCB, and PCN in 1983, 1985, and 1986. PCB was detected in the West Branch Red Clay Creek at Kennett Square at a maximum concentration of 5,600 μg/kg and methoxychlor was detected at a concentration of 88 μg/kg. PCB was detected in the East Branch Red Clay Creek near Five Point at a maximum concentration of 4 μg/kg. PCN was detected at a concentration of 1 μg/kg, and lindane was detected at a concentration of 0.3 μg/kg.

Biological sampling involved the collection of benthic macroinvertebrates so that a diversity index could be determined and used for assessing water quality. Because many benthic invertebrates live on or under rocks on the stream bottom, benthic invertebrate samples were collected from a riffle by selecting 10 rocks and collecting the associated organisms (Lium, 1974).

Stream benthic invertebrate samples were collected at two sites, East Branch Red Clay Creek near Five Point and West Branch Red Clay Creek at Kennett Square. The benthic invertebrate community is described by use of a descriptive statistic called the diversity index. Brillouin's diversity index (Brillouin, 1962) was calculated for both sites. The diversity index is composed of two quantitative properties (1) the number of different kinds of organisms (taxa) and (2) their relative abundances. The diversity index generally ranges from 0 to 4.0; it ranges between 3.0 and 4.0 in waters free of organic waste, between 1.0 and 3.0 in waters receiving moderate quantities of organic waste, and below 1.0 in waters receiving heavy quantities of organic waste (Wilhm and Dorris, 1968; Wilhm, 1970). Brillouin's diversity index has increased at East Branch Red Clay Creek near Five Point from levels indicating a severely stressed community in 1970 to levels that indicate a stressed community in 1990 (fig. 8). Brillouin's diversity index has increased at the West Branch Red Clay Creek at Kennett Square from levels indicating a severely stressed community in 1970 to levels indicating an intermediate community in 1990 (fig. 9). Both sites in the Red Clay Creek Basin have a diversity index that is associated with water containing moderate quantities of organic waste. The increases in diversity index suggest improved water-quality conditions. This improvement may be the result of a decrease in the use of organochlorine pesticides and the implementation of the Clean Water Act.

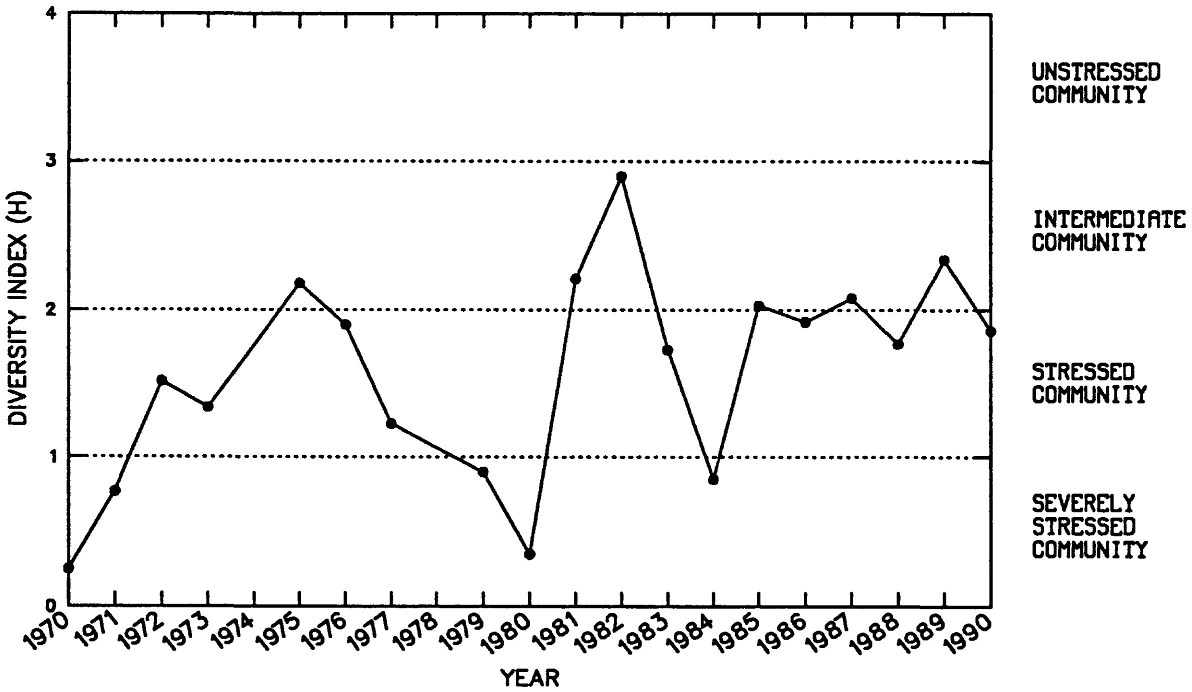

Figure 8.--Brillouin's diversity index at the biological sampling site on East Branch Red Clay Creek near Five Point (01479800), 1970-90.

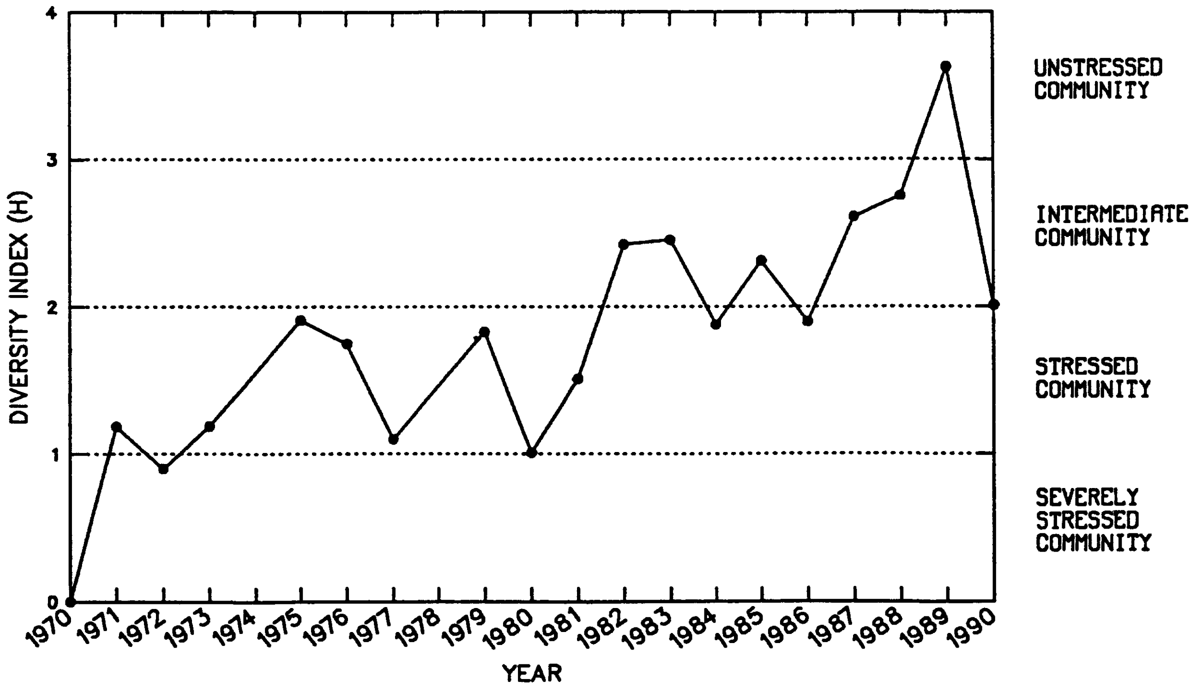

Figure 9.--Brillouin's diversity index at the biological sampling site on West Branch Red Clay Creek at Kennett Square (01479680), 1970-90.

SIMULATION OF GROUND-WATER FLOW

A two-dimensional, finite-difference model of ground-water flow was used to estimate effects of increased ground-water development in the Red Clay Creek Basin. All aquifer hydraulic conductivities used in this report are horizontal hydraulic conductivities. All streambed hydraulic conductivities used in this report are vertical hydraulic conductivities. The design and calibration of the model is discussed below.

Model Description

Ground-water flow was simulated using the computer codes written by McDonald and Harbaugh (1988) and Prudic (1989). Ground-water flow in the physical system is represented mathematically by a partial differential equation. The McDonald and Harbaugh code uses a finite-difference approximation to solve the flow equation for hydraulic head. In order to use a finite-difference approximation, a grid is superimposed over the modeled area, and aquifer physical and hydraulic parameters necessary to solve the flow equation are averaged over the area of each cell or grid block and assigned to a node at the center of the block. The strongly implicit procedure was used to simultaneously solve the flow equation for each cell by iteration.

Prudic's (1989) computer code was used to simulate the interaction between the aquifer and stream system and to account for the amount of flow in streams. The stream system is divided into reaches and segments. A reach corresponds to an individual cell. A segment is a group of reaches connected in downstream order. The division of the stream system into segments permits streamflow from two or more tributary segments to be added to the first reach of the downstream segment. Leakage between the stream and the underlying aquifer is calculated on the basis of the head difference between the stream and aquifer and a conductance term. The equation is

$$Q = (K\ L\ W/M)\ (H_s - H_a), \quad (2)$$

where Q is leakage to or from the aquifer,
K is vertical hydraulic conductivity of the streambed,
L is length of the reach,
W is width of stream,
M is thickness of streambed,
H_s is head in the stream, and
H_a is head in the aquifer.

The conductance term is the first part of the equation, K L W/M. The leakage is added or subtracted (for leakage out of or into the aquifer, respectively) from the flow entering the reach.

A two-dimensional steady-state model was used to simulate the aquifer, stream system, and the stresses acting on the stream-aquifer system. Stresses represented in the model are natural recharge to and discharge from the aquifer, pumpage, and pumpage returns. Sources of water to the aquifer include recharge from precipitation, leakage from streams, and pumpage returns. Discharges of water from the aquifer include ground-water evapotranspiration, ground-water discharge to streams, and pumpage.

Model Design

The ground-water-flow system in the Red Clay Creek Basin was discussed in the Hydrology section, which included a description of ground-water flow, specific capacity and well yield of the hydrogeologic units, recharge to and discharge from the basin in the form of water budgets, and ground-water/surface-water relations. In order to design a digital model of the ground-water-flow system, the complex physical system was simplified, the basin was descretized into a rectangular grid, and boundary conditions and model-input data were specified.

Simplified Conceptual Model

The complex physical hydrologic system is simplified in the conceptual model in order to create a digital model. The set of simplifying assumptions used to create the model are as follows:

1. The fractured crystalline rocks and overlying saprolite act as one heterogeneous aquifer under unconfined conditions.
2. The fractured-rock aquifer can be simulated as an equivalent porous medium because fracture density is sufficiently great that aquifer hydraulic characteristics are similar to those of a porous medium when the aquifer is simulated on a regional scale. The water-level map of the basin (Vogel and others, 1991) indicates that ground-water flow is continuous on the regional scale of the basin.
3. Ground-water flow is horizontal.
4. The aquifer is isotropic.
5. Ground water does not cross basin boundaries. The water-level map of the basin (Vogel and others, 1991) indicates that ground-water and surface-water divides coincide.
6. Although hydraulic conductivity varies spatially (both horizontally and vertically) and depends on the hydrogeologic unit in the physical system, an average hydraulic conductivity is assigned to each hydrogeologic unit. For each hydrogeologic unit, the hydraulic conductivity is varied according to the topographic setting of the model cell, such that hydraulic conductivity decreases from valley to hillside to hilltop.
7. Recharge is predominantly from precipitation and is distributed uniformly over non-stream cells. For stream cells, recharge is reduced by a percentage corresponding to the area of the discharge zone in the stream cell.

Model Grid

The modeled area of the Red Clay Creek Basin is slightly smaller than the study area because the contributing drainage area to Hoopes Reservoir (2 mi^2) was excluded from the model. The ground water and surface water in the Hoopes Reservoir drainage area is isolated from the rest of the basin because ground-water divides coincide with surface-water divides, no ground water flows across the ground-water divides, and surface water is not released to Red Clay Creek (see Description of Study Area). Seepage under the dam is considered negligible compared to the total flow system of the basin. Thus, the contributing area to Hoopes Reservoir is not included in the digital model.

The modeled area of the Red Clay Creek Basin was descretized into a rectangular grid composed of 77 rows and 38 columns (fig. 12). Grid spacing was a uniform 1,000 ft throughout the modeled area. The number of active cells in the grid was 1,454 and covers a total area of 52.2 mi^2. The axes of the model grid were aligned with the major directions of ground-water flow determined from the water-level map of the basin (Vogel and others, 1991). The cell location notation used in this report is (row, column). For example, (12, 28) denotes a cell in the 12th row and 28th column of the model grid.

Boundary Conditions

Boundary conditions are specified for the upper surface, bottom, and sides of the modeled area and are coincident with hydrologic features. The upper surface of the modeled area is represented by the water-table surface and by Red Clay Creek. The water-table surface is considered a specified-flux boundary where the flux is constant areal recharge. Where the upper surface is represented by the creek, it is considered a head-dependent-flux boundary (fig. 10). Flux across the streambed-aquifer surface changes in response to changes in head in the aquifer. The base of the aquifer is coincident with the bottom of the open-fracture zone at which depth ground-water flow ceases. Because no flow crosses the bottom of the aquifer, it is a specified-flux (no-flow) boundary. The periphery of active model cells marks the lateral boundary of the Red Clay Creek Basin and coincides with the ground-water divide determined from the water-level map of the basin (Vogel and others, 1991). Because no flow crosses the ground-water divide, the sides of the modeled area are a specified-flux (no-flow) boundary (fig. 10). Thus, the boundary conditions of the upper surface, bottom, and sides of the modeled area are represented by specified-flux, head-dependent-flux, and specified-flux (no-flow) boundaries.

Model-Input Data

Aquifer characteristics specified in the model include the altitude of the base of the aquifer, water-table altitude, and aquifer hydraulic conductivity. The difference between the average land-surface elevation and aquifer thickness was used to define the altitude of the base of the aquifer. The average land-surface elevation for each grid block was determined from 7.5-minute topographic maps. The thickness of the aquifer was determined from a water-bearing zone analysis (table 3). Although no wells in the study area were drilled deeper than 600 ft, a water-bearing-zone analysis by Sloto (1994) for wells drilled in the crystalline rocks of Chester County indicates that wells drilled deeper than 600 ft encountered no fractures below 600 ft. Additional data might indicate water-bearing fractures exist below 600 ft, but ground-water flow at such depths would be a negligible percentage of the total ground-water flow in the aquifer; therefore, the lower extent of the fracture zone or thickness of the aquifer is assumed to be 600 ft below land surface.

Water-table altitudes were estimated from the water-level map of the basin (Vogel and others, 1991). The water-level map was constructed from water levels measured in 375 wells. The accuracy of the water-level contours and, therefore, the water-table altitudes estimated from the contoured water-level surface, depends on the density and distribution of measured water levels.

Specific-capacity tests of 77 wells, aquifer tests of 6 wells, and reported values of aquifer horizontal hydraulic conductivity were used to obtain initial estimates of hydraulic conductivity. Each model cell was assigned a hydraulic conductivity on the basis of the predominant hydrogeologic unit and topographic setting of the cell. If two hydrogeologic units of equal area were found in a cell, the mean of the two hydraulic conductivities was assigned to the cell. The Wissahickon Formation was divided into a northern and southern unit (see discussion in Steady-State Simulation section), and estimates of hydraulic conductivity are given for each unit. The southern Wissahickon Formation is defined as all of the Wissahickon Formation south of Toughkenamon and Rosedale, Pa. (see pl. 1).

The method of Theis (1963, p. 332-336) was used to estimate transmissivity from specific-capacity data. The length of specific-capacity tests ranged from less than 1 hour to 72 hours; the median length was 2 hours. A specific yield of 0.08 was used in estimating transmissivity; this specific yield is within the range determined by Olmsted and Hely (1962, p. 16-18) for the same hydrogeologic units in the adjacent Brandywine Creek Basin. Hydraulic conductivity was estimated by dividing the transmissivity by the footage of uncased borehole below the water table.

Estimates of hydraulic conductivity obtained from the specific-capacity and aquifer tests are listed by hydrogeologic unit and topographic setting in tables 10 and 11, respectively. Because specific capacity decreases with time and other factors, the hydraulic conductivities determined from the aquifer-test data (length of tests ranged from 12 to 48 hours) may be better estimates than the hydraulic conductivities determined from the specific-capacity tests. However, few aquifer-test data are available for the basin. The median hydraulic conductivity determined from specific-capacity tests for wells with a hillside topographic setting was used as the initial estimate of aquifer hydraulic conductivity.

For hydrogeologic units lacking specific-capacity test data, hydraulic conductivities were obtained from other studies. Median hydraulic conductivities of 0.36, 0.96, and 0.44 for wells with a hillside topographic setting for pegmatite, serpentinite, and gneiss, respectively, were obtained from D.J. Low, D.J. Hippe, and D.S. Yannacci (U.S. Geological Survey and Pennsylvania Geological Survey, written commun., 1991). The hydraulic conductivity of gneissic rocks was used for the felsic and mafic gneiss that crop out in Delaware. An initial estimate of hydraulic conductivity of 2.6 for the Potomac Formation was obtained from thickness and model-calibrated transmissivity maps of Martin (1984, p. 13 and 58, respectively).

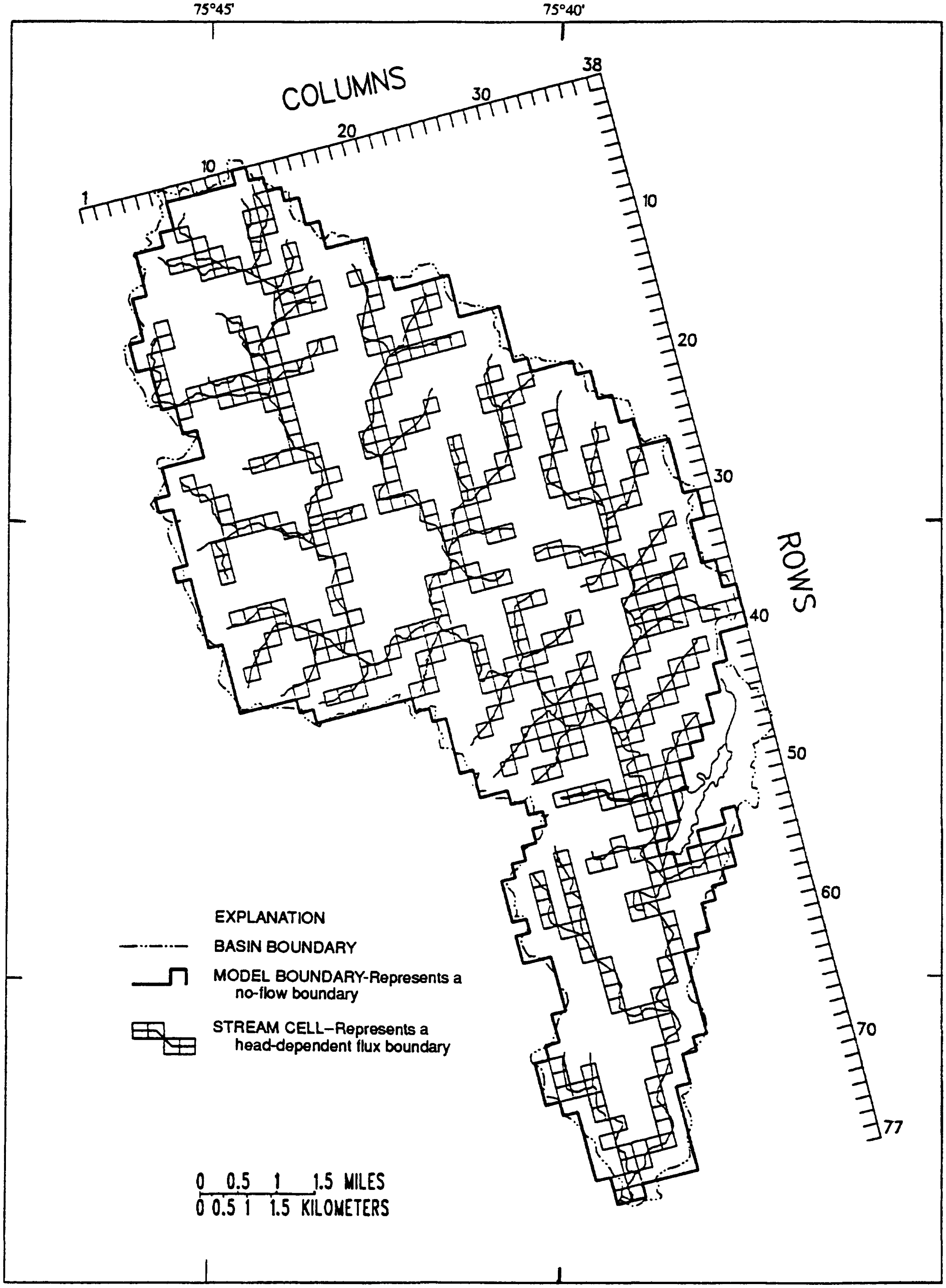

Figure 10.--Model grid and boundary conditions.

Table 10.--Range and median horizontal hydraulic conductivity of hydrogeologic units by topographic setting in the Red Clay Creek Basin, Pennsylvania and Delaware

[Units are feet per day; --, no data]

Hydrogeologic unit	Horizontal hydraulic conductivity											
	Hilltop			Hillside			Valley			All wells		
	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median	Number of wells	Range	Median
Felsic and mafic gneiss	1	0.03	--	--	--	--	--	--	--	1	0.03	--
Wissahickon Formation, northern	2	.05 - .60	0.32	5	0.02 - 2.25	0.31	3	0.47 - 4.20	2.66	10	.02 - 4.20	0.34
Wissahickon Formation, southern	10	< .01 - 6.39	.02	13	.01 - 7.89	.28	2	.02 - .47	.24	25	.01 - 7.89	.05
Cockeysville Marble	--	--	--	1	26.28	--	9	.98 - 325	27.69	10	.98 - 325	27.22
Setters Formation	1	.02	--	5	.15 - 266	.43	--	--	--	6	.02 - 266	.32
Mafic gneiss	1	.46	--	8	.03 - 22.92	.73	--	--	--	9	.03 - 22.92	.47
Felsic gneiss	2	.01 - .22	.12	13	.01 - 16.26	.21	2	.32 - 36.14	31.76	17	.01 - 36.14	.22

Table 11.--Values of transmissivity, coefficient of storage, and horizontal hydraulic conductivity for selected aquifer tests in the Red Clay Creek Basin, Pennsylvania and Delaware

[All aquifer tests were analyzed by the method of Cooper and Jacob (1946); ft^2/d, feet squared per day; ft/d, feet per day; --, no data available; gal/min, gallons per minute; DGS, Delaware Geological Survey]

Well number, topography, and hydrogeologic unit	Date, duration of test, and pumping rate	Analysis by	Transmissivity (ft^2/d)	Coefficient of storage (dimensionless)	Hydraulic conductivity [1] (ft/d)
CH-57 valley Cockeysville Marble	5-28-74 48 hours 245 gal/min	Roy F. Weston [2]	1,270	--	91
CH-1949 valley felsic gneiss	8-8-69 35 hours 110 gal/min	Roy F. Weston	305	0.10	2.8
Bc31-08 hillside Wissahickon Formation, southern	12-1-80 24 hours 48 gal/min	John H. Talley, DGS	24	--	.10
Bc42-10 hillside Wissahickon Formation, southern	11-19-82 12 hours 30 gal/min	John H. Talley, DGS	35	--	.10
Bc42-11 hillside Wissahickon Formation, southern	11-19-82 12 hours 30 gal/min	John H. Talley, DGS	35	--	.12
Bc52-27 hillside Wissahickon Formation, southern	3-16-80 24 hours 90 gal/min	John H. Talley, DGS	[3] .38	--	.16

[1] Hydraulic conductivity calculated by the U.S. Geological Survey by dividing transmissivity by the depth of uncased borehole.
[2] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey.
[3] Calculated for last 300 minutes of the aquifer test.

Because the water-yielding potential of the aquifer is related to topographic setting (see Hydrology section), hydraulic conductivity was adjusted according to the predominant topographic setting of each model cell determined from a 7.5-minute topographic map. The topographic settings used were hilltop, hillside, and valley. Hydraulic conductivity was multiplied by a factor of 0.3, 1.0, or 1.75 for a hilltop, hillside, or valley setting, respectively. If two topographic settings were represented equally in a model cell, the mean of the two multipliers was used. The topographic multipliers used in this report are similar to topographic multipliers used by Gerhart and Lazorchick (1988) and Sloto (1990). Gerhart and Lazorchick (1988, p. 23) used topographic multipliers of 0.2 for hilltop, 1.0 for hillside, and 1.5 for valley settings for Piedmont and Conestoga Valley metamorphic rocks. Sloto (1990, p. 40) used topographic multipliers of 0.5 for hilltop, 1.0 for hillside, and 1.5 for valley settings for Triassic sedimentary rocks, Cambrian and Ordovician carbonate rocks, and Precambrian and Cambrian metamorphic rocks.

Data needed to simulate the stream system are identification of model cells representing streams and stream routing (interconnection), stream stage, altitude of streambed bottom and top, and streambed conductance. Prudic's (1989) computer code uses these data to calculate leakage between the aquifer and the stream and to account for the total streamflow entering and leaving each stream reach. Red Clay Creek was descretized (fig. 10) into 419 stream cells. The average stream stage for each model cell was estimated from 7.5-minute topographic maps. The altitude of the streambed bottom and top was set to 2 ft and 1 ft below stream stage, respectively.

Streambed conductance is defined as the vertical hydraulic conductivity of the streambed material times the product of the width of the stream and its length divided by the thickness of the streambed and is determined for each stream reach. Streambed hydraulic conductivity is unknown. Streambed commonly consists of gravel and fractured bedrock with sand and clay deposits on the inside of meanders or behind impoundments. The initial value of streambed hydraulic conductivity for all stream reaches was set to 0.28 ft/d, a value within the range of hydraulic conductivities of fractured metamorphic rocks (Freeze and Cherry, 1979, p. 29). The length of the stream reach is the length of the model cell. The width of the stream reach was set equal to the measured width of the stream at the nearest downstream base-flow measurement site. Thickness of the streambed was assumed to be 1 ft.

The aquifer stresses simulated were recharge, ground-water evapotranspiration, and pumpage. Under steady-state conditions, the volume of water recharging an aquifer is equal to the volume of water discharged from the aquifer (no change in storage). In the model, water is discharged from the aquifer as base flow, ground-water evapotranspiration, and ground-water pumpage removed from the basin. Thus, model recharge is set equal to the sum of base flow, ground-water evapotranspiration, and pumpage removed from the basin. Recharge from precipitation is distributed evenly over the basin for non-stream model cells. For stream cells, recharge was reduced to account for the part of the stream cell that is assumed to be a discharge area. The reduction in recharge for stream cells ranged from 4 to 25 percent depending on the size of the stream valley.

Sloto's estimated average annual ground-water evapotranspiration (GW ET) rate of 2 in/yr (Sloto, 1990, p. 28) was used in this study. The model simulates ET from the water table by adjusting the ET rate from a maximum rate at land surface to zero at a specified extinction depth. Between the land surface and the extinction depth, ET varies linearly with water-table altitude. The extinction depth is 10 ft. The maximum GW ET rate was adjusted during model calibration to obtain a GW ET rate of 2 in/yr.

Ground-water pumpage was simulated for ground-water users that withdrew an average of 0.03 Mgal/d or more and discharged wastewater to a stream or a spray-irrigation system. Wastewater returned to the aquifer by a spray-irrigation system was simulated as a recharge well; 50 percent of the pumpage was assumed lost to consumption and evapotranspiration (Pennsylvania Department of Environmental Resources, 1972). Information on ground-water withdrawals for 1988-90 was obtained from the State Water Plan Division of the Pennsylvania Department of Environmental Resources Water-Use-Data System, Division of Water Resources Water Supply Branch of the Delaware Department of Natural Resources and Environmental Control, Engineering Division of the Chester County Health Department, and Chester County Planning Commission (1985a, b).

Domestic users and small commercial or industrial users with small consumptive losses (less than 10 percent) commonly return pumpage to the aquifer by on-site septic systems. Thus, the amount of domestic and small commercial and industrial pumpage lost to the basin was assumed to be negligible and was not simulated.

In the model, some ground-water pumpage was returned to streams as wastewater discharge. Prudic's (1989) computer code permits streamflow to be added to the first reach of a stream segment; therefore, wastewater discharges located near headwater stream reaches were easily added to streamflow. In order to add wastewater discharge to stream segments at locations other than the first reach, a "tributary" of one reach and a streambed conductance equal to zero was specified at the location of the actual wastewater-discharge site. Setting the streambed conductance to zero prevented interaction between the aquifer and wastewater "tributary." Thus, no leakage from the aquifer was added to the wastewater "tributary," and wastewater did not leak from the "tributary" to the underlying aquifer.

Prudic's (1989) computer code was used to simulate surface-water diversions where the diverted water was not returned to the surface-water system. The NVF Company diverts surface water from the Red Clay Creek near the Pennsylvania-Delaware State line. The majority of this water is returned to Red Clay Creek downstream at Yorklyn, Del. A smaller percentage of the diversion is sent to the New Castle

County Sewage Treatment Plant outside of the basin, and some of the diversion is lost through evaporation. The amount of the diversion lost through evaporation and exportation is the amount simulated as a diversion from Red Clay Creek. A one-model-cell reach was used to simulate the diversion; Prudic's (1989) computer code permits the amount of diverted streamflow to be subtracted from the streamflow of the creek. The conductance of the diversion reach is set equal to zero to prevent the diversion from leaking into the aquifer and to prevent ground water from discharging to the diversion reach. Thus, the diversion is effectively removed from the simulated basin system just as it is removed from the basin.

Model Calibration

The steady-state model was calibrated by trial and error adjustment of the input data in order to produce model-simulated heads and base flows that compared favorably to measured values of head and base flow. The input data adjusted during calibration were aquifer and streambed hydraulic conductivities and maximum GW ET rate. Simulated heads and base flows were tested for sensitivity to changes in aquifer and streambed hydraulic conductivities, as well as other input variables, during and after model calibration.

Calibration Criteria

The criteria used to determine an acceptable match between simulated heads and measured and inferred heads and between simulated and measured base flows are subjective, although the goal of the matching process is to minimize the difference between simulated and measured heads and base flows. During model calibration, improvements in the model were determined by calculating the root mean square error (RMSE). The RMSE is a measure of the error in the simulated head over the entire modeled area and is calculated by use of the following equation:

$$\text{RMSE} = \left(\frac{\Sigma\,(\text{measured or inferred head} - \text{simulated head})^2}{\text{number of comparisons}}\right)^{\frac{1}{2}}. \qquad (3)$$

If the RMSE decreased, then the adjustments to the input data were retained. In addition to the RMSE, the percentage difference between measured and simulated base flows was evaluated. If the percentage difference decreased, then the adjustments to the input data were retained. The model was considered calibrated when the following criteria were met:

1) A distribution of aquifer and streambed hydraulic conductivities was maintained within the range of values obtained from specific-capacity and aquifer tests (tables 10 and 11) and published values from laboratory tests, field measurements, or other reports (table 12), respectively. Although no unique solution meets these criteria, the solution obtained is supported by hydrologic data.
2) The simulated heads and base flows reasonably matched measured or inferred heads and base flows.
3) Simulated flow directions agree with those represented in the water-level map constructed from static water-level measurements in 375 wells (Vogel and others, 1991).
4) Visual inspection of the areal distribution of the residuals or differences between heads interpolated from the water-level map (Vogel and others, 1991) and simulated heads indicated no consistent pattern of positive and negative or high and low values.

Steady-State Simulation

Steady-state conditions imply that the system is in equilibrium, such that inflow is equal to outflow, and ground-water storage does not change. If no change in ground-water storage occurs, then ground-water levels remain constant. A steady-state simulation of base-flow conditions on November 2, 1990, was

Table 12.--Values for streambed hydraulic conductivity used by various investigators
[Modified from Willey and Achmad (1986); ft, feet; ft/d, feet per day]

Hydraulic conductivity (ft/d)	Remarks	Reference
0.99	Assuming a semiconfining layer 1 ft thick, Wissahickon Formation	Willey and Achmad (1986, p. 17)
0.06 - 5.2	Seepage loss measurements	Fidler (1975, p. 11)
1.9	Field test average for sand and gravel	Haeni (1978, p. 19)
.09 - 3.9	Laboratory, sand and gravel	Haeni (1978, p.19)
2	Final value used in model simulation for this study	Haeni (1978, p. 29)
.09 - 15.2	Variable head permeameter, field tests in various materials	Rosenshein and others (1968, p. 23)
3.4	Flood-plain sediments, laboratory tests	Kilpatrick (1964, p. 332)
10.5 - 31.5	Silty sands, laboratory tests	Kilpatrick (1964)
10.5	Saprolite, laboratory tests	Kilpatrick (1964)
5.3	When assuming a restrictive layer 1 ft thick, graphitic gneiss	McGreevy and Sloto (1980, p. 18)

used to calibrate aquifer and streambed hydraulic conductivity. Ground-water levels measured at 15 observation wells in the basin showed an average change of only 0.57 ft from October through November 1990 (fig. 6). In addition, the basin is not undergoing any long-term adjustments because of natural or anthropogenic events.

The stresses simulated for the steady-state conditions on November 2, 1990, were recharge, GW ET, pumpage, and pumpage returns. Recharge was calculated by adding base flow, GW ET, and pumpage removed from the basin on November 2. A recharge rate of 1.9×10^{-3} ft/d (8.32 in/yr) was used. Base flow from the area underlain by crystalline rock was 29.8 ft^3/s (8.03 in/yr) at the Stanton, Del., streamflow-measurement station on November 2. A maximum GW ET rate of 1.4×10^{-4} ft/d (0.61 in/yr) was used; this rate yielded 0.01 in. of GW ET. GW ET of 0.01 in. was estimated for November 2 by dividing the estimated average annual GW ET by the number of days of GW ET annually. GW ET was assumed from April through November (244 days). Pumpage simulated in the basin is listed in table 13. Pumpage returns as wastewater discharge to streams and surface-water diversions are listed in table 14. Pumpage removed from the basin was 0.71 Mgal/d (0.28 in/yr).

Final calibrated aquifer hydraulic conductivities are compared to the initial values in table 15. The calibrated values are of the same order of magnitude as the initial values, except for the Cockeysville Marble and pegmatite. Specific-capacity tests used for estimating the hydraulic conductivity of the Cockeysville Marble are for nondomestic wells, and the well locations commonly were chosen to obtain the maximum yield. Thus, the data are skewed toward high-yielding wells and probably do not represent the hydrogeologic unit as a whole. The final model value for the Cockeysville Marble agrees well with the median hydraulic conductivity of 3.51 ft/d provided by D.J. Low, D.J. Hippe, and D.S. Yannacci (U.S. Geological Survey and Pennsylvania Geologic Survey, written commun., 1991) for domestic wells completed on slopes in Cockeysville Marble.

The calibrated model values for aquifer and streambed hydraulic conductivity are estimates of these properties on a regional scale. The hydraulic conductivity varies locally; however, in the model, an average value of hydraulic conductivity was assigned to each hydrogeologic unit. The calibrated values of hydraulic conductivity are within the range of measured values.

Streambed vertical hydraulic conductivity was evaluated with respect to the underlying hydrogeologic unit. Observations of streambed material made during base-flow measurements indicated that the streambed mainly is composed of coarse material and bedrock, except for the streambed over the Cockeysville Marble, which is composed of fine sand and clay. Thus, the streambed hydraulic conductivity is assumed to reflect the hydrologic properties of the underlying bedrock.

Table 13.--Ground-water pumpage and pumpage return rates used in simulation for November 2, 1990

[Negative sign indicates recharge to the aquifer; Mgal/d, million gallons per day; CCHD, Chester County Health Department; PaDER, Pennsylvania Department of Environmental Resources; DNREC, Delaware Department of Natural Resources and Environmental Control]

Model node				
Row	Column	Pumpage rate (Mgal/d)	Well owner and well number	Source of data
13	6	0.03	University of Pennsylvania, New Bolton Center, CH-2062 and CH-2063	CCHD
15	21	.369	Borough of Kennett Square Water System, CH-45	CCHD
16	24	.04	Longwood Gardens, CH-57	CCHD
16	26	.04	Longwood Gardens, CH-2125	CCHD
17	25	-.008	Longwood Gardens, spray-irrigation system simulated as a recharge well	PaDER [1]
24	13	.093	Seneca-Kennett Foods; CH-2012, CH-2013, and CH-2400	PaDER [2]
25	14	.243	National Vulcanized Fiber Company, CH-31 and CH-43	PaDER [2]
25	17	.166	Mushroom Co-op Canning, CH-3210, CH-3211, and CH-3212	PaDER [2]
58	26	.040	Hercules, Inc; composite of 3 wells	DNREC
59	27	.120	Hercules, Inc; composite of 8 wells	DNREC

[1] For 1990, 50 percent of Longwood Garden's wastewater was disposed through the spray-irrigation system (Jim Cogill, Longwood Gardens, oral commun., 1991). An estimated 50 percent of the wasterwater disposed through the spray-irrigation system reached the aquifer.

[2] Data for 1990 were not available; therefore, pumpage rates were estimated from 1988 data.

Table 14.--Sewage treatment plant, industrial, and commercial discharges to and withdrawals from Red Clay Creek used in the simulation for November 2, 1990

[Negative sign indicates surface-water withdrawal; Mgal/d, million gallons per day; PaDER, Pennsylvania Department of Environmental Resources; NVF, National Vulcanized Fiber]

Model node				
Row	Column	Discharge rate (Mgal/d)	Discharger and stream	Source of data
14	5	0.028	University of Pennsylvania, New Bolton Center, South Brook	PaDER
19	26	.016	Longwood Gardens, unnamed tributary to East Branch Red Clay Creek referred to in this report as Longwood tributary	PaDER [1]
21	24	.031	East Marlborough Township Sewage Treatment Plant, Longwood tributary	PaDER
24	13	.026	Seneca-Kennett Foods, West Branch Red Clay Creek	PaDER
26	14	.314	NVF Company, unnamed tributary to West Branch Red Clay Creek	PaDER [2]
26	18	.074	Mushroom Co-op Canning, East Branch Red Clay Creek	PaDER
27	12	.760	Borough of Kennett Square Sewage Treatment Plant, West Branch Red Clay Creek	PaDER
39	19	[3] -.826	NVF Company, Red Clay Creek	NVF

[1] For 1990, 50 percent of Longwood Garden's wastewater was disposed through the spray-irrigation system and 50 percent was discharged to the Longwood tributary (Jim Cogill, Longwood Gardens, oral commun., 1991).

[2] Data for 1990 were not available; therefore, discharge rates were estimated from 1991 data.

[3] Diversion is set equal to the amount of withdrawal not returned to the Red Clay Creek. The diverted water is exported from the basin to the New Castle County Sewage Treatment Plant.

Table 15.--Initial estimates and calibrated values for aquifer horizontal hydraulic conductivity in the Red Clay Creek Basin, Pennsylvania and Delaware
[Values are for hillside topographic setting]

Hydrogeologic unit	Hydraulic conductivity (feet per day)	
	Initial estimate	Calibrated value
Potomac Formation	2.60	2.60
Felsic and mafic gneiss (Delaware)	.44	.44
Serpentinite	.96	.96
Pegmatite	.36	.07
Wissahickon Formation, northern	.31	.27
Wissahickon Formation, southern	.28	.15
Cockeysville Marble	26.28	1.52
Setters Formation	.43	.24
Mafic gneiss (Pennsylvania)	.73	.15
Felsic gneiss (Pennsylvania)	.22	.19

Final calibrated streambed hydraulic conductivities are compared to the initial values in table 16. Although the streambed hydraulic conductivity may vary locally and with hydrogeologic unit, the same initial value was assigned to all hydrogeologic units because of the lack of data on streambed hydraulic conductivity. Calibration of the streambed hydraulic conductivity was accomplished by adjusting the initial value of streambed hydraulic conductivity in the same manner for all stream reaches overlying the same hydrogeologic unit. Because no data on streambed hydraulic conductivity in the study area were available, the adjustment of streambed hydraulic conductivity was constrained to the range of values obtained from laboratory tests, field measurements, and other ground-water-flow-simulation reports (table 12). If simulated base flows were not sensitive to changes in the streambed hydraulic conductivity, the initial model value of streambed hydraulic conductivity was retained. Final streambed hydraulic conductivities range from 0.08 to 26 ft/d. The low streambed hydraulic conductivity for the Cockeysville Marble, 0.08 ft/d, probably is because the streambed material consists of fine sand and clay. The streambed hydraulic conductivities for the northern and southern Wissahickon Formation units differed in the same manner that the aquifer hydraulic conductivity differed; aquifer and streambed hydraulic conductivity was higher in the northern Wissahickon Formation than in the southern Wissahickon Formation.

Table 16.--Initial estimates and calibrated values for streambed vertical hydraulic conductivity in the Red Clay Creek Basin, Pennsylvania and Delaware

Underlying hydrogeologic unit	Streambed hydraulic conductivity (feet per day)	
	Initial estimate	Calibrated value
Potomac Formation	0.28	26.00
Felsic and mafic gneiss (Delaware)	.28	.28
Wissahickon Formation, northern	.28	8.2
Wissahickon Formation, southern	.28	.15
Cockeysville Marble	.28	.08
Setters Formation	.28	4.7
Mafic gneiss (Pennsylvania)	.28	.28
Felsic gneiss (Pennsylvania)	.28	.15

Eighty-five sites measured during base-flow conditions from October 31 to November 2, 1990, were used for comparison of simulated and measured base flow. A comparison of simulated and measured base flow is shown in figure 11 and listed in table 17. For 67 percent of the sites, simulated base flow is within 20 percent of the measured base flow, and for 80 percent of the sites, simulated base flow is within 30 percent of the measured base flow. Figure 11 shows that for base flows greater than 1 ft^3/s, the relation between simulated and measured base flows is good. For base flows less than 1 ft^3/s, the percentage difference between measured and simulated base flow may be more than 20 percent of the measured base flow, although the actual difference can be as low as 0.01 to 0.02 ft^3/s.

For simulated and measured and interpolated head comparisons, head for each model cell was estimated from the water-level map of the Red Clay Creek Basin constructed from measurements made June through October 1989 and March 1990 (Vogel and others, 1991). The water-level surface mapped in 1989 is considered comparable to water-level conditions on November 2, 1990, because the configuration of the water-level surface generally remains the same, but water levels fluctuate in response to natural recharge and discharge; the amplitude of this fluctuation generally was less than 10 ft for 1988-90 (table 18). Thus, the amplitude of the water-level fluctuation is within the accuracy of the 20-ft-contour interval used on the water-level map. A comparison of water levels at 15 observation wells during the measurement period for the water-level map and the steady-state calibration (table 18) shows that the median water-level difference for the two periods is 3.60 ft.

The RMSE for the calibrated model is 20.53 ft. This is comparable to RMSE values of 19.54 ft obtained by Sloto (1990) and 21.19 ft obtained by Sloto and others (1991) for fractured-rock-aquifer models of similar size and scale. The average difference between simulated and measured or inferred head for all model cells is 0 ft and the absolute average difference is 15 ft.

A comparison of simulated and measured head at 14 observation wells is listed in table 19. Simulated head at observation well locations was calculated from weighted values of head at the nearest surrounding nodes such that the weight is proportional to the inverse of distance to the observation well location (Harbaugh and Tilley, 1984, p. 21). The average difference between simulated and measured head at observation wells is 5.8 ft, and the absolute average difference is 17.4 ft. The median difference between simulated and measured head at observation wells is -1.6 ft.

The altitude and configuration of the simulated water-level surface of the aquifer is shown on plate 2. The subbasin ground-water divides that coincide with the surface-water divides for the East and West Branches of the Red Clay Creek and Burroughs Run are simulated by the model, as well as many of the subbasin ground-water divides that coincide with the surface-water divides of smaller tributaries. Thus, the simulated heads maintain the ground-water-flow directions inferred from the water-level map (Vogel and others, 1991).

No distributional biases or patterns are in the areal distribution of residuals (difference between simulated and measured or inferred head), either in positive and negative values or in high and low values. Distributional biases in the residuals may indicate that the hydrologic characteristics used in the model are inappropriate (Gerhart and Lazorchick, 1988, p. 30). If the residuals for a hydrogeologic unit show distributional biases, Gerhart and Lazorchick (1988, p. 30) suggest dividing the unit. During steady-state calibration, the Wissahickon Formation showed distributional biases of the residuals; therefore, the Wissahickon Formation was divided into a northern and southern unit (as described in the Model-Input Data section). Examination of the hydraulic conductivity estimates from specific-capacity and aquifer tests indicates that the hydraulic conductivity of the southern unit is less than that of the northern unit (see tables 10 and 11) and that dividing the Wissahickon Formation into two units is appropriate.

In some areas of the model, simulated and estimated heads do not match well. Generally, these areas are located adjacent to the basin boundaries or in areas of large changes in topography and water-level altitude. The area from Ashland, Del., to Hoopes Reservoir is an area where the topography is steep; here the Red Clay Creek Basin narrows so that the basin boundaries are close together. In this area, the difference between simulated heads and heads interpolated from the water-level map ranges from -81 ft to +86 ft, and simulated and interpolated ground-water divides of the small subbasins do not match.

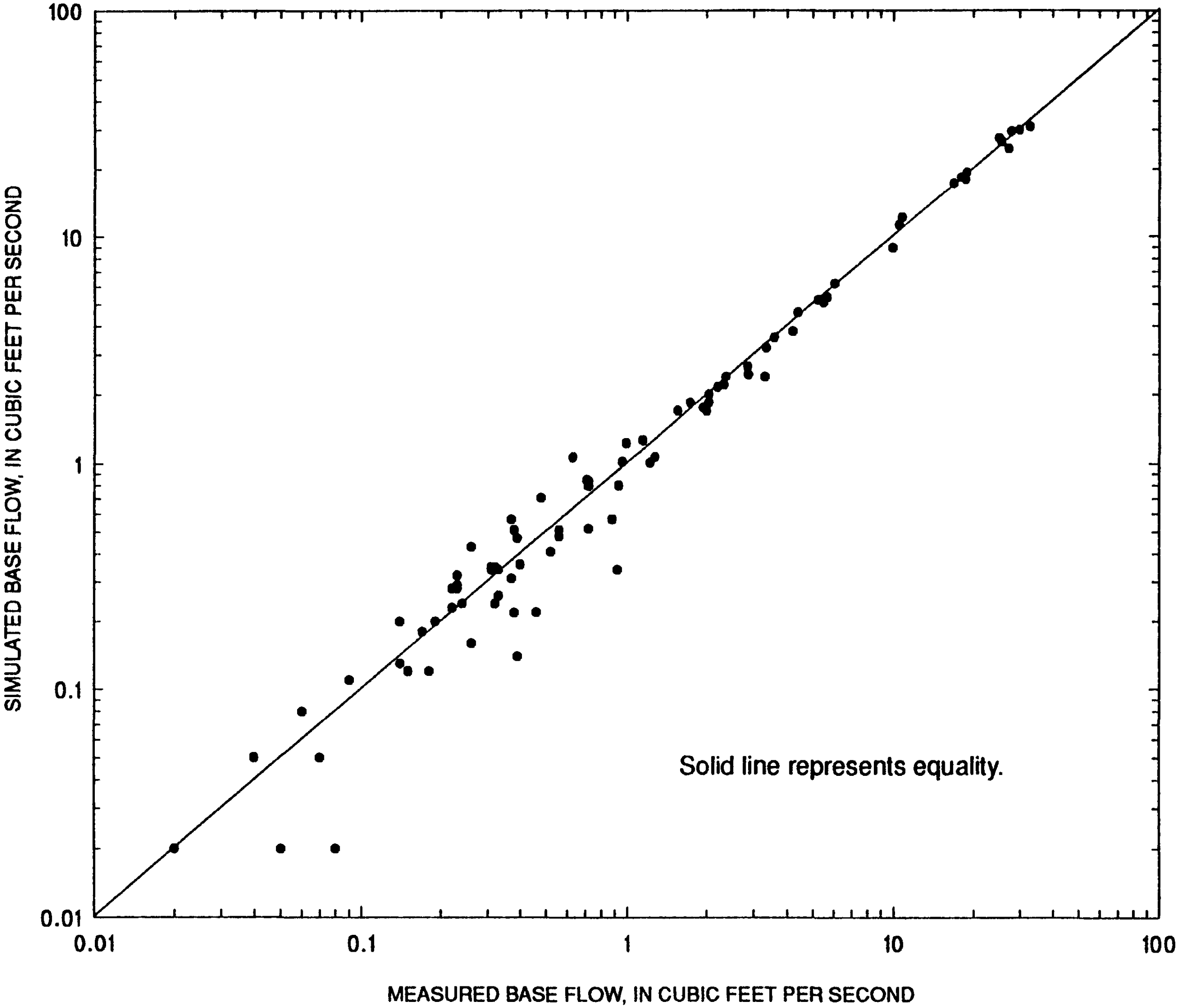

Figure 11.--Relation between measured (October 31 to November 2, 1990) and simulated base flow of Red Clay Creek.

Table 17.--Measured and simulated base flow of Red Clay Creek

[Measurement sites shown on plate 1; base flow measured October 31-November 2, 1990; ft^3/s, cubic feet per second; <, less than]

Site number	Measured base flow (ft^3/s)	Simulated base flow (ft^3/s)	Difference: Flow (ft^3/s)	Difference: Percent
1	0.72	0.84	0.12	17
2	.56	.51	-.05	9
5	2.2	2.2	.0	0
6	3.3	2.4	-.9	27
6A	.32	.35	.03	9
7	2.8	2.7	-.1	4
8	.06	.08	.02	33
9	.04	.05	.01	25
10	3.3	3.2	.1	3
11	4.4	4.6	.2	5
12	.31	.35	.04	13
13	.37	.57	.20	54
14	.63	1.1	.44	70
16	.09	.11	.02	22
17	5.2	5.2	.0	0
18	5.7	5.4	-.3	5
19	.38	.51	.13	34
20	6.1	6.2	.1	2
22	.52	.41	-.11	21
23	.56	.48	-.08	14
25	.46	.22	-.24	52
27	1.1	1.3	.2	18
28	9.9	8.9	-1.0	10
31	10	11	1	10
32	.72	.80	.08	11
33	.22	.23	.01	4
34	.99	1.23	.24	24
35	.24	.24	0	0
36	11	12	2	18
37	.33	.34	.01	3
38	.71	.85	.14	20
39	.15	.12	-.03	20
41	.37	.31	-.06	16
42	.23	.29	.06	26
43	2.0	1.7	-.3	15
44	1.9	1.8	-.1	5
45	2.0	1.9	-.1	5
46	2.9	2.5	-.4	14
47	.72	.52	-.20	28
48	.93	.80	-.13	14
49	1.3	1.1	-.2	15
50	.33	.26	-.07	21

Table 17.--Measured and simulated base flow of Red Clay Creek--Continued

Site number	Measured base flow (ft^3/s)	Simulated base flow (ft^3/s)	Difference: Flow (ft^3/s)	Difference: Percent
51	1.6	1.7	0.1	6
52	1.7	1.9	.2	12
53	2.0	2.0	0	0
54B	.26	.16	-.10	38
55	5.5	5.1	-.4	7
56A	.39	.14	-.25	64
56B	17	17	0	0
58	.23	.28	.05	22
62	.88	.57	-.31	35
63	19	18	-1	5
64	18	18	0	0
65	.02	.02	0	0
66A	.18	.12	-.06	33
66B	.14	.20	.06	43
66C	.07	.05	-.02	28
66D	.05	.02	-.03	60
67	19	19	0	0
68	1.2	1.0	-.2	17
69	.39	.47	.08	20
70	2.3	2.2	-.1	4
71	.40	.36	-.04	10
72	2.4	2.4	0	0
73	.22	.28	.06	27
74	.17	.18	.01	6
75	.32	.24	-.08	25
76	3.6	3.6	0	0
77	.14	.13	-.01	7
78	4.2	3.80	-.4	10
79	.92	.34	-.58	63
80	27	25	-2	11
81	.19	.20	-.01	5
82	.23	.32	.09	39
83	.31	.34	.03	10
84	.08	.02	-.06	75
85	.38	.22	-.16	42
86	26	27	1	< 1
87	25	27	2	8
88	.48	.71	.23	48
89	.96	1.02	.06	6
90	28	29	1	4
91	30	30	0	0
92	.26	.43	.17	65
93	33	31	-2	6

Table 18.--Water-level fluctuations in observation wells[1] in the Red Clay Creek Basin, Pennsylvania and Delaware, 1988-90

[Water levels in feet below land surface; difference in feet; negative sign indicates water level above land surface; >, greater than]

	Maximum		Minimum			June 1989		November 1990		
Well number	Date	Water level	Date	Water level	Difference	Date	Water level [2]	Date [3]	Water level	Difference
CH-21	5- 8-89	23.89	12-13-90	28.32	4.43	6- 6-89	24.03	11- 7-90	28.00	3.97
CH-28	5-19-89	11.10	11- 4-88	21.32	10.22	6- 6-89	13.58	11- 7-90	19.16	5.58
CH-1921	8-21-89	37.24	2-21-89	46.95	9.71	6- 6-89	40.37	11- 7-90	41.69	1.32
CH-2120	8- 7-89	5.66	10- 8-90	7.38	1.72	6- 6-89	6.32	11- 7-90	7.33	1.01
CH-3283	5- 8-89	39.23	11- 4-88	41.85	2.62	6- 6-89	39.97	11- 7-90	41.05	1.08
CH-3284	8- 7-89	16.25	11- 4-88	22.05	5.80	6-23-89	16.70	11- 8-90	21.20	4.50
CH-3285	6- 6-89	20.73	11- 4-88	25.40	4.67	6- 6-89	20.73	11- 7-90	23.59	2.86
CH-3286	7- 6-89	1.82	11- 4-88	11.40	9.58	6-23-89	3.86	11- 2-90	8.08	4.22
CH-3287	7- 6-89	18.00	12-13-90	25.42	7.42	6- 6-89	18.17	11- 7-90	24.37	6.20
CH-3288	5-22-89	- .21	11- 4-88	11.25	11.46	6-23-89	1.32	11- 8-90	10.86	9.54
Bb25-31	7- 6-89	[4] >3.30	11- 7-90	6.95	---	6- 6-89	3.55	11- 7-90	6.95	3.40
Bb25-32	7- 6-89	18.72	11- 4-88	24.83	6.11	6-30-89	20.82	11- 2-90	24.42	3.60
Bc32-10	7- 6-89	29.04	12-13-90	33.20	4.16	6- 6-89	31.87	11- 7-90	33.16	1.29
Bc43-01	5-31-90	23.61	11- 7-90	32.90	9.29	6-30-89	25.30	11- 2-90	32.67	7.37
Bc43-16	8- 7-89	10.23	11- 4-88	18.10	7.87	6-30-89	13.12	11- 2-90	16.60	3.48

[1] Obervation well CH-2598 excluded because of interference from nearby pumping well.
[2] From Vogel and others (1991).
[3] Measurement nearest to date of steady-state calibration (November 2, 1990).
[4] Well is located in a pit with top of casing 3.30 feet below land surface, and well was flowing.

Table 19.--Measured and simulated water levels at observation-well sites [1] in the Red Clay Creek Basin, Pennsylvania and Delaware

[Well locations shown on plate 1; measurement dates given in table 25; water level in feet above mean sea level]

	Water level		
Well number	Measured	Simulated	Difference (feet)
CH-21	352.0	350.5	1.5
CH-28	348.8	361.4	-12.6
CH-1921	363.3	362.7	.6
CH-2120	385.7	400.7	-15.0
CH-3283	208.9	224.9	-16.0
CH-3284	383.8	371.7	12.1
CH-3285	406.4	378.2	28.2
CH-3286	366.9	387.1	-20.2
CH-3287	320.6	324.4	- 3.8
CH-3288	304.1	314.2	-10.1
Bb25-31	193.1	170.7	22.4
Bb25-32	175.6	189.6	-14.0
Bc32-10	161.8	154.5	7.3
Bc43-16	238.4	157.5	80.9

[1] Observation well CH-2598 excluded because of interference from nearby pumping well. Bc43-01 excluded becaused it is within the Hoopes Reservoir drainage area, which is not included in the model.

Reducing grid spacing in areas of the model where there are large changes in topography and water-level altitude may improve the match between simulated and interpolated heads and refine the locations of ground-water divides.

The ground-water-flow model for the Red Clay Creek Basin is considered to be calibrated under steady-state conditions. The match between simulated and measured base flows and simulated and interpolated heads is considered acceptable. Because a porous-media model is used to simulate flow in a fractured-rock system, the model should not be used to estimate site-specific effects of stresses on head or base flow. The model can be used to simulate regional effects of long-term changes in recharge and discharge on the base flow of streams and on changes in head.

Sensitivity Analysis

Sensitivity analyses were used during model calibration to refine initial estimates of input variables and after model calibration to determine which input variables have the largest effect on simulated head and base flow. The model is said to be sensitive to an input variable when small changes in the value of that variable result in large changes in simulated head or base flow. Conversely, if large changes in the value of an input variable result in little or no change in simulated head or base flow, then the model is not sensitive to that variable, and the model is not useful for refining the initial estimate of the variable. If the model is sensitive to an input variable, additional data on the variable can help improve model calibration.

The calibrated model input variable values were used in the final sensitivity analysis simulations; the value of one variable, such as recharge rate, was varied over a reasonable range to test sensitivity. Incremental changes were made to the calibrated value of the tested variable, and heads and base flows from the sensitivity simulation were compared to heads and base flows from the calibrated model simulation. Incremental changes for each variable ranged from one-half to double the calibrated value.

The variables tested were aquifer thickness, aquifer hydraulic conductivity, streambed hydraulic conductance, recharge rate, and maximum ground-water evapotranspiration rate. In sensitivity analysis simulations for aquifer hydraulic conductivity and streambed hydraulic conductance, values for each hydrogeologic unit were not varied independently of the other units in order to simplify the analysis. However, aquifer hydraulic conductivity and streambed hydraulic conductance were varied for each hydrogeologic unit for sensitivity analyses made during model calibration.

The effects of changing the value of an input variable on RMSE and total base flow are shown on figures 12 and 13, respectively. The slope of the line on figures 12 and 13 indicates the sensitivity of the model to the tested variable. The steeper the slope, the more sensitive the model is to the tested variable. Although some simulations produced a lower RMSE than the calibrated model, base flows resulting from these simulations were not as close to base flows from the calibrated model.

The model was most sensitive to the recharge rate (figs. 12 and 13). When the recharge rate was varied from one-half to double the November 2, 1990, rate (4.16 to 16.64 in/yr), the RMSE ranged from 19.76 to 47.72 ft. Simulated base flow ranged from 12 percent less to 104 percent more (7.02 to 16.33 in.) than the calibrated base flow (8.02 in.) near the mouth of Red Clay Creek (site 93, pl. 1).

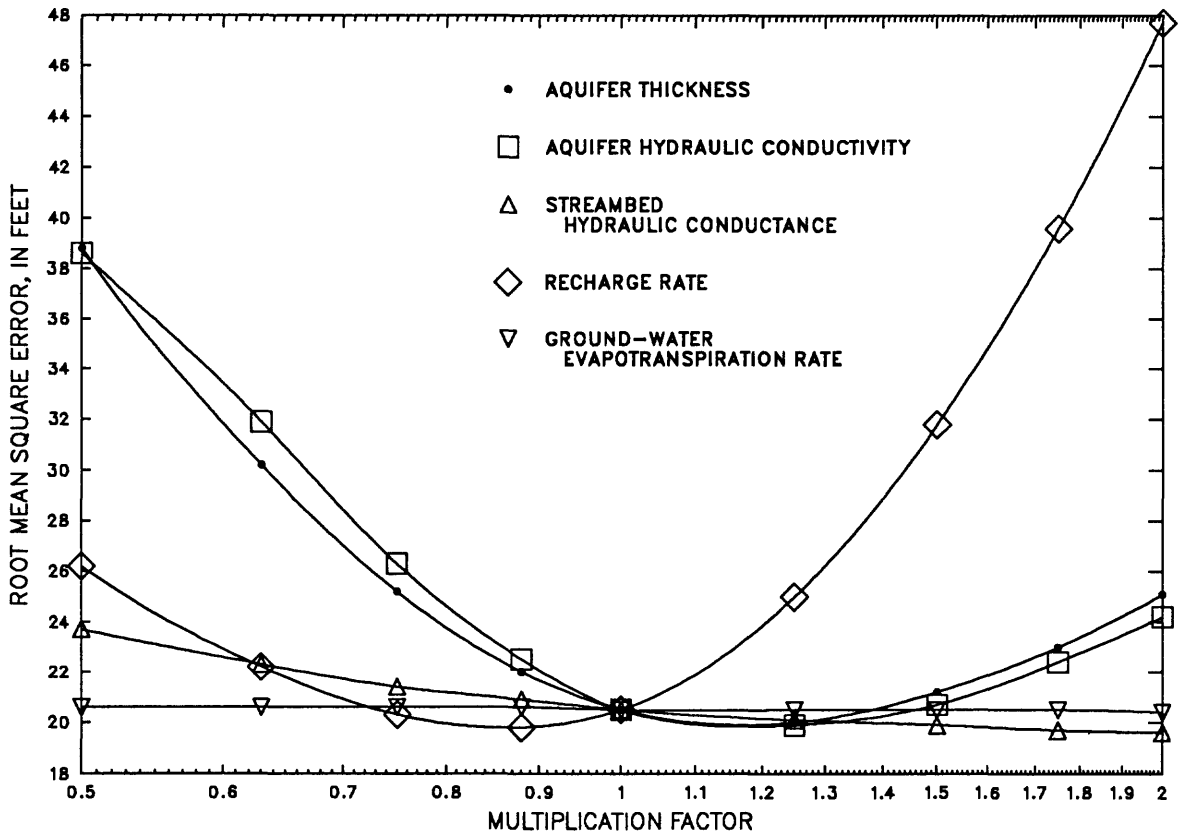

Figure 12.--Effect of varying the value of input variables on the root mean square error between measured or inferred and simulated head.

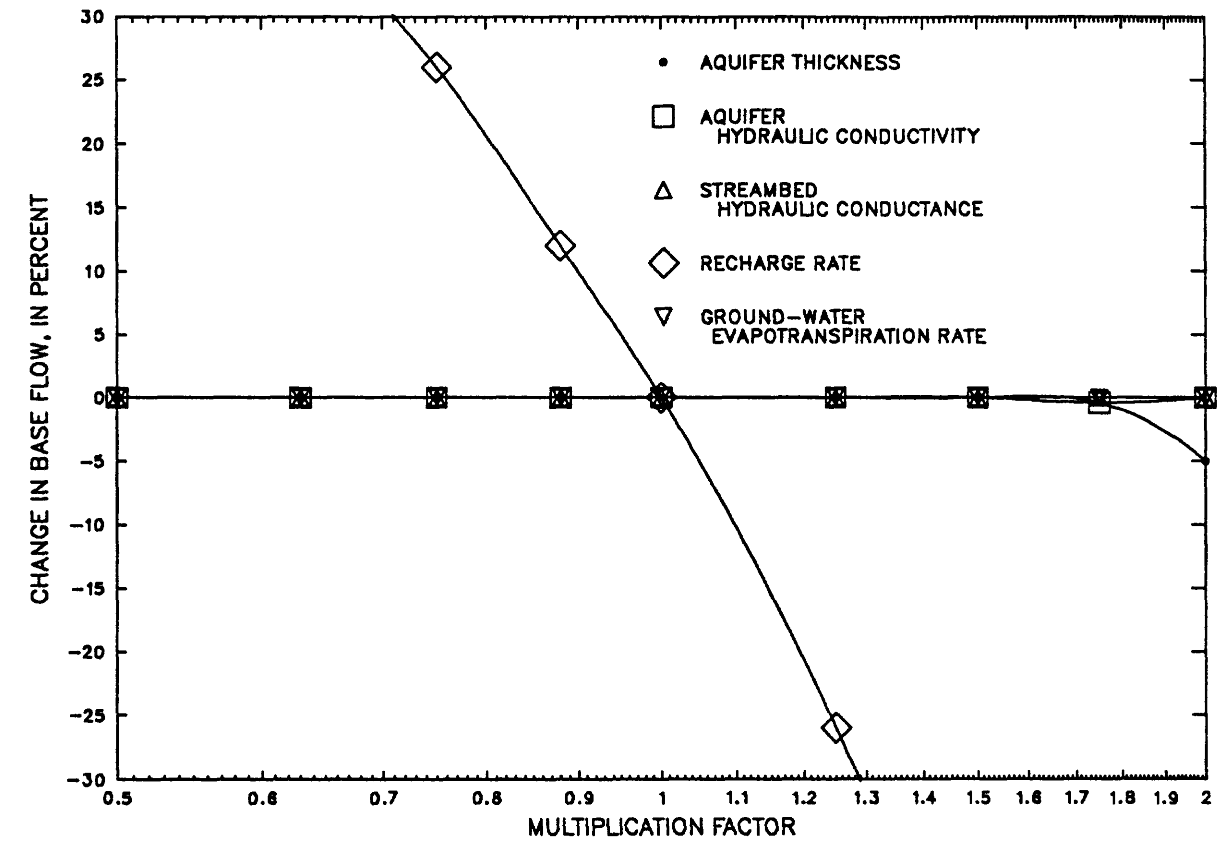

Figure 13.--Effect of varying the value of input variables on total base flow.

The model was less sensitive to aquifer hydraulic conductivity and aquifer thickness. When aquifer hydraulic conductivity was varied from one-half to double the calibrated values, the RMSE ranged from 19.89 to 38.62 ft. Simulated base flow was insensitive to changes in aquifer hydraulic conductivity; it ranged from no change in base flow to 0.4 percent more than the calibrated base flow at the mouth of Red Clay Creek. When aquifer thickness was varied from 300 to 1,200 ft, the RMSE ranged from 19.99 to 38.79 ft. Simulated base flow was insensitive to changes in aquifer thickness; it ranged from no change in base flow to 5 percent more than the calibrated base flow at the mouth of Red Clay Creek.

The model was least sensitive to streambed hydraulic conductance and maximum GW ET rate. When the streambed hydraulic conductance was varied from one-half to double the calibrated values, the RMSE ranged from 19.62 to 23.70 ft. Simulated base flow did not change at the mouth of Red Clay Creek. Sensitivity analyses made during model calibration indicated that base flow for some tributaries was sensitive to changes in streambed hydraulic conductance; however, these changes in base flow are small compared to the base flow at the mouth of Red Clay Creek and, therefore, are not seen in the final sensitivity analysis. When the maximum GW ET rate was varied from one-half to double the calibrated value (0.32 to 1.2 in/yr), the RMSE ranged from 20.45 to 20.57 ft. Simulated base flow did not change at the mouth of Red Clay Creek.

Effects of Increased Ground-Water Development

Prior to simulating the potential effects of several hypothetical ground-water-development plans, the calibrated steady-state model was modified to approximate long-term average conditions in the basin. A long-term average recharge rate of 3.22×10^{-3} ft/d (14.12 in/yr) was used. The recharge rate was calculated by adding the long-term average base flow, estimated GW ET, and annual average pumpage removed from the basin. A long-term median base flow of 11.92 in/yr was determined by hydrograph separation for the period of record (1944-90) at the Wooddale, Del., streamflow-measurement station. GW ET was estimated to be 2 in/yr. Annual average pumping rates were determined from 1988-90 pumpage data for ground-water users that withdrew an average of 0.03 Mgal/d or more and discharged wastewater to a stream or a spray-irrigation system (table 20). Annual average pumpage returns as wastewater discharge to streams and surface-water diversions were determined from 1988-90 discharge data (table 21). The initial recharge rate and maximum GW ET rate were then adjusted until the simulated base flow

Table 20.--Ground-water pumpage and pumpage return rates used for long-term average simulation of ground-water flow in the Red Clay Creek Basin, Pennsylvania and Delaware

[Negative sign indicates recharge to the ground-water system; Mgal/d, million gallons per day; CCHD, Chester County Health Department; PaDER, Pennsylvania Department of Environmental Resources; DNREC, Delaware Department of Natural Resources and Environmental Control]

Model node				
Row	Column	Pumpage rate (Mgal/d)	Well owner and well number	Source of data
13	6	0.03	University of Pennsylvania, New Bolton Center, CH-2062 and CH-2063	CCHD
15	21	.256	Borough of Kennett Square Water System, CH-45	CCHD
16	24	.045	Longwood Gardens, CH-57	CCHD
16	26	.045	Longwood Gardens, CH-2125	CCHD
17	25	-.017	Longwood Gardens, spray irrigation system simulated as a recharge well	PaDER [1]
24	13	.093	Seneca-Kennett Foods, CH-2012, CH-2013, and CH-2400	CCHD
25	14	.243	National Vulcanized Fiber Company, CH-31 and CH-43	PaDER [2]
25	17	.166	Mushroom Co-op Canning, CH-3210, CH-3211, and CH-3212	PaDER [2]
58	26	.058	Hercules, Inc., composite of 3 wells	DNREC
59	27	.175	Hercules, Inc., composite of 8 wells	DNREC

[1] After 1990, approximately 95 percent of Longwood Garden's wastewater will be disposed through the spray-irrigation system (Jim Cogill, Longwood Gardens, oral commun., 1991). An estimated 50 percent of the wastewater disposed through the spray-irrigation system reaches the aquifer.

[2] Data for 1989 and 1990 were not available; pumpage rates were estimated from 1988 data.

Table 21.--Sewage treatment plant, industrial, and commercial discharges to and withdrawals from Red Clay Creek used for long-term average simulation of ground-water flow in the Red Clay Creek Basin, Pennsylvania and Delaware

[Negative sign indicates recharge to the ground-water system; Mgal/d, million gallons per day; PaDER, Pennsylvania Department of Environmental Resources; NVF, National Vulcanized Fiber Company]

Model node				
Row	Column	Discharge rate (Mgal/d)	Discharger or withdrawer and stream	Source of data
14	5	0.026	University of Pennsylvania, New Bolton Center, South Brook	PaDER
19	26	.002	Longwood Gardens, Longwood tributary	PaDER [1]
21	24	.031	East Marlborough Township Sewage Treatment Plant, Longwood tributary	PaDER
24	13	.031	Seneca-Kennett Foods, West Branch Red Clay Creek	PaDER
26	14	.314	NVF, unnamed tributury to West Branch Red Clay Creek	PaDER [2]
26	18	.074	Mushroom Co-op Canning, East Branch Red Clay Creek	PaDER
27	12	.84	Borough of Kennett Square Sewage Treatment Plant, West Branch Red Clay Creek	PaDER
39	19	[3] -.71	NVF, Red Clay Creek	NVF

[1] After 1990, approximately 95 percent of Longwood Garden's wastewater will be disposed through the spray-irrigation system and 5 percent will be discharged to the Longwood tributary (Jim Cogill, Longwood Gardens, oral commun., 1991).

[2] Data for 1988 and 1990 were not available; discharge rates were estimated from 1989 data.

[3] Amount of withdrawal not returned to the Red Clay Creek.

and GW ET closely matched the values specified above. The long-term average steady-state model simulated a base flow of 11.98 in. at Wooddale, Del., and a GW ET of 2.17 in. The final maximum GW ET rate used was 1.37×10^{-3} ft/d (6.0 in/yr).

A set of heads and base flows that represent long-term average conditions in the basin were simulated in the steady-state model. The heads from the long-term average steady-state model were used as initial heads for the hypothetical ground-water-development simulations. The heads and base flows from the long-term average steady-state model were used as a base line against which simulated heads and base flows from the hypothetical ground-water-development simulations were compared.

The long-term average steady-state model is subject to the same assumptions and generalizations discussed in earlier sections of this report. The hydrologic system in the basin is always undergoing a transient response to many complex processes. Long-term average conditions in the basin are approximated by the steady-state model. Thus, the response of the long-term average steady-state model to any imposed stresses will be similar to, but not necessarily the same as, the basin response. The effect of the simulated stress may be imposed on any set of basin conditions by superposition. The simulated water-level and base-flow changes in response to the imposed stresses are general indicators of the relative distribution and magnitude of the effects that would result from these stresses and can be used to evaluate the effect of ground-water development in the basin. Because a steady-state model is used, the simulated water-level and base-flow changes are the maximum long-term changes expected for any simulated stress.

Hypothetical Ground-Water Development

Different combinations of ground-water supply and wastewater disposal were simulated in order to assess potential effects on the stream-aquifer system. The hypothetical ground-water-development plans represent a range of potential alternatives; it is unlikely that development in the Red Clay Creek Basin will follow the hypothetical development plans exactly. However, a range of likely development plans was simulated so that the magnitude of possible effects could be compared. The simulations address only the effects of water supply and wastewater disposal on the quantity of water available from the stream-aquifer system. Issues of water quality that may arise from wastewater disposal and the proximity of disposal sites to water supply wells are not addressed.

Five areas (fig. 14) ranging from 0.93 to 1.83 mi^2 were chosen for simulation of the effects of development. The total area for simulation of development is 7.42 mi^2. The areas were chosen because little development is currently present, and the areas represent different subbasins and geology.

The hypothetical development plans chosen for simulation are listed in table 22. Hypothetical development plans simulated the effect of different combinations of lot size (1 acre and 1/2 acre), ground-water supply (individual on-lot wells or a total of 30 public-supply wells), and wastewater disposal (individual on-lot septic systems, removal from the basin by public sewers, discharge to in-basin streams by public sewers, or spray-irrigation systems). The locations of the public-supply wells were selected to coincide with model cells having relatively high hydraulic conductivity. Well locations are the same for all simulations utilizing public-water-supply wells. In simulations with public-sewer systems, it is assumed that there is no leakage from or into the sewer system. Model cells for land disposal of wastewater by spray-irrigation systems were selected to coincide with model cells having relatively high hydraulic conductivity.

Water use in the development areas was determined on the basis of an average of 3 persons per household (Martin Wollaston, Water Resources Agency for New Castle County, oral commun., 1992) and an average water-use rate of 75 gallons per person per day (Mark Shumar, Chester County Planning Commission, oral commun., 1992). For development plans 1a-1e, each area was divided into 1-acre lots with a total population of 14,283 and a water use of 1.07 Mgal/d. For development plan 2, the population and water use was the same as for development plans 1a-1e; however, half of the development area was divided into 1/2-acre lots and half of the area was open space used for public-supply wells or for the disposal of wastewater by spray-irrigation systems. In development plan 3, the entire development area was divided into 1/2-acre lots; thus, the total population was doubled to 28,566, and water use was doubled to 2.14 Mgal/d.

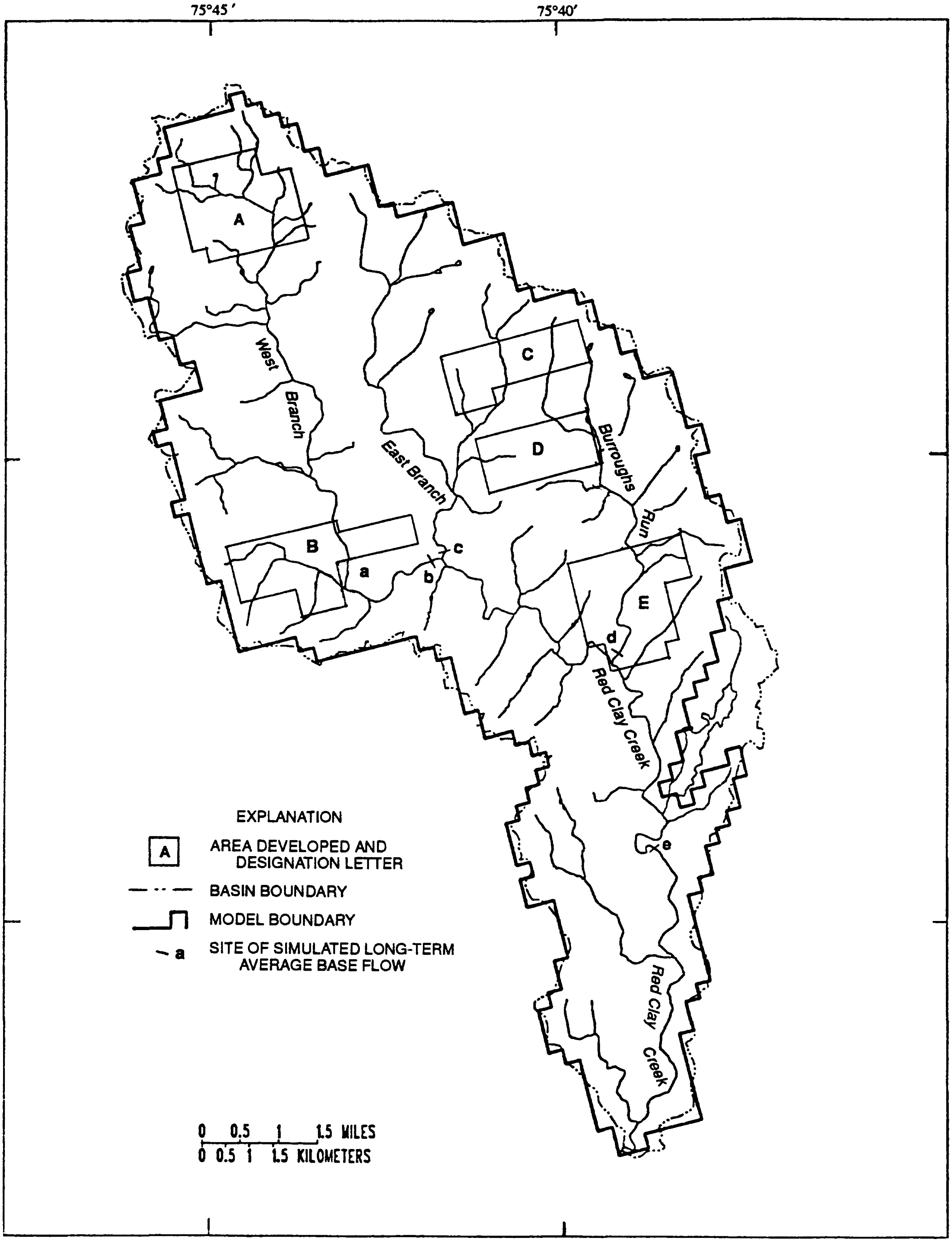

Figure 14.--Five areas of hypothetical ground-water development in the Red Clay Creek Basin.

Table 22.--Hypothetical ground-water development plans used in the simulation of ground-water flow in the Red Clay Creek Basin, Pennsylvania and Delaware

		Water supply		Waste-water disposal				Percentage of pumpage returned to basin		
					Treated sewer discharge					
Plan	Lot size	On-lot wells	Public-supply wells	On-lot septic system	Out of basin	To basin streams	Spray irrigation	90	40	0
1a	1 acre	X		X				X		
1b	1 acre	X			X					X
1c	1 acre		X	X				X		
1d	1 acre		X		X					X
1e	1 acre		X			X		X		
2	1/2 acre		X				X		X	
3	1/2 acre		X		X					X

For the ground-water-development plans, consumptive loss is assumed to be 10 percent (Loper and others, 1989, p. 10) of the pumpage. Sewering the development results in 100 percent of the pumpage being removed from the aquifer. For the development plans that use spray irrigation, 10 percent of the pumpage is considered consumptive loss and 50 percent of the pumpage is returned to the aquifer by artificial recharge.

Pumping rates for the five areas of development are listed in table 23. In development plan 1a, 90 percent of the pumpage is returned to the ground-water system through on-lot septic systems, and 10 percent of the pumpage is lost to consumptive use. Thus, the pumpage and return of wastewater to the aquifer was simulated by setting the pumping rate equal to the consumptive loss rate (10 percent of pumpage) for each model node. The pumping rate for plan 1b was set equal to the water-use rate for each model cell in the development areas. Pumping rates for development plans 1c, 1d, 1e, 2, and 3 were calculated by dividing the water use of the development area by the number of public-supply wells in that area. The number of public-supply wells in each development area ranged from 4 to 8 wells.

Table 23.--Water use and pumping rates for each development area and hypothetical ground-water development plan
[mi^2, square miles; Mgal/d, million gallons per day]

				Pumping rate					Pumping rate
				Plan 1a	Plan 1b	Plans 1c, 1d, 1e, and 2		Water use	Plan 3
Development area	Area (mi^2)	Population	Water use (Mgal/d)	(Mgal/d per node)		(Mgal/d per well)	Population	(Mgal/d)	(Mgal/d per well)
A	1.83	3,519	0.264	0.0005	0.005	0.038	7,038	0.528	0.075
B	1.68	3,243	.243	.0005	.005	.035	6,486	.486	.069
C	.93	1,794	.135	.0005	.005	.034	3,588	.269	.067
D	1.15	2,208	.166	.0005	.005	.041	4,416	.331	.083
E	1.83	3,519	.264	.0005	.005	.033	7,038	.528	.066

Hydrologic Effects of Hypothetical Ground-Water Development

Development plans 1a-1e simulated different combinations of ground-water supply and wastewater disposal for 1-acre lots (table 23). Development plans 1a and 1b examine the effect of on-site wells and different methods of wastewater disposal. In plan 1a, 90 percent of the pumpage is returned to the aquifer by on-lot septic systems. Water-level declines (fig. 15) are less than 1 ft and commonly are confined to the development area. In development areas B and C, water-level declines extend to the model boundary. In the basin, pumping wells near a ground-water divide can cause the ground-water divide to shift so that ground water from outside the basin flows toward the pumped well. In the model, the ground-water divide is simulated as a no-flow boundary that prevents ground-water flow from one basin to another. The effect of the pumping well near a no-flow boundary in the model is to cause a slightly greater decline in water levels near the boundary and a slightly greater reduction in base flow than would result in the basin. However, the water-level decline at the basin boundary for development area B is less than 1 ft. In plan 1b, 100 percent of the pumpage is removed from the basin by public sewers.

Installation of public sewer lines in the development area results in an increase in the area and magnitude of water-level declines (fig. 16). Water levels decline 10 ft or more in some areas. Reductions in long-term average base flow (table 24) are inversely proportional to the amount of pumpage returned to the stream-aquifer system. Pumpage returns of 90 and 0 percent produce base-flow reductions of the Red Clay Creek at Wooddale, Del., of less than 1 percent and 3 percent, respectively. Base-flow reductions in smaller subbasins (table 24) are greater than in larger subbasins because the pumpage not returned to the aquifer represents a larger part of the natural base flow. GW ET (table 24) was reduced by less than 1 percent and 4 percent for development plans 1a and 1b, respectively.

Development plans 1c-1e examine the effect of different wastewater-disposal methods for developments that obtain water from public-supply wells. Wastewater disposal by septic systems is simulated in plan 1c. Areas near the public-supply wells show water-level declines (fig. 17), whereas areas not near the pumped wells show a water-level rise because of recharge to the aquifer from on-lot septic systems. Water-level rises of 10 ft are in model cells with low hydraulic conductivity (model cells with a hilltop topographic setting and hydraulic-conductivity multiplier of 0.3) that do not permit rapid ground-water flow from a recharge well. In the basin, hydraulic conductivity would vary over the model-cell area and water-level rises probably would be less than water-level rises simulated by the model. In plan 1d, wastewater is removed from the basin by public sewers, and the magnitude of water-level decline (fig. 18) increases and extends to areas outside the development area. However, the extent of the water-level decline is less than that of plan 1b (on-lot wells and public sewers) because the public supply wells are located in model cells with high hydraulic conductivity. In plan 1e, treated wastewater is discharged to in-basin streams. Water-level declines (fig. 19) are similar to plan 1d except for a slight water-level rise in areas where the wastewater-discharge point is located at the headwaters of a small tributary stream. Long-term average base-flow reductions of Red Clay Creek at Wooddale (table 24) are greater for plan 1d than plans 1c or 1e because 100 percent of the pumpage is removed from the basin. Long-term average base-flow reductions (table 24) in each subbasin depends on the location of the public-supply wells and wastewater disposal. If a development area straddles more than one subbasin, water pumped from one subbasin and discharged to a different subbasin results in a reduction in base flow in the subbasin where water is pumped and an increase in flow in the subbasin where water is discharged. GW ET increases for plan 1c in response to the rise in water levels.

Development plan 2 has the same population and water use as plans 1a-1e; however, lot size is reduced to 1/2 acre, leaving one-half of the development area as open space used for public-supply wells and land disposal of treated wastewater by spray-irrigation systems. As in plan 1c, areas surrounding the public-supply wells show water-level declines, and areas surrounding wastewater disposal areas show a water-level rise (fig. 20). In plan 2, the area of water-level decline is more extensive than in plan 1c because recharge to the aquifer by wastewater disposal is concentrated in a small area of the development rather than throughout the development area as in plan 1c. Reductions in long-term average base flow (table 24) for plan 2 are greater than for plan 1c because only 40 percent of the pumpage is returned to the basin rather than 90 percent as in plan 1c.

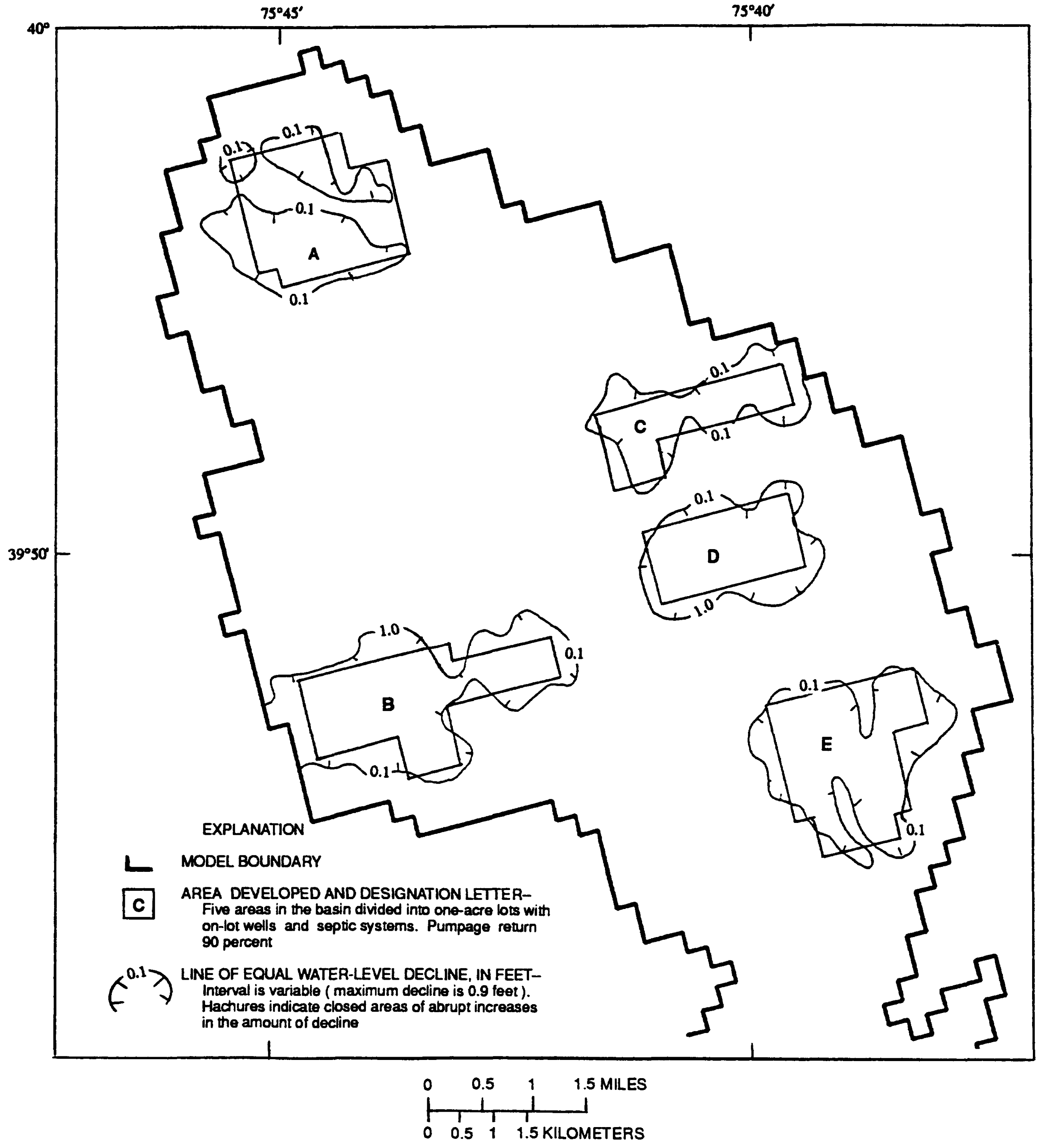

Figure 15.--Simulated change in water levels for hypothetical development plan 1a.

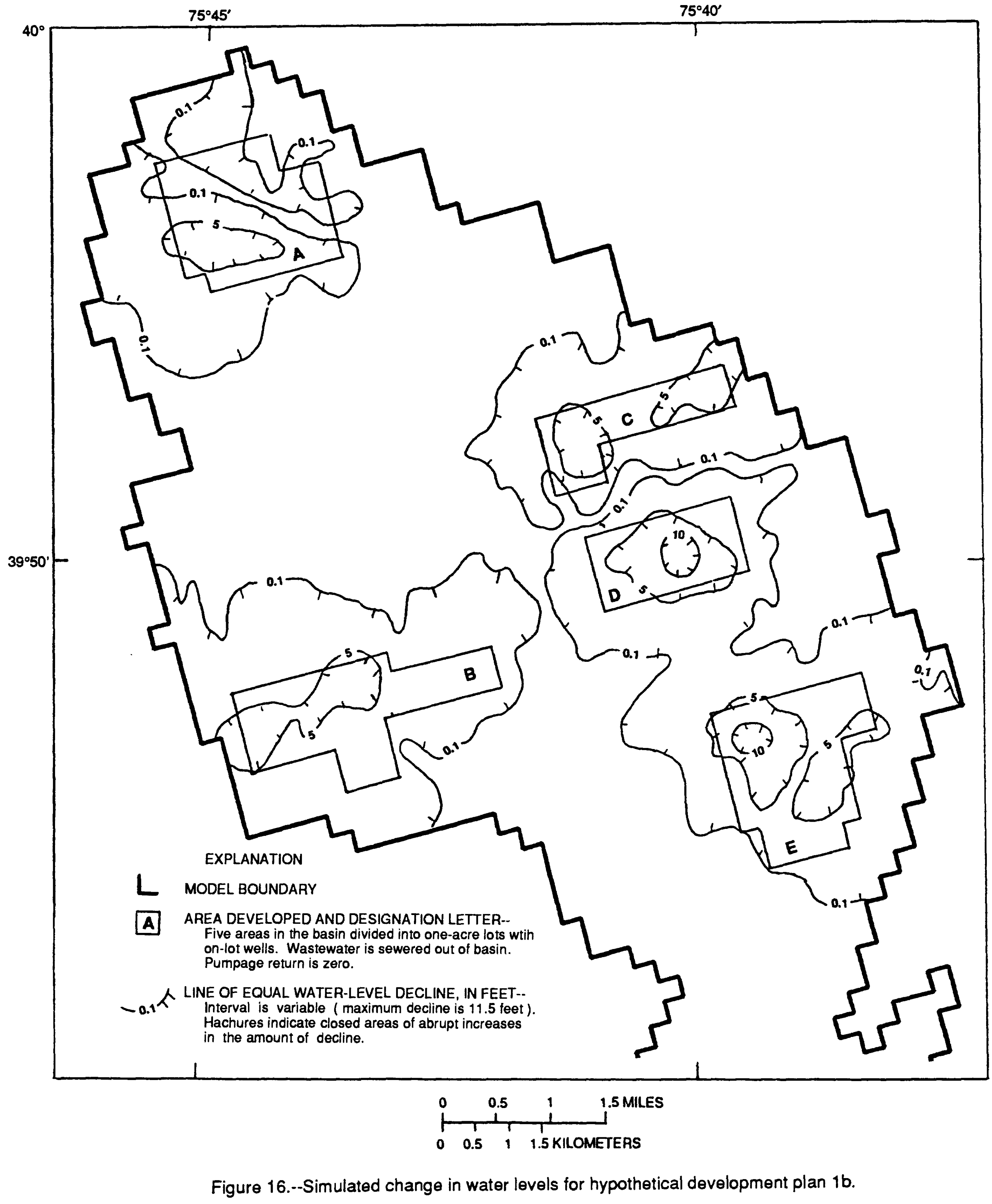

Figure 16.--Simulated change in water levels for hypothetical development plan 1b.

Table 24.--Simulated long-term average base flows and ground-water evapotranspiration for hypothetical development plans in the Red Clay Creek Basin, Pennsylvania and Delaware

[Simulated long-term average base flow sites shown on figure 14; ft^3/s, cubic feet per second; GW ET, ground-water evapotranspiration; in., inches]

	Base flow (ft^3/s) (Percent difference prior to simulated development in parentheses)					GW ET (in.)
Hypothetical development plan	Site a Bucktoe Creek	Site b West Branch Red Clay Creek	Site c East Branch Red Clay Creek	Site d Burroughs Run	Site e Red Clay Creek at Wooddale	(Percent difference prior to simulated development in parentheses)
Prior to simulated development	1.84	16.7	7.96	6.28	39.7	2.17
1a	1.83	16.7	7.95	6.26	39.6	2.16
	(-0.5)	(0)	(-0.1)	(-0.3)	(-0.2)	(-0.5)
1b	1.63	16.0	7.78	5.94	38.4	2.08
	(-11)	(-4)	(-2)	(-5)	(-3)	(-4)
1c	1.84	16.6	7.88	6.14	39.4	2.21
	(0)	(-0.6)	(-1)	(-2)	(-0.8)	(+1.8)
1d	1.66	16.0	7.71	5.86	38.2	2.14
	(-10)	(-4)	(-3)	(-7)	(-4)	(-1.4)
1e	1.99	16.7	8.12	6.22	39.7	2.14
	(+8)	(0)	(+2)	(-1)	(0)	(-1.4)
2	1.77	16.2	7.78	5.95	38.8	2.16
	(-4)	(-3)	(-2)	(-5)	(-2)	(-0.5)
3	1.45	15.2	7.45	5.41	36.7	2.11
	(-21)	(-9)	(-6)	(-14)	(-8)	(-2.8)

The method of water supply and wastewater disposal in development plan 3 is the same as in plan 1d. However, the population and water use is doubled. The distribution of water-level declines (fig. 21) is similar to that of plan 1d (fig. 18); however, the magnitude is greater. In development area A, the decline of water levels was sufficient to induce leakage of 0.01 ft^3/s of stream water into the aquifer (induced stream infiltration) at model cell (6, 12). Reductions in long-term average base flow and GW ET are about twice the amount as in plan 1d (table 24).

Simulations of ground-water development show the effects of various combinations of ground-water-supply and wastewater-disposal plans. The development plans show how water levels, GW ET, and the long-term average base flow of streams is affected. The effects of pumping are reductions in long-term average base flow and GW ET and declines in aquifer water levels. The effects of the wastewater-disposal plans are declines in water levels when the wastewater is sewered out of the basin or returned to in-basin streams and a rise in water levels when it is returned to the aquifer by on-lot septic or spray-irrigation systems. Reductions in long-term average base flow are proportional to the amount of pumpage removed from the stream-aquifer system. The development plan that would have the greatest effect on water levels and base flow would be the removal of ground water by public-supply wells and the disposal of waste-water by public sewers to areas outside the basin (plan 1d and 3). The development plan that would have the least effect on water levels and base flow would be on-lot wells and on-lot septic systems (plan 1a).

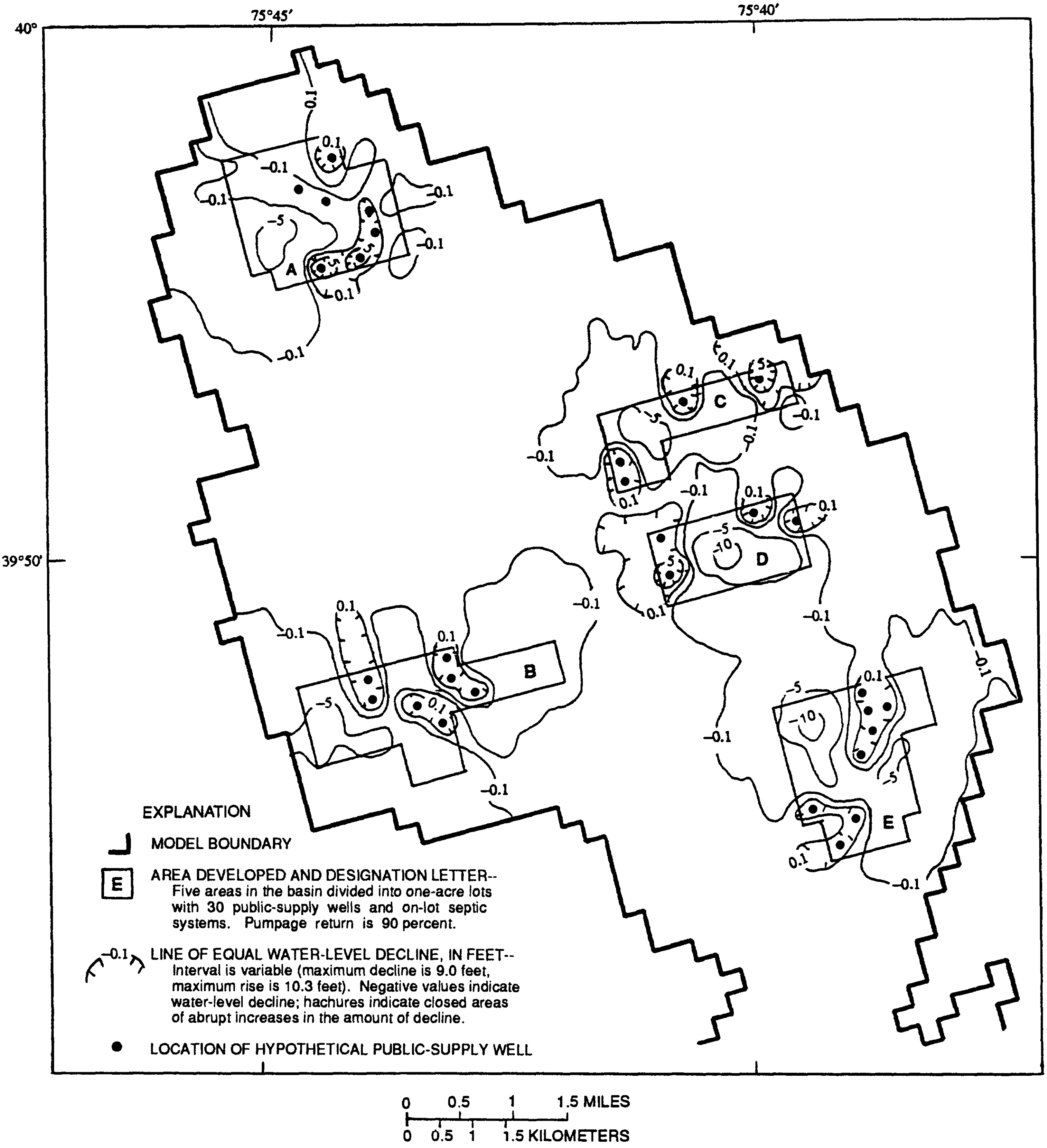

Figure 17.--Simulated change in water levels for hypothetical development plan 1c.

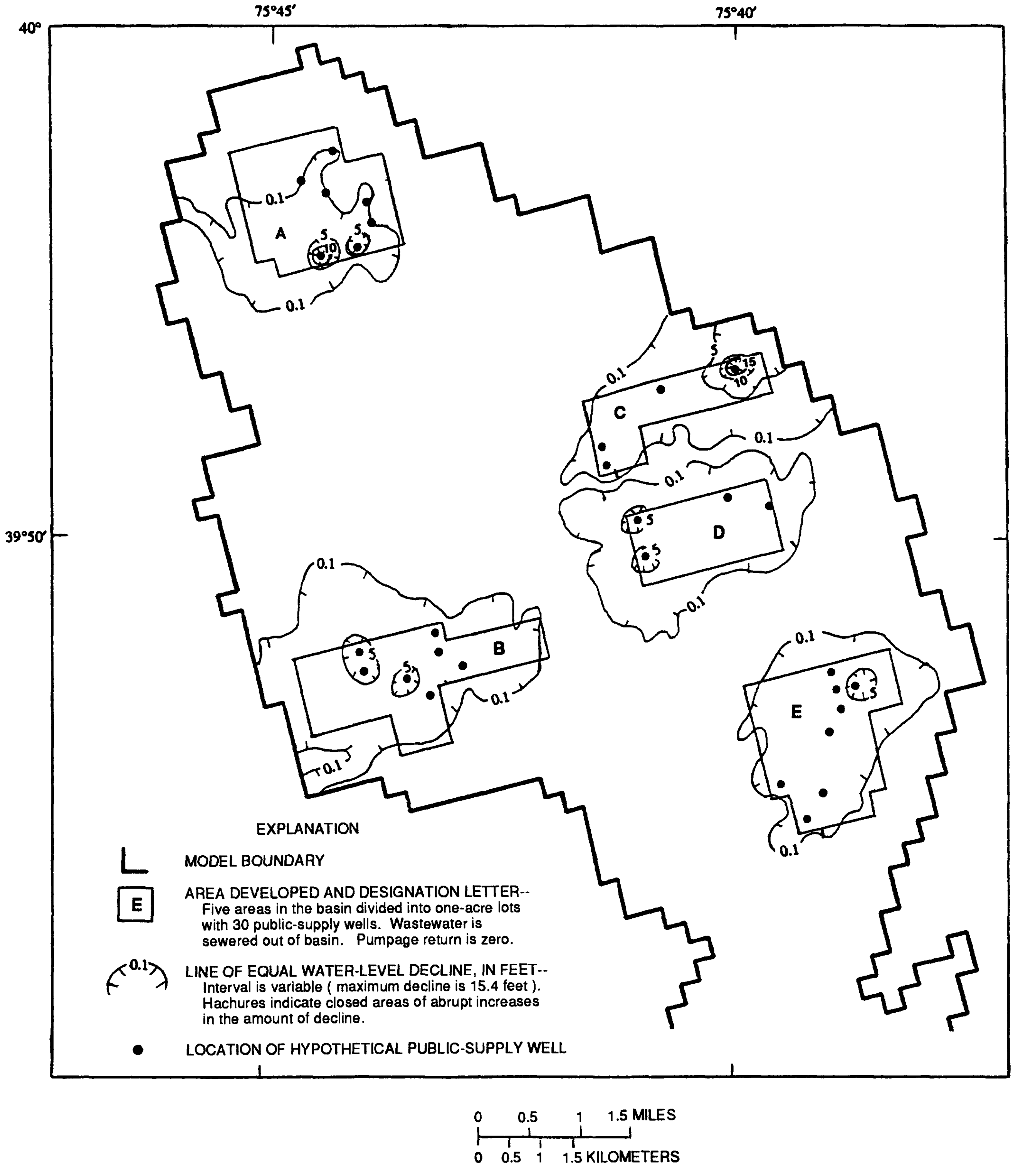

Figure 18.--Simulated change in water levels for hypothetical development plan 1d.

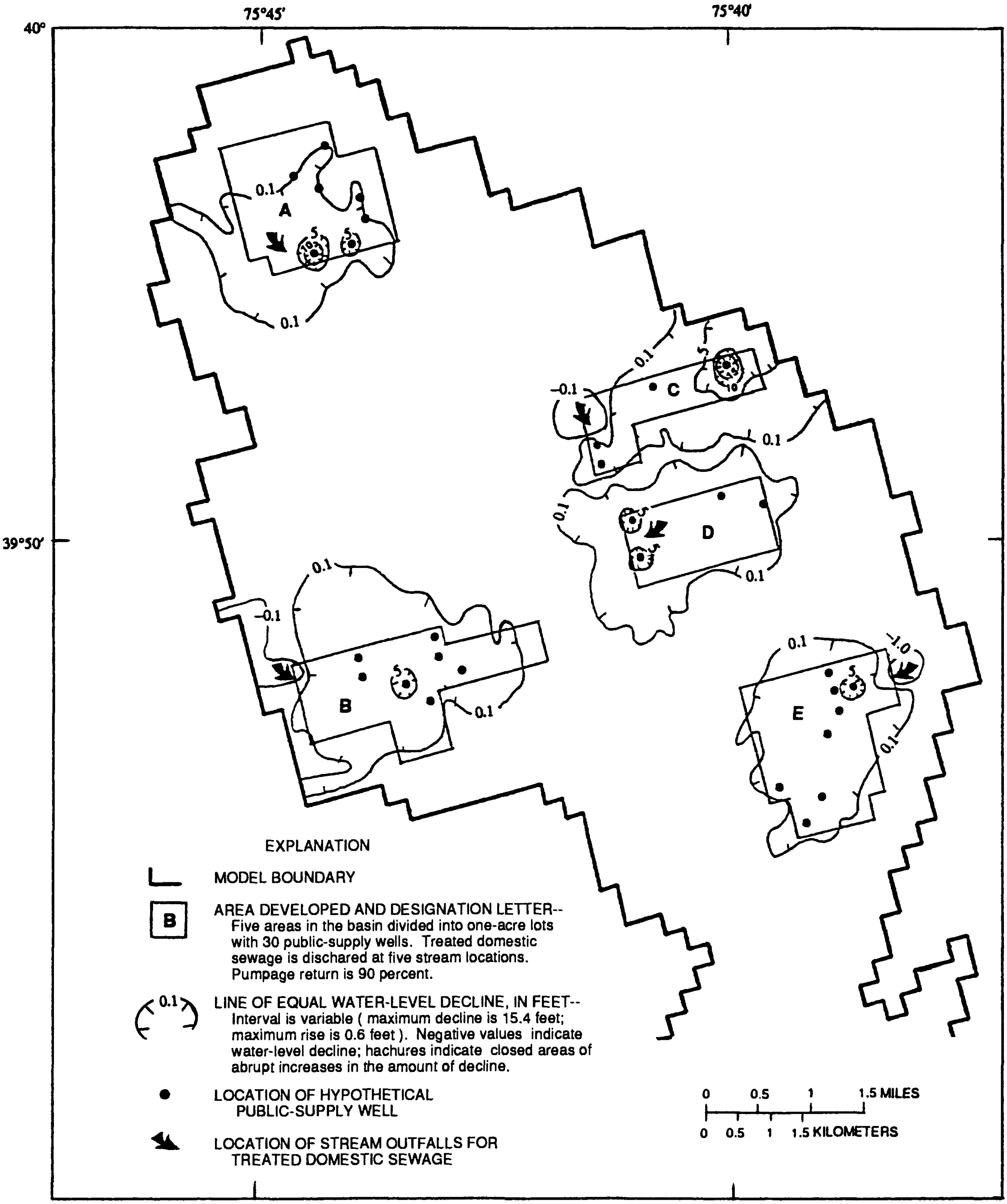

Figure 19.--Simulated change in water levels for hypothetical development plan 1e.

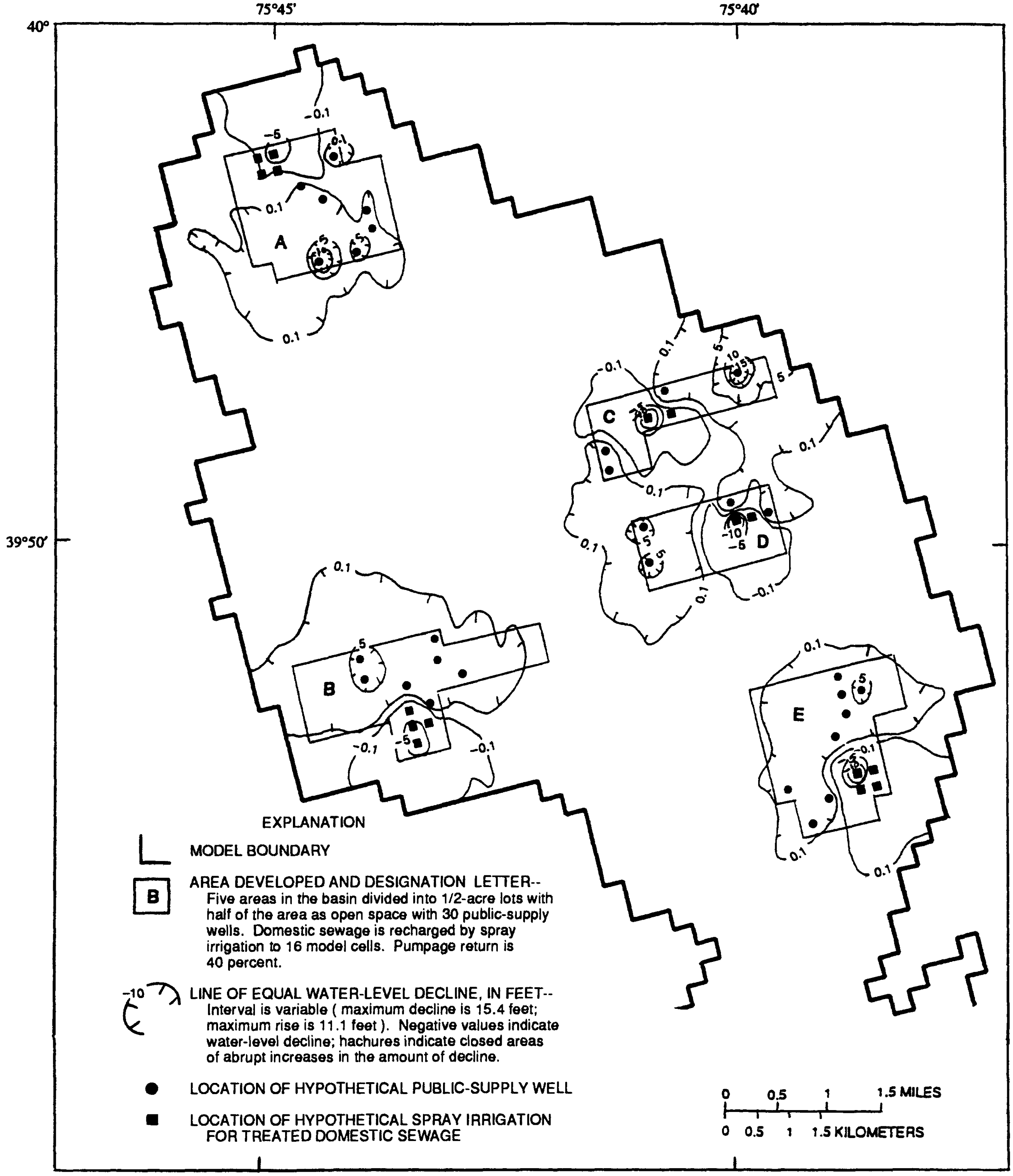

Figure 20.--Simulated change in water levels for hypothetical development plan 2.

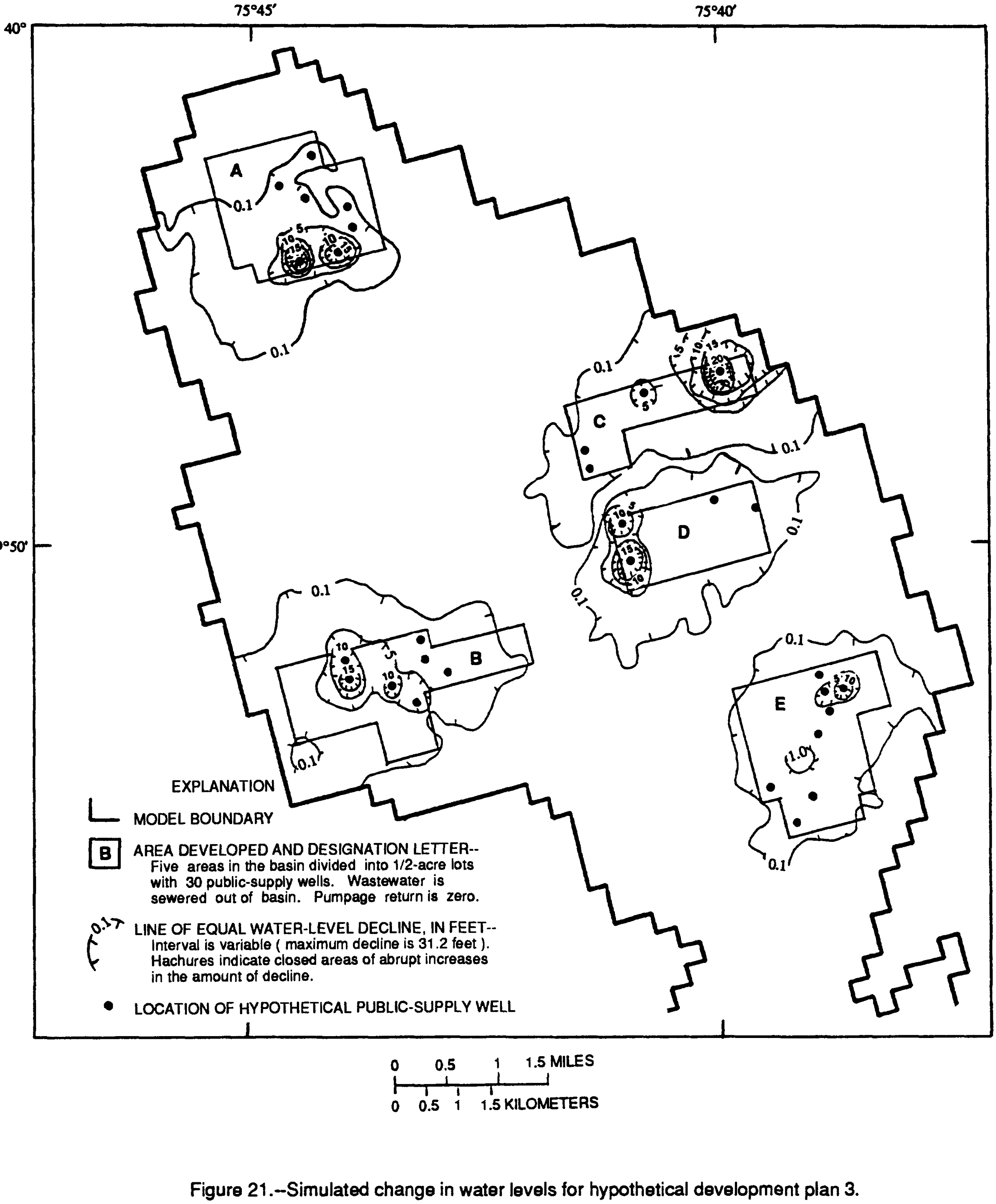

Figure 21.--Simulated change in water levels for hypothetical development plan 3.

SUMMARY

Red Clay Creek drains 54 mi^2 in the lower Delaware River Basin in southeastern Chester County, Pa., and northern New Castle County, Del. The basin is underlain by metamorphic rocks of Precambrian to Lower Paleozoic age. Near the mouth of the Red Clay Creek, these rocks are mantled by unconsolidated sediments of Cretaceous to Holocene age.

Ground water flows through secondary openings in fractured crystalline rock and through primary openings below the water table in the overlying saprolite. Secondary openings in marble may be enlarged by solution. Regionally, fracture density and connection between the fractured bedrock and saprolite is sufficient so that the fractured crystalline bedrock and overlying saprolite act as a single aquifer under unconfined conditions. In the Red Clay Creek Basin, there are numerous local ground-water-flow systems with short flow paths from hilltops to nearby stream valleys. Natural recharge and discharge in the system is predominantly precipitation and ground-water discharge to streams, respectively.

The permeability of the crystalline rocks is determined by the degree to which the fractures, joints, faults, and cleavage planes are interconnected. Thirty-nine percent of water-bearing zones are encountered within 100 ft of the land surface, and 79 percent of water-bearing zones are encountered within 200 ft of the land surface.

Ground-water discharge to streams (base flow) comprises 62 to 71 percent of streamflow and ranged from 10.43 in. in 1988 to 17.08 in. in 1989 for the three continuous-record streamflow-measurement stations in the basin. Water budgets for 1988-90 for the 45-mi^2 effective drainage area above the Wooddale, Del., streamflow-measurement station were calculated. Annual precipitation ranged from 43.59 to 59.14 in. and averaged 49.81 in. Annual streamflow ranged from 15.35 to 26.33 in. and averaged 20.24 in. Annual evapotranspiration ranged from 27.87 to 30.43 in. and averaged 28.98 in.

Five organochlorine insecticides--lindane, DDT, dieldrin, heptachlor, and methoxychlor--were detected in water from 9 of 31 wells (29 percent) sampled. Four organophosphorus insecticides--malathion, parathion, diazinon, and phorate--were detected in water from 6 of 20 wells (30 percent) sampled. Four VOC's--benzene, toluene, tetrachloroethylene, and trichloroethylene--were detected in water from 13 wells sampled. Phenol was detected in water from 50 percent of 14 wells sampled.

The concentration of dissolved nitrate as nitrogen in water from nine wells (18 percent of wells sampled) exceeded the USEPA MCL. Concentrations of nitrate as nitrogen were as great as 19 mg/L. Concentrations of manganese in water from 17 percent of 29 wells sampled and concentrations of iron in water from 6 percent of 32 wells sampled exceeded the USEPA MCL's. Activities of radon-222 ranged from 97 to 4,200 pCi/L; the median was 590 pCi/L.

PCB was detected in the bottom material of West Branch Red Clay Creek at Kennett Square at a maximum concentration of 5,600 μg/kg, and methoxychlor was detected at a concentration of 88 μg/kg. Lindane was detected in the bottom material of East Branch Red Clay Creek near Five Point at a concentration of 0.3 μg/kg.

A two-dimensional digital computer model was developed to simulate ground-water flow in the Red Clay Creek Basin. Sources of water to the aquifer include recharge from precipitation, leakage from streams, and pumpage returns. Discharges of water from the aquifer include ground-water evapotranspiration, ground-water discharge to streams, and pumpage from wells.

The model was calibrated for steady-state conditions on November 2, 1990. Recharge was calculated as base flow plus ground-water evapotranspiration plus pumpage removed from the basin; recharge was 1.9×10^{-3} ft/d (8.32 in/yr). Simulated base flow was within 20 percent of the measured base flow for 67 percent of the base-flow measurement sites and within 30 percent of the measured base flow for 80 percent of the sites. The root mean square error between measured or inferred and simulated head over the entire model area was 20.53 ft. Of the five major input variables, the model is most sensitive to the recharge rate. The model is less sensitive to aquifer hydraulic conductivity and aquifer thickness and least sensitive to streambed hydraulic conductivity and ground-water evapotranspiration rate.

After calibrating the model to steady-state conditions (November 1990) and prior to simulating the effects of different potential ground-water development plans, the model was modified to approximate long-term average conditions in the basin. The long-term steady-state model simulated a base flow of 11.98 in. at the Wooddale, Del., streamflow-measurement station and a ground-water evapotranspiration rate of 2.17 in. The heads and base flows from the long-term steady-state model were compared to simulated heads and base flow from hypothetical ground-water development plans.

Different combinations of ground-water supply and wastewater disposal were simulated to assess the effects on the stream-aquifer system. Five development areas with a total area of 7.42 mi^2 were chosen to simulate increased ground-water development in the basin. Six of the simulations use an increase in population of 14,283 and water use of 1.07 Mgal/d. One simulation doubles the increase in population to 28,566 and water use to 2.14 Mgal/d. The effects of pumping are reductions in long-term average base flow and ground-water evapotranspiration and water-level declines. The effects of the wastewater-disposal plans are declines in water level when the wastewater is removed from the basin through sewers, returned to in-basin streams, or returned to the aquifer through on-lot septic systems. A rise in water level results when wastewater is returned to the aquifer by spray-irrigation systems. Reductions in long-term average base flow are proportional to the amount of water removed from the stream-aquifer system. Reduction of long-term average base flow is greatest for development plans with wastewater removed from the basin through sewers. The development plan with the least effect on water levels and base flow was use of on-lot wells and on-lot septic systems.

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- PAGE 67 FOLLOWS -

Table 25.--Records of selected wells in Pennsylvania

Township or borough: Name refers to borough unless noted as T or Twp for township.

Driller license number: 0110, Brown Bros. Drilling Inc.; 0154, Leroy Myers; 0176, R. Walter Slauch & Sons; 0248, Thomas G. Keyes; 0308, Petersheim Bros.; 0319, Myers Bros.; 0347, Burley L. Mayberry; 0543, Walton Corp.; 0904, Brookover Well Drilling Co.; 0909, Calvin E. Powell; 0938, Constantine DiFilippo, Jr.; 0950, J. Norman Connell; 1083, Kenneth L. Madron; 1240, Mills and Hayworth; 1290, B. L. Myers; 1333, Leonard R. Mayberry; 1457, Bonnie J. Myers; 1583, J. Ernest Brewer; 1609, Edward Powell Well Drilling; 1628, B. L. Myers Bros. Inc.; 1715, Arthur A. Astle.

Use of site: O, observation; U, unused; W, withdrawal.

Use of water: C, commercial; H, domestic; I, irrigation; N, industrial; P, public supply; S, stock; T, institutional; U, unused.

Topographic setting codes: F, flat; H, hilltop; S, hillside; V, valley; W, draw.

Hydrogeologic unit codes: 000MFCGH, mafic gneiss, amphibolite facies; 300CCKV, Cockeysville Marble; 300STRS, Setters Formation; 300WSCKO, Wissahickon Formation; 400FLCGH, felsic gneiss, amphibolite facies.

Elevation of land surface is estimated from topographic maps. Datum is sea level.

Water level is in feet below land surface.

gal/min, gallons per minute; gal/min/ft, gallons per minute per foot of drawdown; μS/cm, microsiemens per centimeter at 25 degrees Celsius

Table 25.--Records of selected wells in Pennsylvania

[--, no data]

USGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Township or borough	Owner	Driller license number	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
CH-21	395254	0754410	E Marlborough T	Walker, J	0154	1954	O	U	400	S	300WSCKO
28	395222	0754232	E Marlborough T	Edgar, Clifton	--	1900	O	U	366	V	300CCKV
30	395046	0754150	Kennett Twp	P B Way & Sons	--	1925	W	I	325	S	300STRS
31	395030	0754258	Kennett Square	National Vulc Fibre	--	1929	W	N	292	V	300CCKV
35	395004	0754459	New Garden Twp	Rayne, Howard	--	1950	W	H	310	V	300CCKV
38	394846	0754449	New Garden Twp	Jones, G	--	1900	O	H	420	H	300WSCKO
41	394901	0754306	Kennett Twp	Harker, Frank	--	--	U	U	280	S	300WSCKO
43	395029	0754259	Kennett Square	NVF Company	--	1956	U	U	290	V	300CCKV
44	395113	0754517	E Marlborough T	U. of Pennsylvania	--	--	U	U	470	H	400FLCGH
45	395215	0754209	E Marlborough T	Boro of Kennett Square	0308	1958	W	P	345	V	300CCKV
46	395159	0754209	E Marlborough T	Abondi, Fred	0154	1949	W	I	368	S	400FLCGH
47	395223	0754029	E Marlborough T	Longwood Gardens	--	1927	W	H	455	S	400FLCGH
48	394952	0754519	New Garden Twp	Vincent Losito & Sons	--	1946	W	N	320	V	300CCKV
52	395219	0754405	Franklin Twp	Welling, T	--	--	W	H	335	V	300STRS
54	395106	0754149	Kennett Twp	Chiabrera, B	--	1934	W	I	395	S	400FLCGH
69	395019	0754315	Kennett Twp	J B Swayne And Son	0154	--	W	N	272	V	300CCKV
71	395011	0754348	New Garden Twp	Cordivano, Bernard	--	--	W	H	275	V	300CCKV
453	395205	0754009	Kennett Twp	Rouse, George	--	--	W	H	455	H	400FLCGH
455	395202	0753914	Kennett Twp	Walker, James	--	--	W	H	460	S	400FLCGH
459	395100	0754200	Kennett Twp	Fahey, Edward	--	--	W	H	370	H	300STRS
468	395028	0754231	Kennett Square	Kennett Square Ice Co.	--	--	W	N	385	V	300CCKV
770	395238	0754138	E Marlborough T	Steele, Wilmer	0176	1932	W	H	390	S	300STRS
848	395359	0754519	E Marlborough T	Hannum, John	0154	1968	W	H	530	H	300WSCKO
1921	394757	0754321	New Garden Twp	Minshall	0176	1970	O	U	405	S	300WSCKO
1943	394844	0754327	New Garden Twp	Barber, Kenneth	0950	1966	W	H	264	V	300WSCKO
1950	395033	0754529	New Garden Twp	Modern Mushroom Farm	0248	1969	W	I	410	V	300STRS
1951	395031	0754539	New Garden Twp	Modern Mushroom Farm	0176	1970	W	C	458	S	400FLCGH
1966	394950	0754309	Kennett Twp	Baccino, Albert	0110	1972	W	H	290	S	000MFCGH
1995	394833	0755541	L Oxford Twp	Lincoln University	--	1955	W	T	518	S	300WSCKO
2015	395010	0754320	Kennett Twp	Deandrea, Atlio	0950	1966	W	H	283	S	300CCKV
2021	394933	0754038	Kennett Twp	Shade, E	0176	1970	W	H	315	S	300WSCKO
2022	395108	0754010	Kennett Twp	Chew, Alfred	0248	1968	W	H	394	H	400FLCGH
2031	395152	0754037	E Marlborough T	Longwood Dairy Queen	0248	1971	W	C	420	S	400FLCGH
2034	395324	0754255	E Marlborough T	Syms, William	0248	1970	W	H	445	S	300WSCKO
2061	395203	0754514	E Marlborough T	U. of Pennsylvania	0176	1962	U	U	410	S	300STRS
2062	395202	0754514	E Marlborough T	U. of Pennsylvania	0176	1963	W	T	410	S	300STRS
2066	395120	0754533	E Marlborough T	U. of Pennsylvania	0248	1967	W	H	490	H	400FLCGH
2067	395132	0754520	E Marlborough T	U. of Pennsylvania	0248	1967	W	H	397	S	400FLCGH
2070	395121	0754527	E Marlborough T	U. of Pennsylvania	0248	1970	W	H	486	H	400FLCGH
2120	395204	0754050	E Marlborough T	Longwood Gardens	--	--	W	C	395	V	400FLCGH
2122	395231	0754028	E Marlborough T	Longwood Gardens	--	--	W	C	410	V	400FLCGH
2124	395157	0753944	Kennett Twp	Longwood Gardens	--	--	W	H	440	H	400FLCGH
2125	395227	0754101	E Marlborough T	Longwood Gardens	--	--	W	C	395	V	300CCKV
2342	395213	0754119	E Marlborough T	Longwood Gardens	0248	1974	W	H	450	S	400FLCGH
2414	395037	0754332	Kennett Twp	Sam's Inn	--	--	W	C	380	V	300CCKV

Table 25.--Records of selected wells in Pennsylvania--Continued

Depth of well (feet)	Casing		Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level mesured	Reported yield (gal/min)	Measured yield			Field water quality			USGS well number
	Depth (feet)	Diameter (inches)					Specific capacity [(gal/min)/ft]	Dis-charge (gal/min)	Pumping period (hours)	Date measured	Specific conduc-tance (µS/cm)	pH (stan-dard units)	
135	27	6	--	24.20	11-22-55	--	--	--	--	--	--	--	CH- 21
25	--	--	--	20.50	09-20-88	--	--	--	--	--	--	--	28
86	66	6	--	--	--	--	--	--	--	--	--	--	30
90	80	8	--	--	--	150	--	--	--	--	--	--	31
60	--	--	--	--	--	40	--	--	24.0	--	--	--	35
18	--	--	--	9.70	09-20-88	--	--	--	--	--	--	--	38
32	--	42	--	17.39	03-07-56	--	--	--	--	--	--	--	41
118	118	10	--	20.00	07-01-56	--	7.41	200	.3	--	--	--	43
33	--	--	--	26.00	02-25-58	--	--	--	--	--	--	--	44
262	229	8	67/127/200	--	05-01-59	542	--	--	25.0	02-25-58	310.00	8.30	45
120	60	8	--	10.00	04-15-58	40	--	--	--	--	--	--	46
100	--	--	--	--	--	30	--	--	--	--	--	--	47
110	60	8	--	18.00	09-25-57	--	--	--	--	--	--	--	48
26	26	6	--	5.00	05-25-59	50	--	--	--	--	--	--	52
80	--	--	--	--	--	--	--	--	--	--	--	--	54
50	35	8	--	15.00	03-01-57	--	24.17	145	10.0	--	--	--	69
50	50	6	--	8.67	03-15-57	--	--	--	--	--	--	--	71
36	--	--	--	3.00	01-01-25	15	--	--	--	--	--	--	453
60	--	--	--	20.00	01-01-25	15	--	--	--	--	--	--	455
84	--	--	--	56.00	12-31-34	12	--	--	--	--	--	--	459
69	--	--	--	--	--	60	--	--	--	--	--	--	468
94	60	6	--	3.00	01-01-32	--	--	--	--	06-15-64	125	6.8	770
80	43	6	--	40.00	09-01-68	7	--	--	--	--	--	--	848
65	24	6	40/ 55/ 65	41.00	08-08-74	--	4.00	20	2.0	--	--	--	1921
238	35	6	41/160/223	--	--	6	--	--	--	08-19-74	120.00	7.90	1943
343	298	8	--	--	--	50	--	--	--	08-21-74	175	--	1950
124	58	6	110/124	20.00	12-03-70	--	.14	12	2.0	--	--	--	1951
187	72	6	144/180	36.08	09-03-74	--	.86	12	1.0	09-03-74	180.00	7.10	1966
450	96	8	--	13.00	02-01-55	41	--	--	--	--	--	--	1995
197	49	6	150	19.00	09-24-74	20	--	--	--	09-24-74	260.00	6.90	2015
97	61	6	85/ 97	5.00	09-17-70	--	2.00	30	2.0	--	--	--	2021
162	54	5	149	32.00	09-25-74	15	--	--	--	09-25-74	220.00	6.60	2022
87	50	6	58/ 70	18.00	07-14-71	--	.22	15	1.0	--	--	--	2031
120	56	6	--	30.00	08-19-70	--	.23	20	1.0	--	--	--	2034
214	129	6	--	44.00	10-03-74	5	--	--	--	--	--	--	2061
148	130	6	--	46.00	10-03-74	100	--	--	--	--	--	--	2062
182	43	6	88	80.00	05-10-67	--	.02	2	1.0	--	--	--	2066
175	70	6	151/157	65.00	10-03-74	30	--	--	--	10-03-74	420	6.9	2067
225	61	6	25/ 60/121	16.00	03-12-70	--	.02	4	1.0	--	--	--	2070
95	21	10	--	12.20	12-09-74	50	--	--	--	--	--	--	2120
202	39	8	--	16.00	12-09-74	30	--	--	--	--	--	--	2122
45	--	--	--	5.00	12-09-74	40	--	--	--	--	--	--	2124
200	55	10	--	13.00	06-01-67	--	2.14	300	50.0	--	--	--	2125
152	51	6	60/141/152	55.00	05-06-74	--	1.04	100	--	--	--	--	2342
--	--	--	--	--	--	--	--	--	--	08-26-80	560.00	7.50	2414

Table 25.--Records of selected wells in Pennsylvania--Continued

USGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Township or borough	Owner	Driller license number	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
CH-2515	395035	0754120	Kennett Twp	Burdett, R.	1083	1981	W	H	320	S	000MFCGH
2586	395040	0754037	Kennett Twp	Kennett Twp	0154	1976	W	H	280	S	300CCKV
2591	395011	0754445	New Garden Twp	Manfredi, J	1083	1981	W	H	315	S	300CCKV
2598	395018	0754141	Kennett Twp	Unruh, H	--	1933	U	U	280	S	000MFCGH
2600	394935	0754325	Kennett Twp	Wilson, W	--	1918	W	H	311	S	300WSCKO
2784	395124	0754617	W Marlborough T	Malnoto, M	--	--	W	H	360	S	300CCKV
2790	395112	0754508	E Marlborough T	U. of Pennsylvania	--	--	W	T	465	S	400FLCGH
2791	394938	0754523	New Garden Twp	Frezzo, E	--	1971	U	U	370	S	300WSCKO
3084	394941	0754419	New Garden Twp	Pratola, Fred	0938	1981	W	H	390	S	300WSCKO
3110	395123	0754213	Kennett Twp	Pia, Joseph	--	--	W	H	375	S	400FLCGH
3129	395057	0754007	Kennett Twp	Winslow, Don	--	1969	W	H	400	H	300STRS
3130	394832	0754355	New Garden Twp	Sullivan, Paul	--	1962	W	H	435	H	300WSCKO
3283	394848	0754213	Kennett Twp	Campbell, Shirley	--	1962	U	U	255	S	300WSCKO
3284	395122	0754142	Kennett Twp	Way, Robert	--	--	U	U	405	F	400FLCGH
3285	395158	0754320	E Marlborough T	Schenarts, Tom	--	--	U	U	435	S	400FLCGH
3286	395154	0754520	E Marlborough T	U. of Pennsylvania	0248	1978	U	U	375	S	300STRS
3287	395013	0754459	New Garden Twp	Richards	--	1800	U	U	345	S	300STRS
3288	395021	0754435	New Garden Twp	Johnson	--	--	U	U	315	V	300CCKV
3293	394937	0754424	E Marlborough T	Pratola, Ralph	--	1956	W	I	393	W	000MFCGH
3307	394833	0754404	New Garden Twp	Bertrando, Richard	--	1966	W	H	409	F	300WSCKO
3308	395137	0754047	E Marlborough T	Caruthers, John	--	1955	W	H	360	S	400FLCGH
3310	394947	0754203	Kennett Twp	Dampman, Richard	--	--	W	H	355	S	300WSCKO
3312	394944	0754224	Kennett Twp	Phillips Mushroom	0308	1985	W	I	350	W	300WSCKO
3313	395018	0754153	Kennett Twp	Yaun, Jane	--	--	W	H	255	W	000MFCGH
3314	394918	0754513	New Garden Twp	Kiernan, John B	--	--	W	H	420	F	300WSCKO
3318	395000	0754228	Kennett Twp	Hahn, Bernard	--	--	W	H	360	F	000MFCGH
3321	395104	0753904	E Marlborough T	Kelly, Frank	--	--	W	H	335	W	400FLCGH
3323	394856	0754504	New Garden Twp	Rominger, Barbara	0319	1987	W	H	400	F	300WSCKO
3356	395313	0754517	E Marlborough T	Jordan, Judith	1628	1985	W	H	440	F	300WSCKO
3366	395254	0754321	E Marlborough T	Zachary, Scott	0909	1986	W	H	419	F	300WSCKO
3367	395339	0754346	E Marlborough T	Willhite	0248	1976	W	H	480	H	300WSCKO
3368	395328	0754353	E Marlborough T	Shepherd, Francis	--	--	W	H	425	F	300WSCKO
3369	395340	0754408	E Marlborough T	Reese, Sarah	0909	1981	W	H	435	F	300WSCKO
3370	395308	0754346	E Marlborough T	Francis, John	1083	1984	W	H	415	S	300WSCKO
3371	395124	0754344	E Marlborough T	Brewer, M	0176	1984	W	H	335	S	400FLCGH
3372	395113	0754340	E Marlborough T	Tate	0110	1985	W	H	311	F	400FLCGH
3373	395128	0754246	E Marlborough T	Ticknor, Gary	1628	1986	W	H	378	S	400FLCGH
3374	395259	0754348	E Marlborough T	Joyner, James	1083	1986	W	H	389	V	300WSCKO
3375	395120	0754338	E Marlborough T	Drinker, Don	0248	1985	W	H	395	H	400FGLCGH
3376	395147	0754328	E Marlborough T	McNamara	1583	1985	W	H	462	H	400FLCGH
3377	395137	0754345	E Marlborough T	Vogel, Liz	--	1977	W	H	440	H	400FLCGH
3378	395214	0754302	E Marlborough T	Pratt, J.	0909	1984	W	H	411	F	400FLCGH
3379	395235	0754143	E Marlborough T	Marchi, Robert	0909	1985	W	H	379	W	300STRS
3380	395207	0754204	W Marlborough T	White, Doug	1609	1988	W	H	400	H	400FLCGH
3381	395214	0754157	E Marlborough T	White, Doug	0909	--	W	H	395	S	400FLCGH

Table 25.--Records of selected wells in Pennsylvania--Continued

	Casing						Measured yield			Field water quality			
Depth of well (feet)	Depth (feet)	Diameter (inches)	Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level mesured	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Dis-charge (gal/min)	Pumping period (hours)	Date measured	Specific conduc-tance (µS/cm)	pH (stan-dard units)	USGS well number
126	60	6	106/112	41.38	08-03-83	10	--	--	--	--	--	--	CH - 2515
57	87	6	--	17.69	09-26-83	--	5.0	15	2.0	--	--	--	2586
85	50	6	50/ 75	18.97	09-27-83	100	--	--	--	--	--	--	2591
49	--	--	--	21.62	09-28-83	--	--	--	--	--	--	--	2598
--	--	--	--	27.31	09-29-83	--	--	--	--	--	--	--	2600
--	--	--	--	2.63	06-28-84	--	--	--	--	--	--	--	2784
--	--	--	--	18.08	06-28-84	--	--	--	--	--	--	--	2790
--	--	--	--	26.64	07-16-84	--	--	--	--	--	--	--	2791
200	42	6	80/190	30.00	04-21-81	--	.75	9	2.0	08-05-87	135	6.15	3084
--	--	--	--	--	--	--	--	--	--	08-25-87	270	6.1	3110
225	--	--	--	--	--	--	--	--	--	09-02-87	122	5.4	3129
110	--	--	--	--	--	--	--	--	--	09-02-87	310	6.2	3130
120	--	--	--	40.90	01-05-88	--	--	--	--	--	--	--	3283
62	4	48	--	21.10	01-05-88	--	--	--	--	--	--	--	3284
--	--	--	--	32.55	01-05-88	--	--	--	--	--	--	--	3285
336	90	8	100/110/128/213	9.11	01-05-88	75	--	--	--	--	--	--	3286
36	--	--	--	23.25	01-12-88	--	--	--	--	--	--	--	3287
82	--	--	--	6.91	02-05-88	--	--	--	--	--	--	--	3288
60	--	--	--	--	--	--	--	--	--	06-02-88	500	6.1	3293
118	--	--	--	--	--	--	--	--	--	06-30-88	112	6.05	3307
80	--	--	--	--	--	--	--	--	--	06-30-88	450	5.75	3308
63	--	--	--	--	--	--	--	--	--	07-06-88	320	5.45	3310
160	60	6	70/ 85/115	--	--	--	.41	45	.5	07-07-88	610	5.75	3312
25	--	--	--	--	--	--	--	--	--	07-08-88	620	6.25	3313
--	--	--	--	--	--	--	--	--	--	07-11-88	330	6.1	3314
--	--	--	--	--	--	--	--	--	--	08-08-88	480	6.25	3318
--	--	--	--	--	--	--	--	--	--	08-15-88	140	6.1	3321
200	75	6	98/125/174	5.24	07-21-89	12	--	--	--	08-15-88	320	6.35	3323
280	60	6	100/200	81.35	06-02-89	15	--	--	--	06-02-89	220	5.8	3356
240	58	6	--	7.09	06-20-89	18	--	--	--	--	--	--	3366
--	--	--	--	38.35	06-20-89	--	--	--	--	--	--	--	3367
200	--	--	--	3.37	06-20-89	--	--	--	--	--	--	--	3368
260	63	6	164/173/245/253	15.16	06-20-89	--	.03	6	1	--	--	--	3369
166	65	6	110/160	16.87	06-20-89	25	--	--	--	--	--	--	3370
154	26	6	30	8.45	06-20-89	--	.01	2	2	--	--	--	3371
210	85	6	100/135/175	19.38	06-20-89	--	.05	5	2	--	--	--	3372
405	50	6	70/315	39.44	06-20-89	2	--	--	--	--	--	--	3373
--	--	--	--	-1.51	06-27-89	--	--	--	--	--	--	--	3374
125	--	--	--	55.29	06-19-89	10	--	--	--	--	--	--	3375
175	28	6	65	68.47	06-19-89	--	.01	2	1	--	--	--	3376
--	--	--	--	29.92	06-19-89	--	--	--	--	--	--	--	3377
280	60	6	155/162/178/183	58.04	06-19-89	--	.05	8	1	--	--	--	3378
110	104	6	105/106/107/109	14.47	06-26-89	--	1.15	15	1	--	--	--	3379
300	40	6	127/163/277	23.20	06-26-89	--	.04	8	3.5	--	--	--	3380
--	--	--	--	21.57	06-26-89	--	--	--	--	--	--	--	3381

Table 25.--Records of selected wells in Pennsylvania--Continued

USGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Township or borough	Owner	Driller license number	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
CH- 3382	395202	0754108	E Marlborough T	Booker	1609	1985	W	H	440	W	400FLCGH
3383	395254	0754340	E Marlborough T	Garris, Charles	1628	1985	W	H	390	S	300WSCKO
3384	395201	0754216	E Marlborough T	Roberts, Robert E.	--	1978	W	H	353	H	400FLCGH
3385	395133	0754215	E Marlborough T	Gahlone, Paul	0950	1968	W	H	380	F	400FLCGH
3386	395133	0754316	E Marlborough T	Einstine, Richard	--	1957	W	H	420	S	400FLCGH
3387	395202	0754249	E Marlborough T	Edgard, J. Clifton	1083	1986	W	H	443	F	400FLCGH
3388	395201	0754143	E Marlborough T	Catena, Carolyn	--	1970	W	H	432	F	400FLCGH
3389	395214	0754142	E Marlborough T	Ginter	0909	1989	W	H	398	S	400FLCGH
3390	395252	0754233	E Marlborough T	Naggar	--	1974	W	H	412	S	300WSCKO
3391	395305	0754222	E Marlborough T	Snyder, Susan	0110	1982	W	H	429	H	300WSCKO
3392	395255	0754234	E Marlborough T	Ervin, Mark	0909	1989	W	H	425	W	300WSCKO
3394	395119	0753955	Kennett Twp	Hipp, Ann	1628	1987	W	H	382	S	400FLCGH
3395	395141	0754012	E Marlborough T	Mercer, Evelyn	--	1979	W	H	433	F	400FLCGH
3396	395143	0754745	E Marlborough T	Devitto, Gabriel	0909	1978	W	H	381	S	400FLCGH
3397	395235	0754229	E Marlborough T	Fagone, Sharon	--	1976	W	H	391	F	300WSCKO
3398	395157	0754059	E Marlborough T	Dua, Meena	0543	1983	W	H	410	S	400FLCGH
3399	395223	0754337	E Marlborough T	Allfather, William H.	--	--	W	H	361	F	300STRS
3400	395257	0754221	E Marlborough T	Spimo, Marta	0904	1988	W	H	441	W	300WSCKO
3401	395139	0754333	E Marlborough T	Bradbury, Barbara	--	1954	W	H	394	S	400FLCGH
3402	395138	0754257	E Marlborough T	Hewett, Warren D. Jr.	0909	1981	W	H	409	W	400FLCGH
3403	395225	0754314	E Marlborough T	Thompson, Walton J.	1083	--	W	H	420	F	300STRS
3404	395054	0753940	E Marlborough T	Hurley, Leslie	0248	1974	W	H	351	F	300STRS
3405	395041	0753858	Kennett Twp	Stover, Robert M	1457	1978	W	H	361	S	000HFCGH
3406	395058	0753858	Kennett Twp	Rice, Fredrick	0909	1976	W	H	340	S	300WSCKO
3407	395106	0753924	Kennett Twp	Dunbar, Lawrence	0543	1984	W	H	389	S	400FLCGH
3408	395118	0754314	Kennett Twp	Gouge, Loita	--	1985	W	H	389	F	400FLCGH
3409	395132	0754236	E Marlborough T	Flegal, Linda	0909	1987	W	H	350	S	400FLCGH
3410	395037	0755350	Kennett Twp	Calhoun, Earnest W. Jr.	0543	1987	W	H	315	S	000MFCGH
3411	395137	0754356	E Marlborough T	Holton, Herbert C.	1083	1985	W	H	330	S	400FLCGH
3412	395033	0753906	Kennett Twp	McManus, Jim	1083	--	W	H	800	S	000MFCGH
3413	395003	0753913	Kennett Twp	Knapp, Laurance	1609	1986	W	H	295	S	300WSCKO
3414	395335	0754441	E Marlborough T	Deruschi, Francis	0904	1987	W	H	445	S	300WSCKO
3415	395317	0754410	E Marlborough T	Sellers, Ken Jr.	1290	1972	W	H	430	H	300WSCKO
3416	395244	0754127	E Marlborough T	O'Melia, John	--	1957	W	H	420	S	300STRS
3417	394957	0754032	E Marlborough T	Otto, Thomas	0543	1980	W	H	377	H	000MFCGH
3418	394956	0753957	Kennett Twp	Clayton, Richard	1083	1966	W	H	305	S	300WSCKO
3419	395011	0753915	Kennett Twp	Axon, V. T.	0909	1982	W	H	331	H	000MFCGH
3420	395009	0753908	Kennett Twp	Leounes, Anthony Jr.	0909	1985	W	H	260	W	000MFCGH
3421	395054	0753914	Kennett Twp	Swasey	--	--	W	H	312	S	300WSCKO
3422	395101	0753900	Kennett Twp	Pieters, Edward	0909	1977	W	H	343	S	300WSCKO
3423	395115	0753940	Kennett Twp	Ragon, Maureen	0176	1980	W	H	402	H	400FLCGH
3424	395018	0753953	Kennett Twp	Mercadant	--	1984	W	H	374	H	300WSCKO
3426	395022	0754103	Kennett Twp	Kelly, Pamela	1083	1988	W	H	265	F	300WSCKO
3427	395007	0754025	Kennett Twp	Martz, G.	0543	1987	W	H	355	S	300WSCKO
3428	394858	0754241	Kennett Twp	Crowe, Richard C.	1083	1988	W	H	340	S	300WSCKO

Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level mesured	Reported yield (gal/min)	Measured yield: Specific capacity [(gal/min)/ft]	Measured yield: Dis-charge (gal/min)	Measured yield: Pumping period (hours)	Field water quality: Date measured	Field water quality: Specific conduc-tance (µS/cm)	Field water quality: pH (stan-dard units)	USGS well number
140	39	6	55/ 72/ 85/122	23.05	06-26-89	--	0.58	35	3.5	--	--	--	CH-3382
200	50	6	145/180	5.50	06-27-89	4	--	--	--	--	--	--	3383
80	--	--	--	11.90	06-28-89	--	--	--	--	--	--	--	3384
70	--	--	--	27.05	06-28-89	25	--	--	--	--	--	--	3385
72	--	--	--	20.00	06-28-89	--	--	--	--	--	--	--	3386
385	27	6	--	52.19	06-28-89	1	--	--	--	--	--	--	3387
--	--	--	--	29.96	06-28-89	--	--	--	--	--	--	--	3388
265	60	6	179/195/226/241	21.78	06-28-89	--	.08	9	1	--	--	--	3389
--	--	--	--	29.63	06-29-89	--	--	--	--	--	--	--	3390
310	70	6	82/150/240/305	31.67	06-29-89	--	.14	15	2.0	--	--	--	3391
412	--	--	--	27.90	06-29-89	12	--	--	--	--	--	--	3392
280	34	6	140/255	15.63	06-30-89	15	--	--	--	--	--	--	3394
--	--	--	--	23.19	06-30-89	--	--	--	--	--	--	--	3395
240	78	6	193/199/222/234	54.96	06-30-89	--	.04	6	1	--	--	--	3396
120	--	--	--	20.42	06-30-89	--	--	--	--	--	--	--	3397
200	40	6	56/ 80/120/128	29.25	07-03-89	--	.05	8	4	--	--	--	3398
--	--	--	--	7.07	07-03-89	--	--	--	--	--	--	--	3399
145	42	6	73/118	29.67	07-07-89	--	.33	10	3	--	--	--	3400
--	--	--	--	26.10	07-07-89	--	--	--	--	--	--	--	3401
120	53	6	65/ 71/ 85/110	24.32	07-07-89	--	.24	15	1	--	--	--	3402
--	--	--	--	3.00	07-07-89	--	--	--	--	--	--	--	3403
200	41	6	20/ 46/154	10.12	07-10-89	--	.02	3	1	--	--	--	3404
135	24	6	60/ 90	31.78	07-10-89	5	--	--	--	--	--	--	3405
160	--	--	--	9.38	07-10-89	--	--	--	--	--	--	--	3406
340	40	6	265/326/330/335	51.24	07-10-89	--	.02	5	4	--	--	--	3407
--	--	--	--	21.80	07-10-89	--	--	--	--	--	--	--	3408
200	--	--	--	18.94	08-14-87	--	--	--	--	--	--	--	3409
160	39	6	100/140/145/160	1.30	07-10-89	--	.28	20	4	--	--	--	3410
--	--	--	--	6.50	07-10-89	--	--	--	--	--	--	--	3411
--	--	--	--	17.72	07-11-89	--	--	--	--	--	--	--	3412
120	44	6	60/ 83/105	13.21	07-11-89	--	.83	25	3.5	--	--	--	3413
350	66	6	80/200/260/275/340	14.98	07-12-89	--	.05	15	4.0	--	--	--	3414
--	--	--	--	21.78	07-12-89	--	--	--	--	--	--	--	3415
--	90	--	--	19.01	07-12-89	--	--	--	--	--	--	--	3416
300	--	--	--	38.45	07-12-89	--	--	--	--	--	--	--	3417
--	--	--	--	7.22	07-12-89	--	--	--	--	--	--	--	3418
160	35	6	75/ 99/140/157	46.59	07-12-89	--	1.0	30	--	--	--	--	3419
--	--	--	--	12.74	07-12-89	--	--	--	--	--	--	--	3420
--	--	--	--	7.98	07-14-89	--	--	--	--	--	--	--	3421
--	--	--	--	18.80	07-14-89	--	--	--	--	--	--	--	3422
120	60	6	45/ 90/120	30.13	07-14-89	--	.14	9	2.0	--	--	--	3423
--	--	--	--	27.38	07-14-89	--	--	--	--	--	--	--	3424
125	105	6	110	16.00	07-17-89	50	--	--	--	--	--	--	3426
140	99	6	100/120/130/140	29.64	07-17-89	--	.25	20	4.0	--	--	--	3427
305	65	6	180/295	36.98	07-17-89	15	--	--	--	--	--	--	3428

Table 25.--Records of selected wells in Pennsylvania--Continued

USGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Township or borough	Owner	Driller license number	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
CH- 3429	394847	0754321	Kennett Twp	Fisher, John	1083	1988	W	H	325	H	300WSCKO
3430	395123	0754002	Kennett Twp	Choby, Alex	1609	1988	W	H	405	S	400FLCGH
3431	394937	0753946	Kennett Twp	Lipton, Jeffrey	0110	1988	W	H	401	S	300WSCKO
3432	395008	0754037	Kennett Twp	Miller	0950	1966	W	H	345	S	300WSCKO
3433	394955	0753917	Kennett Twp	Storm, Karl	1609	1987	W	H	282	H	300WSCKO
3434	395004	0753956	Kennett Twp	Massau, J. L.	--	1972	W	H	325	S	300WSCKO
3435	395042	0754003	Kennett Twp	Leto, Charles	1083	1985	W	H	345	F	000MFCGH
3436	394954	0754045	Kennett Twp	Mc Coy, Marsha	--	1981	W	H	385	S	000MFCGH
3437	395003	0753959	Kennett Twp	Carter, Pat	1290	1988	W	H	309	S	300WSCKO
3438	394852	0754132	Kennett Twp	Mcneil, Corbin	1083	1986	W	H	285	S	300WSCKO
3439	395011	0753939	Kennett Twp	Purcell	--	1972	W	H	312	F	300WSCKO
3440	395129	0753914	Kennett Twp	Ellis, W. C.	--	1940	W	H	410	S	400FLCGH
3441	394853	0754340	New Garden Twp	Le Pore, Cheryl	0543	1988	W		332	S	300WSCKO
3442	394904	0754345	New Garden Twp	Baker, R.	0543	1988	W	H	282	S	300WSCKO
3443	395018	0753937	Kennett Twp	Buffington, Doris	--	1969	W	H	344	H	000MFCGH
3444	395033	0753936	Kennett Twp	Stat	--	1975	W	H	315	S	000MFCGH
3445	394833	0754401	New Garden Twp	Tavoni, Leslie	1083	1988	W	H	411	H	300WSCKO
3446	394839	0754250	New Garden Twp	Beatty	--	1974	W	H	250	S	000MFCGH
3447	394939	0754000	Kennett Twp	Borkovich, George	1083	1987	W	H	430	H	300WSCKO
3448	394900	0754406	New Garden Twp	Haga, Joseph	0319	1978	W	H	315	S	300WSCKO
3449	394854	0754221	Kennett Twp	Martin, Aaron	1083	1985	W	H	240	F	300WSCKO
3450	394917	0754131	Kennett Twp	Johnson, Zanna	--	1989	W	H	235	S	300WSCKO
3451	394900	0754213	Kennett Twp	West, Richard	--	1989	W	H	300	S	300WSCK
3452	394901	0754223	Kennett Twp	Hammond, Wayne R.	0909	--	W	H	330	S	300WSCKO
3453	394827	0754206	Kennett Twp	Dockstader, E. K.	--	1952	W	H	360	S	300WSCKO
3454	394847	0754156	Kennett Twp	Hewton, W. R.	1083	1984	W	H	325	S	300WSCKO
3455	394848	0754254	Kennett Twp	Wilkens, John	--	--	W	H	242	F	300WSCKO
3456	394854	0754247	Kennett Twp	Tavoni, Anthony J.	--	--	W	H	290	S	300WSCKO
3457	394943	0754326	Kennett Twp	Whittle, Jeffrey	--	--	W	H	330	H	000MFCGH
3458	394952	0754152	Kennett Twp	Shoemaker, Dave	1290	1987	W	H	305	S	000MFCGH
3459	394941	0754139	Kennett Twp	O'Leary, Ann	--	1956	W	H	304	H	300WSCKO
3460	394840	0754200	Kennett Twp	Rhodes, Robert L.	0909	1978	W	H	275	S	300WSCKO
3461	394918	0754224	Kennett Twp	Hecksler, Otto	1083	1987	W	H	372	H	300WSCKO
3462	394943	0754143	Kennett Twp	Clemens, Ed	1083	1987	W	H	280	S	300WSCKO
3463	395009	0754213	Kennett Twp	Kelly, Michael And Karen	0543	1986	W	H	290	S	300WSCKO
3464	394927	0754043	Kennett Twp	Currin, Robert	0543	1979	W	H	349	S	300WSCKO
3465	394850	0754240	Kennett Twp	Latannzio, John	--	1989	W	H	315	H	300WSCKO
3466	394907	0754151	Kennett Twp	Southridge Homeowner's	0909	1978	W	H	360	H	300WSCKO
3467	395135	0754131	E Marlborough T	Boyer, Catherine	--	1968	W		403	S	400FLCGH
3468	394948	0754213	Kennett Twp	Baldwin, Robert	--	1928	W	H	378	F	000MFCGH
3469	394942	0754414	New Garden Twp	Pratola, Fred	0176	1959	W	H	382	F	300WSCKO
3470	394947	0754342	New Garden Twp	Emerson, Raymond	0347	1962	W	H	292	S	300WSCKO
3471	395049	0754034	Kennett Twp	Leto, Robert	--	1952	W	H	288	S	300STRS
3472	394757	0754333	New Garden Twp	Guerrina	--	1927	W	I	400	H	300WSCKO
3473	395053	0753958	Kennett Twp	Minatelli, Michael	0248	1972	W	H	340	V	300STRS

Table 25.--Records of selected wells in Pennsylvania--Continued

Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level mesured	Reported yield (gal/min)	Measured yield: Specific capacity [(gal/min)/ft]	Measured yield: Dis-charge (gal/min)	Measured yield: Pumping period (hours)	Field water quality: Date measured	Field water quality: Specific conduc-tance (µS/cm)	Field water quality: pH (stan-dard units)	USGS well number
242	84	6	230	55.97	07-17-89	20	--	--	--	--	--	--	CH- 3429
575	55	6	200/486/552	41.67	07-18-89	--	0.01	5	3.5	--	--	--	3430
300	70	6	175/220/281	24.74	07-18-89	--	.10	4	1.0	--	--	--	3431
115	30	6	50/ 80/110	50.10	07-18-89	17	--	--	--	--	--	--	3432
280	44	6	188/210/255	35.23	07-18-89	--	.06	9	3.0	--	--	--	3433
125	--	--	--	14.80	07-18-89	25	--	--	--	--	--	--	3434
85	60	6	70/ 80	12.70	07-19-89	7	--	--	--	--	--	--	3435
125	--	--	--	35.39	07-19-89	10	--	--	--	--	--	--	3436
180	44	6	55/ 80	10.68	07-19-89	20	--	--	--	--	--	--	3437
165	40	6	105/155	40.92	07-19-89	20	--	--	--	--	--	--	3438
155	--	--	--	9.85	07-19-89	50	--	--	--	--	--	--	3439
85	--	--	--	14.80	07-19-89	--	--	--	--	--	--	--	3440
120	60	6	70/ 95/100/120	25.76	07-20-89	--	.22	14	4.0	--	--	--	3441
200	87	6	160/187/200	7.37	07-20-89	--	.22	24	4.0	--	--	--	3442
--	--	--	--	17.78	07-20-89	--	--	--	--	--	--	--	3443
--	--	--	--	19.36	07-20-89	--	--	--	--	--	--	--	3444
225	100	6	160/210	25.85	07-21-89	10	--	--	--	--	--	--	3445
180	--	--	--	26.50	07-21-89	--	--	--	--	--	--	--	3446
510	70	6	240/375/480	60.68	07-21-89	6	--	--	--	--	--	--	3447
300	26	6	180	17.13	07-21-89	--	--	--	--	--	--	--	3448
146	42	6	110/120/135	8.25	07-19-89	30	--	--	--	--	--	--	3449
--	--	--	--	26.37	07-19-89	--	--	--	--	--	--	--	3450
--	--	--	--	52.70	07-19-89	--	--	--	--	--	--	--	3451
--	--	--	--	28.10	07-19-89	--	--	--	--	--	--	--	3452
--	32	6	--	26.60	07-19-89	--	--	--	--	--	--	--	3453
190	52	6	148/180	39.90	07-19-89	25	--	--	--	--	--	--	3454
--	--	--	--	3.50	07-22-89	--	--	--	--	--	--	--	3455
--	--	--	--	20.60	07-19-89	--	--	--	--	--	--	--	3456
--	--	--	--	30.60	07-22-89	--	--	--	--	--	--	--	3457
180	57	6	75/135	4.10	08-01-89	20	--	--	--	08-03-89	268	7.78	3458
200	--	--	--	33.16	08-01-89	--	--	--	--	--	--	--	3459
120	74	6	93/110/113/117	9.91	08-01-89	100	--	--	1	--	--	--	3460
165	60	6	110/135/155	23.84	08-01-89	10	--	--	--	--	--	--	3461
162	100	6	130/160	24.53	08-01-89	10	--	--	--	--	--	--	3462
400	60	6	65/118/132/381	16.41	08-01-89	--	.01	4	4.0	--	--	--	3463
305	60	6	38/ 52/160/280	24.08	08-01-89	--	.02	4	4	--	--	--	3464
--	--	--	--	54.50	07-19-89	--	--	--	--	--	--	--	3465
512	25	6	206/219/250/493	58.65	08-02-89	--	.05	15	1.0	--	--	--	3466
57	48	--	--	--	--	--	--	--	--	08-09-89	360	6.02	3467
60	--	--	--	--	--	--	--	--	--	08-14-89	248	5.67	3468
104	--	--	--	--	--	2	--	--	--	08-15-89	198	6.38	3469
68	--	--	--	--	--	--	--	--	--	08-16-89	132	6.05	3470
--	--	--	--	--	--	--	--	--	--	08-16-89	169	5.75	3471
155	--	--	--	--	--	4	--	--	--	08-17-89	320	6.12	3472
180	85	6	120	-0.45	08-23-89	2	--	--	--	08-23-89	220	6.2	3473

Table 25.--Records of selected wells in Pennsylvania--Continued

USGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Township or borough	Owner	Driller license number	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
CH-3474	395008	0754441	New Garden Twp	Ciorrocco, Pete	0308	1969	W	H	296	V	300CCKV
3476	395123	0754107	Kennett Twp	Pia, Bruno	0950	1966	W	H	365	S	400FLCGH
3477	394957	0754237	Kennett Twp	Cordivano, Marie	--	1962	W	H	375	H	300WSCKO
3478	394927	0754304	Kennett Twp	Diandrea, Artillio	--	1970	W	H	260	V	300WSCKO
3479	394947	0754230	Kennett Twp	Phillips, Donald	--	1959	U	U	325	W	000MFCGH
3480	395005	0754149	Kennett Twp	Thompson, Louis P.	0308	1978	W	H	270	S	000MFCGH
3481	395106	0754503	New Garden Twp	Sturgis, John	0176	1984	W	H	475	H	400FLCGH
3482	395115	0754411	E Marlborough T	Malyska, Diane	0909	1976	W	H	365	S	400FLCGH
3483	395110	0754422	New Garden Twp	Daiuta	1083	1989	W	H	398	S	400FLCGH
3484	395054	0754506	New Garden Twp	Cummings, J.	1583	1987	W	H	445	S	400FLCGH
3485	394927	0754429	New Garden Twp	Pratt, Kenneth	1083	1978	W	H	425	H	300WSCKO
3486	395013	0754335	New Garden Twp	Reid, Christina	1083	1983	W	H	275	V	300CCKV
3487	395121	0753940	Kennett Twp	Beech, Martin	0909	1986	W	H	395	S	400FLCGH
3488	394956	0754439	New Garden Twp	Di Fabio, Anthony	1083	1987	W	H	310	W	300WSCKO
3489	395003	0754426	New Garden Twp	Potter, Donald	1083	1987	W	C	310	W	300WSCKO
3490	395244	0754312	E Marlborough T	Alliance Properties	--	--	W	H	405	S	400FLCGH
3491	394959	0753853	Kennett Twp	Heiney, John F.	--	1970	W	H	235	V	300WSCKO
3492	395029	0753834	Kennett Twp	Henderson, James C.	--	1974	W	H	295	W	000MFCGH
3493	394933	0754000	Kennett Twp	Mcclean, Bates	0909	1979	W	H	370	W	300WSCKO
3494	395052	0753807	Pennsbury Twp	Goddo, Kenneth M.	--	--	W	H	365	H	000PGMT
3495	395215	0754533	W Marlborough T	Codichini, Ruth	1333	1976	W	H	428	H	400FLCGH
3496	395216	0754600	W Marlborough T	Rudd, Terry	--	--	W	H	445	S	400FLCGH
3497	395056	0754418	New Garden Twp	Smith, Robert C.	1083	1975	W	H	370	S	400FLCGH
3498	395220	0754404	E Marlborough T	Caudill, Eddie	--	1958	W	H	335	V	300STRS
3499	395256	0754356	E Marlborough T	Johnson, W. B.	0188	1977	W	H	382	S	300STRS
3500	395111	0754438	E Marlborough T	Edwin H. Paschall, Jr.	1628	1986	W	H	462	H	400FLCGH
3501	395153	0754413	E Marlborough T	Mether-Goodman, Felicia	0909	1977	W	H	305	S	300CCKV
3502	395220	0754455	E Marlborough T	Lasky, Morris	1290	1982	W	H	418	S	400FLCGH
3503	395254	0754424	E Marlborough T	Heald, Grant C.	--	1975	W	H	410	W	300STRS
3504	395406	0754418	E Marlborough T	Pape, William	0319	1988	W	H	475	W	300WSCKO
3505	395404	0754444	E Marlborough T	Hazzard, W. R.	--	1981	W	H	500	S	300WSCKO
3506	395318	0754527	E Marlborough T	Jordan, Judith & Brian	1628	1985	W	H	468	S	300WSCKO
3507	395143	0754445	E Marlborough T	Weisbrod	--	1971	W	H	342	V	400FLCGH
3508	394830	0754506	New Garden Twp	Turkey Hill Mini-mart	1083	1986	W	C	385	W	300WSCKO
3509	395424	0754423	Newlin Twp	Silberman	--	--	W	H	525	S	300WSCKO
3510	395351	0754353	E Marlborough T	Hufford, Helen V.	1083	1989	W	H	485	S	300WSCKO
3511	395318	0754604	W Marlborough T	Davidson, Bruce	--	--	U	U	528	S	300WSCKO
3512	395303	0754118	E Marlborough T	Stengel	--	1969	W	H	460	S	300WSCKO
3513	394832	0754447	New Garden Twp	Bonifacino, Judy	1240	1977	W	H	430	H	300WSCKO
3514	394904	0754456	New Garden Twp	Ferroni, S. J.	0308	1958	W	I	412	W	300WSCKO
3515	395208	0754528	E Marlborough T	U. of Pennsylvania	--	--	W	H	438	H	400FLCGH
3516	395131	0754544	W Marlborough T	U. of Pennsylvania	--	--	W	H	383	V	300CCKV
3517	395102	0754036	Kennett Twp	Buckler, Jim	0909	1981	W	I	290	V	300STRS
3518	395312	0754325	E Marlborough T	Metcalf, Eileen	1260	1987	W	H	450	H	300WSCKO
3519	395210	0754619	W Marlborough T	Pisano, Jerry	--	--	W	H	475	H	400FLCGH

Table 25.--Records of selected wells in Pennsylvania--Continued

Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level mesured	Reported yield (gal/min)	Measured yield: Specific capacity [(gal/min)/ft]	Measured yield: Dis-charge (gal/min)	Measured yield: Pumping period (hours)	Field water quality: Date measured	Field water quality: Specific conduc-tance (µS/cm)	Field water quality: pH (stan-dard units)	USGS well number
70	--	--	--	7.35	08-24-89	75	--	--	--	08-24-89	502	7.72	CH-3474
133	51	6	72/80/104	45.00	08-03-89	8	--	--	--	--	--	--	3476
94	--	--	--	16.44	08-03-89	--	--	--	--	--	--	--	3477
--	--	--	--	9.96	08-03-89	--	--	--	--	09-01-89	224	9.52	3478
100	--	--	--	5.14	08-03-89	8	--	--	--	--	--	--	3479
--	--	--	--	19.52	08-03-89	--	--	--	--	--	--	--	3480
98	52	6	25/85	30.29	08-04-89	--	0.29	15	2.0	--	--	--	3481
195	40	6	133/172	19.49	08-04-89	--	.04	6	1.0	--	--	--	3482
162	40	6	65/110/150	3.02	08-04-89	50	--	--	--	--	--	--	3483
100	35	6	50/75	14.09	08-04-89	--	.75	30	1.25	--	--	--	3484
154	53	6	75/130/150	17.95	08-07-89	10	--	--	--	--	--	--	3485
205	25	6	160/190	22.42	08-07-89	2	--	--	--	--	--	--	3486
305	54	6	209/221/240/255	23.45	07-25-89	--	.04	8	1.0	--	--	--	3487
126	60	6	80/115	8.33	08-07-89	25	--	--	--	--	--	--	3488
145	70	6	100/140	15.20	08-07-89	15	--	--	--	--	--	--	3489
--	--	--	--	10.20	08-15-89	--	--	--	--	--	--	--	3490
40	--	--	--	19.55	07-18-89	--	--	--	--	--	--	--	3491
80	--	--	--	6.45	07-21-89	--	--	--	--	--	--	--	3492
80	33	6	53/58/60/74	3.55	07-17-89	80	--	--	1.0	--	--	--	3493
--	--	--	--	19.40	07-18-89	--	--	--	--	--	--	--	3494
116	80	6	90/110	19.68	08-07-89	--	2.2	22	1.0	--	--	--	3495
--	--	--	--	13.48	08-07-89	--	--	--	--	--	--	--	3496
79	--	--	--	19.68	08-08-89	30	--	--	--	--	--	--	3497
90	--	--	--	3.27	08-07-89	--	--	--	--	--	--	--	3498
180	42	6	--	15.23	08-07-89	--	.36	50	.5	--	--	--	3499
355	53	--	--	40.88	08-08-89	1	--	--	--	--	--	--	3500
--	--	--	--	25.58	08-08-89	--	--	--	--	--	--	--	3501
275	68	6	70/225	18.67	08-08-89	25	--	--	--	--	--	--	3502
--	--	--	--	26.53	08-08-89	--	--	--	--	--	--	--	3503
250	80	6	120/155/190/225	25.13	08-08-89	30	--	--	--	--	--	--	3504
60	--	--	--	6.58	08-08-89	42	--	--	--	--	--	--	3505
285	53	6	125/220	22.10	08-10-89	5	--	--	--	--	--	--	3506
--	--	--	--	10.26	08-10-89	--	--	--	--	--	--	--	3507
385	60	6	320/370	13.00	08-23-89	2	--	--	--	--	--	--	3508
--	--	--	--	22.27	08-14-89	--	--	--	--	--	--	--	3509
260	--	--	--	31.58	08-14-89	--	--	--	--	--	--	--	3510
--	--	--	--	15.00	08-14-89	--	--	--	--	--	--	--	3511
--	--	--	--	41.68	08-14-89	--	--	--	--	--	--	--	3512
76	36	5	26/39	7.00	08-23-89	--	.18	7	3.0	--	--	--	3513
130	120	--	--	6.85	08-23-89	75	--	--	--	--	--	--	3514
--	--	--	--	22.31	08-16-89	--	--	--	--	--	--	--	3515
--	--	--	--	17.25	08-16-89	--	--	--	--	--	--	--	3516
80	28	6	67/69/70/80	2.00	08-18-89	120	--	--	1	--	--	--	3517
280	60	6	90/200	16.44	08-17-89	7	--	--	--	--	--	--	3518
--	--	--	--	19.32	08-17-89	--	--	--	--	--	--	--	3519

Table 25.--Records of selected wells in Pennsylvania--Continued

USGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Township or borough	Owner	Driller license number	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
CH-3520	395306	0754632	W Marlborough T	Real Tech Assoc. Inc.	--	1988	W	H	532	H	300WSCKO
3521	395152	0754610	W Marlborough T	Landhope Farms	1083	1989	W	S	460	H	300STRS
3522	395104	0754524	New Garden Twp	Caudill, Lena	1583	1983	W	H	458	H	400FLCGH
3523	395059	0754049	Kennett Twp	Cappie, Thomas	--	1989	W	H	340	S	300STRS
3524	395110	0753933	Kennett Twp	Baney, Barbara	--	1981	W	H	401	H	400FLCGH
3525	395032	0754127	Kennett Twp	Sfciueffteli	--	1978	W	H	375	H	000MFCGH
3526	395043	0754051	Kennett Twp	Chandler, Michael	--	1949	W	H	310	S	300STRS
3527	394947	0754508	New Garden Twp	Ragazzo, Albert J.	1083	1974	W	H	373	S	300WSCKO
3528	394946	0754534	New Garden Twp	Paisley, Tom	--	1935	W	U	330	V	300CCKV
3529	394927	0754504	New Garden Twp	Warren, Robert A.	--	1967	W	H	427	H	000MFCG
3530	395027	0754546	New Garden Twp	Fortuna, Alfred	1583	1985	W	H	470	S	400FLCGH
3531	395046	0754521	New Garden Twp	Modern Mushroom	0248	1986	W	C	412	W	400FLCGH
3532	395037	0754514	New Garden Twp	Modern Mushroom	0248	1989	W	C	370	W	400FLCGH
3533	395020	0754508	New Garden Twp	Dibello, William	--	1958	W	H	385	S	300STRS
3534	394959	0754515	New Garden Twp	Schuibbeo, Aida	--	1948	W	H	325	S	300CCKV
3535	395053	0754427	E Marlborough T	Dilley, Lorraine	1715	1988	W	H	393	S	400FLCGH
3536	395136	0754112	E Marlborough T	Stengel, Paul G.	--	--	W	H	432	H	400FLCGH
3537	394955	0753841	Kennett Twp	Barringer, C. M.	--	1964	W	H	275	S	000MFCGH
3538	394951	0753842	Kennett Twp	Buonassisi, Charles B.	0909	1978	W	H	250	S	000MFCGH
3539	395005	0754228	Kennett Twp	Gibson, Jack	0176	--	W	H	370	F	300WSCKO
3542	395148	0754302	E Marlborough T	Webb, R.	1083	1986	W	H	435	H	400FLCGH
3543	395141	0754320	E Marlborough T	Doughenty, Patricia	0319	1986	W	H	382	W	400FLCGH
3544	395112	0754324	E Marlborough T	Davenport, Donald	1083	1982	W	H	360	S	400FLCGH
3545	395104	0754302	E Marlborough T	Tyson, Robert	0110	1977	W	H	365	W	400FLCGH
3546	395113	0754139	Kennett Twp	Work - Pannell	0308	1978	W	H	405	S	400FLCGH
3547	395138	0754029	E Marlborough T	Hoffman, John R.	--	1966	W	H	415	W	400FLCGH
3548	395014	0754133	Kennett Twp	Farqunar, Gordon R. Sr.	0909	1989	W	H	290	H	300WSCKO
3549	395013	0754138	Kennett Twp	Farqunar, Gordon Jr.	0909	1977	W	H	270	S	000MFCGH
3550	395157	0754018	E Marlborough T	Carter, Frank & Eileen	0176	1985	W	H	428	S	400FLCGH
3552	394915	0754120	Kennett Twp	Liikala, G.	0909	1989	W	H	314	S	300WSCKO
3553	394912	0754121	Kennett Twp	Meyers, Peter J. Jr.	--	1989	W	H	330	S	300WSCKO
3554	394921	0754116	Kennett Twp	Fedorak, Humphrey	--	1989	W	H	335	H	300WSCKO
3555	394858	0754127	Kennett Twp	Wrigley, Virginia	0543	1981	W	H	200	V	300WSCKO
3556	394859	0754115	Kennett Twp	Marshall, Thomas E. Jr.	--	1973	W	H	205	S	300WSCKO
3557	394903	0754121	Kennett Twp	English, David	0543	1981	W	H	305	S	300WSCKO
3558	394902	0754125	Kennett Twp	Haggard, Homer H.	0543	1982	W	H	300	S	300WSCKO
3559	394911	0754119	Kennett Twp	Volpe Builders	--	1989	W	H	328	S	300WSCKO
3560	394843	0754122	Kennett Twp	McGovern, William	--	1978	W	H	300	W	300WSCKO
3561	395058	0753837	Kennett Twp	Deberardinis, Martin	0909	1951	W	H	320	S	300WSCKO
3562	395003	0753842	Kennett Twp	Moors, Millard	--	1969	W	H	285	S	300WSCKO
3563	395052	0754434	New Garden Twp	Bowman, Bobby	1083	1968	W	H	380	W	400FLCGH
3564	395042	0754335	Kennett Twp	Swift, Richard	1083	1980	U	U	345	S	300STRS
3565	395105	0754422	New Garden Twp	Bonifacino, Steven	0176	1947	W	H	425	S	300STRS
3566	394958	0754312	Kennett Twp	Raimondo, Anthony	--	1959	W	H	288	S	000MFCGH
3567	394942	0754411	New Garden Twp	New Garden Farms	--	--	W	H	373	S	300WSCKO

Table 25.--Records of selected wells in Pennsylvania--Continued

Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level mesured	Reported yield (gal/min)	Measured yield: Specific capacity [(gal/min)/ft]	Measured yield: Discharge (gal/min)	Measured yield: Pumping period (hours)	Field water quality: Date measured	Field water quality: Specific conductance (µS/cm)	Field water quality: pH (standard units)	USGS well number
--	--	--	--	19.30	08-17-89	--	--	--	--	--	--	--	CH- 3520
242	96	--	120	37.25	08-17-89	100	--	--	--	--	--	--	3521
100	--	--	--	12.22	08-17-89	--	--	--	--	--	--	--	3522
--	--	--	--	26.90	08-23-89	--	--	--	--	--	--	--	3523
175	--	--	--	24.76	08-23-89	--	--	--	--	--	--	--	3524
--	--	--	--	42.11	08-24-89	--	--	--	--	--	--	--	3525
--	--	--	--	9.91	08-24-89	--	--	--	--	--	--	--	3526
150	100	6	--	37.74	08-28-89	26	--	--	--	--	--	--	3527
30	--	--	--	--	--	--	--	--	--	--	--	--	3528
--	--	--	--	24.08	08-30-89	--	--	--	--	--	--	--	3529
120	39	6	45/ 85/ 90	15.67	08-30-89	--	5.0	40	3.25	--	--	--	3530
350	50	6	165	19.65	09-05-89	30	--	--	2.0	--	--	--	3531
450	80	4	--	3.28	09-05-89	80	--	--	--	--	--	--	3532
68	--	--	--	7.06	09-05-89	--	--	--	--	--	--	--	3533
--	--	--	--	17.09	09-06-89	--	--	--	--	--	--	--	3534
100	52	6	38/ 72/ 93	25.83	09-06-89	--	.11	8	.5	--	--	--	3535
--	--	--	--	33.80	08-26-89	--	--	--	--	--	--	--	3536
131	59	8	--	15.85	08-26-89	20	--	--	--	--	--	--	3537
160	64	6	96/105/137/152	13.20	08-26-89	--	.40	12	1	--	--	--	3538
--	--	--	--	22.85	08-30-89	--	--	--	--	08-30-89	202	6.28	3539
365	110	6	170/260/350	50.00	09-05-89	3	--	--	--	--	--	--	3542
75	45	6	55/ 67/ 73	7.70	09-05-89	30	--	--	--	--	--	--	3543
--	--	--	--	14.62	09-05-89	--	--	--	--	--	--	--	3544
124	93	6	97/116	45.52	09-05-89	--	.50	15	.5	--	--	--	3545
259	40	6	60/175/230	42.07	09-06-89	--	.30	6	--	--	--	--	3546
--	--	--	--	15.85	09-05-89	--	--	--	--	--	--	--	3547
505	60	6	265/275/350/485	35.80	08-30-89	--	.03	6	1.0	--	--	--	3548
220	27	6	165/182/204/209	17.56	08-30-89	--	.09	12	1.0	--	--	--	3549
112	53	6	30/ 60/ 90	14.60	09-06-89	--	.50	20	2.0	--	--	--	3550
445	35	6	291/342/389/406/421	59.86	09-02-89	--	.24	12	1.0	--	--	--	3552
650	--	--	--	75.20	09-02-89	3	--	--	--	--	--	--	3553
720	--	--	--	78.41	09-02-89	3	--	--	--	--	--	--	3554
180	22	6	--	5.70	08-30-89	--	.04	5	4.0	--	--	--	3555
--	--	--	--	11.27	08-30-89	--	--	--	--	--	--	--	3556
504	40	6	400/450/475/500	59.93	08-12-89	--	.01	2	4.0	--	--	--	3557
401	55	6	195/400	75.97	08-11-89	1	--	--	--	--	--	--	3558
--	--	--	--	29.92	09-02-89	--	--	--	--	--	--	--	3559
--	--	--	--	19.63	09-13-89	--	--	--	--	--	--	--	3560
53	--	--	--	15.71	09-25-89	--	--	--	--	--	--	--	3561
--	--	--	--	14.26	09-25-89	--	--	--	--	--	--	--	3562
--	--	--	--	2.85	09-06-89	--	--	--	--	--	--	--	3563
420	50	6	--	20.89	09-06-89	2	--	--	--	--	--	--	3564
60	--	--	--	32.99	09-08-89	8	--	--	--	--	--	--	3565
85	--	--	--	16.20	09-08-89	--	--	--	--	--	--	--	3566
--	--	--	--	44.80	09-08-89	--	--	--	--	--	--	--	3567

Table 25.--Records of selected wells in Pennsylvania--Continued

USGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Township or borough	Owner	Driller license number	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting	Hydro-geologic unit
CH-3568	394917	0754523	New Garden Twp	Stike, Paul	1083	1987	U	U	410	S	000MFCGH
3569	394815	0754433	New Garden Twp	Springer, John A	--	1850	W	H	430	S	300WSCKO
3570	394805	0754338	New Garden Twp	Robinson	--	1917	W	H	415	S	300WSCKO
3571	394806	0754406	New Garden Twp	Crossan, Harvey	--	1976	W	H	431	H	300WSCKO
3572	394812	0754229	Kennett Twp	Pearson, Deborah	--	1952	W	H	375	S	300WSCKO
3573	394804	0754232	Kennett Twp	Muhlenberg, Henry	0176	1949	W	H	403	H	300WSCKO
3574	394848	0754132	Kennett Twp	Worthy, James C.	0909	1982	W	H	350	H	300WSCKO
3575	394815	0754417	New Garden Twp	Ciarrochi, Charles	--	1959	U	U	420	S	300WSCKO
3576	395008	0753756	Pennsbury Twp	Johston, Karl	--	1970	W	H	365	S	300WSCKO
3578	395018	0753841	Kennett Twp	Owens, John T.	0909	--	W	H	335	S	000MFCGH
3579	394931	0754014	Kennett Twp	Tichenor, William H.	0909	1983	W	H	396	H	300WSCKO
3580	394912	0754005	Kennett Twp	Carter, James	1083	1983	W	H	315	W	300WSCKO
3581	394918	0754003	Kennett Twp	Quinn, William G.	--	1950	W	H	360	S	300WSCKO
3582	394917	0754340	New Garden Twp	Jasienski, Alexander	0176	1987	W	H	360	H	300WSCKO
3583	394952	0754246	Kenett Twp	Brun, Walter	--	1952	W	H	365	S	300WSCKO
3584	395039	0754129	Kennett Twp	McGee, Ron	1083	1988	W	H	340	S	000MFCGH
3585	395109	0754156	Kennett Twp	Delduco, Dan	1083	1987	W	H	410	H	400FLCGH
4004	395312	0754313	E Marlborough T	U-ville-Chadds Ford Sch	--	--	W	T	442	F	300WSCKO
4005	394832	0754357	New Garden Twp	Faulds, Ann	1083	1985	W	I	423	S	300WSCKO
4023	395108	0753829	Kennett Twp	Mcginnis, Shirley	0176	1954	W	H	333	F	300WSCKO
4024	395200	0754056	E Marlborough T	Schmoyer, Robert	0938	1975	W	H	398	S	400FLCGH

Table 25.--Records of selected wells in Pennsylvania--Continued

	Casing						Measured yield			Field water quality			
Depth of well (feet)	Depth (feet)	Diameter (inches)	Depth of water-bearing zone(s) (feet)	Water level (feet)	Date water level mesured	Reported yield (gal/min)	Specific capacity [(gal/min)/ft]	Dis-charge (gal/min)	Pumping period (hours)	Date measured	Specific conduc-tance (µS/cm)	pH (stan-dard units)	USGS well number
162	50	6	90/155	21.80	09-08-89	15	--	--	--	--	--	--	CH-3568
16	--	--	--	11.91	09-11-89	--	--	--	--	--	--	--	3569
--	--	--	--	23.32	09-11-89	--	--	--	--	--	--	--	3570
--	--	--	--	29.49	09-11-89	--	--	--	--	--	--	--	3571
--	--	--	--	26.45	09-12-89	--	--	--	--	--	--	--	3572
140	--	--	--	34.15	09-12-89	6	--	--	--	--	--	--	3573
370	21	6	354/356/359/362	35.12	09-13-89	--	0.14	30	1.0	--	--	--	3574
300	--	--	--	12.95	09-11-89	5	--	--	--	--	--	--	3575
--	--	--	--	20.95	09-25-89	--	--	--	--	--	--	--	3576
--	--	--	--	28.64	09-26-89	--	--	--	--	--	--	--	3578
--	--	--	--	60.46	09-27-89	--	--	--	--	--	--	--	3579
144	70	6	90/120/135	6.91	09-27-89	120	--	--	--	--	--	--	3580
--	--	--	--	33.11	09-27-89	--	--	--	--	--	--	--	3581
236	50	6	100/225	29.85	10-04-89	--	.04	7	2.0	--	--	--	3582
85	--	--	--	20.03	10-04-89	--	--	--	--	--	--	--	3583
205	80	6	--	21.23	10-04-89	20	--	--	--	--	--	--	3584
222	55	6	190/210	28.42	10-04-89	5	--	--	--	--	--	--	3585
365	--	--	--	--	--	--	--	--	--	08-01-90	137	7.21	4004
250	--	--	--	--	--	--	--	--	--	08-14-90	152	6.7	4005
125	--	--	--	--	--	--	--	--	--	09-04-90	249	5.65	4023
90	--	--	--	17.04	09-04-90	5	--	--	--	09-04-90	222	5.85	4024

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Table 26.--Records of selected wells in Delaware

DGS well number: Well number assigned by the Delaware Geological Survey.

Use of site: O, observation; U, unused; W, withdrawal.

Use of water: C, commercial; H, domestic; I, irrigation; T, institutional; U, unused.

Topographic setting codes: F, flat; H, hilltop; S, hillside; V, valley; W, draw.

Hydrogeologic unit codes: 300CCKV, Cockeysville Marble; 300WSCK, Wissahickon Formation; 300WLMG, Wilmington Complex.

Elevation of land surface is estimated from topographic maps. Datum is sea level.

Water level is in feet below land surface.

gal/min, gallons per minute; gal/min/ft, gallons per minute per foot of drawdown; µS/cm, microsiemens per centimeter at 25 degrees Celsius

Table 26.--Records of selected wells in Delaware

[--, no data]

DGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Quadrangle name	Owner	Driller	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topographic setting
Bb15-01	394905	0754011	Kennett Square	Sumser, F.	Powell	1989	W	H	322	H
Bb24-14	394817	0754139	Kennett Square	Matwey, Benjamin	Powell	1957	W	H	396	H
Bb24-15	394824	0754118	Kennett Square	Donahue, John	Walton Corp.	--	U	U	345	S
Bb24-16	394818	0754147	Kennett Square	Braithwaite, Gavin	Gaster	1967	W	H	365	S
Bb24-17	394823	0754105	Kennett Square	Carpenter, Frank	Gaster	1972	W	H	297	S
Bb24-18	394810	0754123	Kennett Square	Gilston, H.	--	1972	W	H	365	S
Bb25-26	394808	0754002	Kennett Square	Amer	Madron	1989	W	H	335	S
Bb25-27	394818	0754036	Kennett Square	Sciota Jr., Michael	Walton Corp.	--	W	H	184	V
Bb25-28	394835	0754015	Kennett Square	Verbeck, Arthur	Walton Corp.	1985	W	H	230	H
Bb25-29	394837	0754002	Kennett Square	Gipe, Charles	--	1968	W	H	275	S
Bb25-30	394806	0754051	Kennett Square	Hartnett, Lawrence	Powell	1966	W	H	292	S
Bb25-31	394824	0754006	Kennett Square	Reynolds	--	1950	O	U	200	W
Bb25-32	394820	0754025	Kennett Square	NVF Co.	--	--	O	U	200	S
Bb34-60	394738	0754125	Kennett Square	Berry, Ken	Auld	1947	W	H	382	H
Bb34-61	394752	0754127	Kennett Square	Klaristenfeld, David	Powell	1968	W	H	352	S
Bb34-62	394747	0754115	Kennett Square	Owens, John	Powell	1963	W	H	335	S
Bb34-63	394743	0754104	Kennett Square	Reitter, Erwin	--	--	W	H	305	S
Bb34-64	394732	0754118	Kennett Square	Hutt, Irvin	Powell	1965	W	H	335	S
Bb35-17	394800	0754056	Kennett Square	Welch, Raymond	--	1961	W	H	315	S
Bb35-18	394750	0754034	Kennett Square	Blades, Herbert	Powell	--	W	H	300	W
Bb35-19	394744	0754036	Kennett Square	Howe, Jane	Powell	1964	W	H	340	S
Bb35-20	394745	0754000	Kennett Square	Gay, Frank	--	1966	W	H	245	S
Bb35-21	394739	0754002	Kennett Square	Bates, Alan	Powell	1966	W	H	260	S
Bb35-22	394718	0754011	Kennett Square	Vinton, Bill	--	--	W	H	361	F
Bb35-23	394717	0754023	Kennett Square	Libby, Jim	Powell	1950	W	H	362	F
Bb35-24	394720	0754043	Kennett Square	St. John, Daniel	--	1963	W	H	300	S
Bb35-25	394714	0754035	Kennett Square	McBride, Daniel	Delaware V. C.	1960	W	H	350	W
Bb35-26	394727	0754103	Kennett Square	Huber, Rodney	Walton Corp.	1963	W	H	310	S
Bb45-21	394616	0754016	Kennett Square	Odell, Frank	Walton Corp.	1977	W	H	365	H
Bb55-12	394548	0754018	Kennett Square	Mayir, Henry & Loyd	Walton Corp.	1959	W	H	301	W
Bb55-13	394516	0754007	Kennett Square	Riblett, Richard	Walton Corp.	1960	W	H	303	W
Bc11-05	394911	0753909	Kennett Square	Moseley, Christopher	Walton Corp.	1975	W	H	275	W
Bc11-06	394908	0753957	Kennett Square	Bryce, Steve	Powell	1989	W	H	340	H
Bc12-03	394920	0753830	Kennett Square	Kelly	Walton Corp.	1983	W	H	245	S
Bc12-04	394916	0753834	Kennett Square	DuPont, Ed	--	1949	W	H	208	S
Bc12-05	394907	0753858	Kennett Square	Porter, Richard	--	--	W	H	250	S
Bc12-06	394912	0753847	Kennett Square	O'Connell, Jean	Walton Corp.	1987	W	H	198	V
Bc13-15	394924	0753739	Kennett Square	Ewing, William	Caster	1964	W	H	365	S
Bc13-16	394928	0753745	Kennett Square	Brittingham, Margret	--	1975	W	H	325	W
Bc13-17	394920	0753758	Kennett Square	Qualls, Spencer	Powell	1985	W	H	355	S
Bc13-18	394917	0753743	Kennett Square	Manerchia, Lou	Walton Corp.	1989	W	H	340	S
Bc13-19	394931	0753711	Wilmington North	Witsil, Pamela	Walton Corp.	1989	W	H	421	H
Bc13-20	394924	0753720	Wilmington North	Colman, Robert	Powell	--	W	H	419	H
Bc13-21	394914	0753712	Wilmington North	Duncan, Betty	--	--	W	H	422	H
Bc13-22	394903	0753736	Kennett Square	Hunt, Sharon	--	--	W	H	400	S

Table 26.--Records of selected wells in Delaware--Continued

Hydro-geologic unit	Depth of well (feet)	Casing Depth (feet)	Casing Diameter (feet)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Measured yield Specific capacity (gal/min)/ft	Measured yield Dis-charge (gal/min)	Measured yield Pumping period (hours)	DGS well number
300WSCK	185	80	--	--	37.42	09-27-89	20	--	--	--	Bb15-01
300WSCK	--	--	--	--	38.44	09-12-89	--	--	--	--	Bb24-14
300WSCK	220	40	6	--	31.04	09-12-89	--	--	--	--	Bb24-15
300WSCK	--	--	7	--	38.47	09-14-89	--	--	--	--	Bb24-16
300WSCK	200	--	7	--	48.19	09-14-89	--	--	--	--	Bb24-17
300WSCK	120	--	7	--	23.4	09-14-89	8	--	--	--	Bb24-18
300WSCK	320	--	--	--	66.26	09-13-89	--	--	--	--	Bb25-26
300WSCK	--	--	--	--	9.6	09-13-89	--	--	--	--	Bb25-27
300WSCK	220	40	6	--	70.27	09-21-89	--	0.04	7	4	Bb25-28
300WSCK	350	--	--	--	42.87	09-21-89	--	--	--	--	Bb25-29
300WSCK	--	--	6	--	61.98	09-26-89	--	--	--	--	Bb25-30
300WSCK	48	--	--	--	6.77	01-06-89	--	--	--	--	Bb25-31
300CCKV	83	--	--	--	24.83	11-04-88	--	--	--	--	Bb25-32
300WSCK	89	--	6	--	29.82	07-14-89	2	--	--	--	Bb34-60
300WSCK	--	--	--	--	14.81	09-13-89	--	--	--	--	Bb34-61
300WSCK	--	--	--	--	33.25	09-13-89	--	--	--	--	Bb34-62
300WSCK	--	--	--	--	32.50	09-13-89	--	--	--	--	Bb34-63
300WSCK	120	--	--	--	32.03	09-21-89	--	--	--	--	Bb34-64
300WSCK	170	--	6	--	24.97	09-26-89	--	--	--	--	Bb35-17
300WSCK	--	--	--	--	20.68	09-14-89	--	--	--	--	Bb35-18
300WSCK	--	--	7	--	31.37	09-14-89	--	--	--	--	Bb35-19
300WSCK	130	--	--	--	28.93	07-26-89	30	--	--	--	Bb35-20
300WSCK	--	--	6	--	35.93	07-26-89	3	--	--	--	Bb35-21
300WSCK	125	--	--	--	26.4	07-29-89	--	--	--	--	Bb35-22
300WSCK	65	--	--	--	36.02	07-18-89	8	--	--	--	Bb35-23
300WSCK	100	--	6	--	5.3	09-21-89	--	--	--	--	Bb35-24
300WSCK	60	--	--	--	25.16	09-14-89	--	--	--	--	Bb35-25
300WSCK	175	100	6	--	30.29	09-21-89	--	--	--	--	Bb35-26
300WSCK	255	88	6	--	21.48	09-28-89	--	.01	3	4	Bb45-21
300WSCK	70	--	--	--	13.13	10-17-89	--	--	--	--	Bb55-12
300WSCK	100	25	6	--	43.81	10-17-89	15	--	--	--	Bb55-13
300WSCK	625	--	--	--	.45	08-03-89	--	--	--	--	Bc11-05
300WSCK	260	36	6	--	27.84	09-27-89	--	.07	10	3	Bc11-06
300WSCK	250	--	--	--	36.23	08-02-89	25	--	--	--	Bc12-03
300WSCK	--	--	--	--	7.06	08-03-89	--	--	--	--	Bc12-04
300WSCK	--	--	--	--	16.60	08-03-89	--	--	--	--	Bc12-05
300WSCK	120	45	6	--	1.29	08-03-89	--	.29	20	4	Bc12-06
300WSCK	65	--	--	--	56.29	08-02-89	--	--	--	--	Bc13-15
300WSCK	300	--	--	--	52.08	08-02-89	--	--	--	--	Bc13-16
300WSCK	405	--	--	--	53.33	09-25-89	20	--	--	--	Bc13-17
300WSCK	260	98	6	--	19.98	09-27-89	15	--	--	4	Bc13-18
300WSCK	300	109	6	--	27.51	03-07-90	--	.02	5	4	Bc13-19
300WSCK	--	--	--	--	34.46	03-07-90	--	--	--	--	Bc13-20
300WSCK	--	--	--	--	25.01	03-07-90	--	--	--	--	Bc13-21
300WSCK	--	--	--	--	59.31	03-14-90	--	--	--	--	Bc13-22

Table 26.--Records of selected wells in Delaware--Continued

DGS well number	Location: Latitude (degrees)	Location: Longitude (degrees)	Quadrangle name	Owner	Driller	Year drilled	Primary: Use of site	Primary: Use of water	Elevation of land surface (feet)	Topo-graphic setting
Bc13-23	394928	0753706	Wilmington North	Keane, Barry	Keyes	--	W	H	433	H
Bc21-07	394826	0753916	Kennett Square	DuPont, Eugenic	Walton Corp.	1976	W	H	225	W
Bc21-08	394849	0753926	Kennett Square	Lippert, Arnold	Powell	1969	W	H	362	H
Bc21-09	394841	0753920	Kennett Square	Cripps, Harry	Powell	1989	W	H	272	S
Bc21-10	394853	0753910	Kennett Square	Lattomus, William	Walton Corp.	1958	W	H	325	F
Bc21-11	394845	0753932	Kennett Square	Reese Jr., Charles	Powell	1967	W	H	343	F
Bc21-12	394834	0753953	Kennett Square	Blevins, Thomas	Duffy	1976	W	H	260	S
Bc22-10	394835	0753819	Kennett Square	Frederick, Richard	--	1960	W	H	325	S
Bc22-11	394810	0753803	Kennett Square	Heckrotte, Robert	Auld	1956	W	H	315	S
Bc23-09	394853	0753740	Kennett Square	Kane, Edward	Walton Corp.	1962	W	H	340	W
Bc23-10	394849	0753749	Kennett Square	Conway, James	Walton Corp.	1979	W	H	355	S
Bc23-14	394838	0753754	Kennett Square	Godfrey, James	Madron	1980	W	H	305	S
Bc23-15	394824	0753707	Wilmington North	Herr, Frederick	--	1970	W	H	329	S
Bc23-16	394832	0753704	Wilmington North	Wilson, Donald	--	--	W	H	385	S
Bc23-17	394840	0753714	Wilmington North	Feeney, Donald	--	--	W	H	411	H
Bc23-18	394834	0753728	Wilmington North	Burrus, Elizabeth	--	1985	W	H	395	S
Bc23-19	394837	0753742	Kennett Square	Quisenberry, Richard	--	1976	W	H	342	S
Bc23-20	394846	0753751	Kennett Square	Wolf, Dale	--	--	W	H	362	H
Bc23-21	394807	0753754	Kennett Square	Winey, Art	--	1956	W	H	345	S
Bc23-22	394856	0753731	Kennett Square	Greenville Cntry Club	Powell	1961	W	C	365	S
Bc23-23	394804	0753754	Kennett Square	Ivy, Ed	Powell	1965	W	H	362	H
Bc23-24	394852	0753754	Kennett Square	Jacobson, Conrad	Madron	1981	W	H	360	S
Bc23-25	394812	0753750	Kennett Square	Palmer, Nancy	--	1956	W	H	340	W
Bc24-13	394808	0753643	Wilmington North	Greggo, Vincent	--	--	W	H	365	H
Bc24-14	394821	0753650	Wilmington North	L. Brandywine Club	Powell	1988	W	T	380	H
Bc31-08	394715	0753909	Kennett Square	DuPont-Copeland, L.	Walton Corp.	1980	W	H	315	W
Bc31-09	394739	0753954	Kennett Square	Uniacke	Powell	1971	W	H	277	S
Bc31-10	394717	0753954	Kennett Square	Vague, Lisa	Powell	1988	W	H	310	S
Bc31-11	394730	0754000	Kennett Square	Prichard, W.	Powell	1954	W	H	328	S
Bc32-08	394729	0753817	Kennett Square	--	Walton Corp.	1986	W	H	252	S
Bc32-09	394743	0753809	Kennett Square	Zylkin, Mark	Powell	1961	W	H	330	S
Bc32-10	394718	0753845	Kennett Square	Dupont-Copeland, L.	Walton Corp.	1988	O	U	195	S
Bc32-11	394703	0753859	Kennett Square	Copeland, L.	--	--	W	I	200	V
Bc33-05	394744	0753758	Kennett Square	Drake	Slough	1962	W	H	245	S
Bc33-06	394731	0753752	Kennett Square	DuPont, Henry	--	--	W	H	326	H
Bc33-07	394750	0753739	Kennett Square	Rollins Sr., John	--	1929	W	H	308	H
Bc33-08	394703	0753716	Wilmington North	Huang, Peter	--	1959	W	H	322	S
Bc34-14	394754	0753651	Wilmington North	Brevort, F.	Walton Corp.	1963	W	H	321	H
Bc34-15	394708	0753637	Wilmington North	Hobbs, Andrew	--	1970	W	H	347	S
Bc34-16	394628	0753650	Wilmington North	Minker, Mat	Walton Corp.	1980	W	H	330	S
Bc34-17	394725	0753647	Wilmington North	Martinez, Frank	--	--	W	H	335	H
Bc41-10	394617	0753904	Kennett Square	Hester, David	--	1959	W	H	300	S
Bc41-11	394652	0753903	Kennett Square	Boothby, H.	Powell	1969	W	H	275	S
Bc41-12	394640	0753919	Kennett Square	The Ralston Farm	--	--	W	H	370	S
Bc41-13	394628	0753936	Kennett Square	Florick, Alfred	Walton Corp.	--	W	H	335	S

Table 26.--Records of selected wells in Delaware--Continued

Hydro-geologic unit	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (feet)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Measured yield: Specific capacity (gal/min)/ft	Measured yield: Dis-charge (gal/min)	Measured yield: Pumping period (hours)	DGS well number
300WSCK	--	--	--	--	33.80	03-14-90	--	--	--	--	Bc13-23
300WSCK	205	95	--	--	7.76	08-01-89	25	--	--	--	Bc21-07
300WSCK	--	--	--	--	29.85	08-01-89	--	--	--	--	Bc21-08
300WSCK	260	54	6	--	2.67	08-01-89	11	--	--	--	Bc21-09
300WSCK	--	--	--	--	17.35	08-03-89	--	--	--	--	Bc21-10
300WSCK	138	--	--	--	13.04	09-26-89	--	--	--	--	Bc21-11
300WSCK	50	29	6	21/42	7.31	09-26-89	20	1.0	--	3	Bc21-12
300WSCK	--	--	--	--	34.7	07-19-89	--	--	--	--	Bc22-10
300WSCK	57	40	6	--	19.7	07-17-89	--	--	--	--	Bc22-11
300WSCK	160	25	6	--	--	--	20	.15	--	2	Bc23-09
300WSCK	305	59	--	60/276	9.43	08-01-89	--	--	--	--	Bc23-10
300WSCK	--	--	--	--	13.63	08-01-89	--	--	--	--	Bc23-14
300WSCK	--	--	6	--	14.21	08-28-89	--	--	--	--	Bc23-15
300WSCK	250	--	--	--	70.35	08-28-89	--	--	--	--	Bc23-16
300WSCK	195	--	--	--	24.64	08-28-89	--	--	--	--	Bc23-17
300WSCK	275	--	6	--	34.38	08-28-89	10	--	--	--	Bc23-18
300WSCK	--	--	--	--	16.63	08-28-89	--	--	--	--	Bc23-19
300WSCK	--	--	--	--	60.5	07-27-89	--	--	--	--	Bc23-20
300WSCK	55	--	--	--	26.4	07-19-89	--	--	--	--	Bc23-21
300WSCK	--	--	--	--	10.75	07-27-89	--	--	--	--	Bc23-22
300WSCK	60	--	--	--	12	07-27-89	--	--	--	--	Bc23-23
300WSCK	120	--	7	--	13.93	09-28-89	--	--	--	--	Bc23-24
300WSCK	80	--	--	--	29.3	09-14-89	--	--	--	--	Bc23-25
300WSCK	--	--	--	--	21.78	08-23-89	--	--	--	--	Bc24-13
300WSCK	--	--	--	--	40.55	08-28-89	--	--	--	--	Bc24-14
300WSCK	330	92	8	--	39.0	09-20-89	48	.30	--	24	Bc31-08
300WSCK	--	--	--	--	24.56	07-26-89	--	--	--	--	Bc31-09
300WSCK	220	28	6	--	24.08	07-26-89	--	.01	<1	3	Bc31-10
300WSCK	97	65	6	--	30.85	07-14-89	3	--	--	--	Bc31-11
300WSCK	--	--	--	--	40.07	07-24-89	--	--	--	--	Bc32-08
300WSCK	--	--	--	--	13.38	09-14-89	--	--	--	--	Bc32-09
300WSCK	401	61	6	78/145	33.14	11-04-88	20	.05	--	4	Bc32-10
300WSCK	150	--	--	--	5.3	09-20-89	--	--	--	--	Bc32-11
300WSCK	95	--	--	--	3.64	07-24-89	--	--	--	--	Bc33-05
300WSCK	--	--	--	--	67.06	07-23-89	--	--	--	--	Bc33-06
300WSCK	--	--	--	--	34.87	09-14-89	--	--	--	--	Bc33-07
300WSCK	--	--	6	--	54.55	10-17-89	--	--	--	--	Bc33-08
300WSCK	312	42	6	--	33.77	08-23-89	--	.11	20	8	Bc34-14
300WSCK	200	--	--	--	31.65	08-23-89	15	--	--	--	Bc34-15
300WSCK	330	65	--	80	38.43	08-23-89	3	--	--	--	Bc34-16
300WSCK	--	--	--	--	35.41	08-14-89	--	--	--	--	Bc34-17
300WSCK	70	--	--	--	25.86	07-25-89	--	--	--	--	Bc41-10
300WSCK	127	--	6	--	19.17	07-22-89	14	--	--	--	Bc41-11
300WSCK	--	--	--	--	35.05	09-28-89	--	--	--	--	Bc41-12
300WSCK	300	--	--	--	42.51	09-29-89	--	--	--	--	Bc41-13

Table 26.--Records of selected wells in Delaware--Continued

	Location						Primary			
DGS well number	Latitude (degrees)	Longitude (degrees)	Quadrangle name	Owner	Driller	Year drilled	Use of site	Use of water	Elevation of land surface (feet)	Topo-graphic setting
Bc42-13	394607	0753818	Kennett Square	Mammen, Thomas	Powell	1982	W	H	165	S
Bc42-15	394658	0753808	Kennett Square	Popel, George	Powell	1986	W	H	250	S
Bc42-16	394636	0753833	Kennett Square	Spencer, Thaddeus	--	1970	W	H	150	S
Bc42-17	394625	0753850	Kennett Square	Aunet, Gerald	--	1958	W	H	275	S
Bc42-18	394621	0753856	Kennett Square	Roberts, Frank	Walton Corp.	1957	W	H	280	S
Bc42-19	394622	0753839	Kennett Square	Oglesby, John	Powell	1970	W	H	201	F
Bc42-20	394618	0753832	Kennett Square	Galloway, John	Powell	1962	U	U	235	S
Bc42-21	394617	0753827	Kennett Square	Plank, I. David	Powell	1963	W	H	140	S
Bc42-22	394612	0753845	Kennett Square	Miller, Robert	Walton Corp.	1960	W	H	237	W
Bc42-23	394614	0753839	Kennett Square	Sutherland, Donald	--	--	W	H	255	S
Bc42-24	394614	0753831	Kennett Square	Cann, William	Walton Corp.	1987	W	H	310	H
Bc42-25	394606	0753819	Kennett Square	Cox, Tim	Walton Corp.	1982	W	H	170	S
Bc42-26	394559	0753821	Kennett Square	Raskin, David	--	--	W	H	107	S
Bc43-01	394653	0753730	Kennett Square	Worth, W.	--	1938	O	U	330	H
Bc43-08	394647	0753711	Wilmington North	Voile, John	Powell	1985	W	H	301	S
Bc43-09	394641	0753726	Wilmington North	Zutz, Joyce	--	1957	W	H	285	W
Bc43-10	394623	0753747	Kennett Square	Scott, B.	--	1953	W	H	295	H
Bc43-11	394618	0753758	Kennett Square	Haq, Muhammad	Walton Corp.	1985	W	H	245	S
Bc43-12	394618	0753746	Kennett Square	Plaster, Mark	Walton Corp.	1987	W	H	180	S
Bc43-13	394613	0753745	Kennett Square	Jackson, Ned	Powell	1985	W	H	190	S
Bc43-14	394608	0753749	Kennett Square	Strickler, Edward	Walton Corp.	1985	W	H	230	S
Bc43-15	394607	0753746	Kennett Square	Krespan, Carl	Powell	1979	W	H	262	H
Bc43-16	394603	0753735	Kennett Square	Hercules Research	--	--	O	U	255	H
Bc43-17	394615	0753718	Wilmington North	Kortman, Harold	--	--	W	I	280	H
Bc44-05	394654	0753629	Wilmington North	Schutt Sr., C.	--	1983		H	320	H
Bc51-09	394559	0753910	Kennett Square	McCormick, R.	--	1901	W	H	290	W
Bc52-30	394558	0753844	Kennett Square	Kandler, J.	Powell	1965	W	H	180	S
Bc52-31	394555	0753858	Kennett Square	Cosak, Gerrie	Powell	1966	W	H	215	S
Bc53-06	394547	0753753	Kennett Square	Hercules, Inc.	--	--	U	U	201	S
Bc53-07	394543	0753719	Wilmington North	Hull, Donald	--	--	W	H	205	S
Cc11-13	394403	0753931	Newark East	True, Katherine	--	1787	U	U	145	S
Cc11-16	394407	0753909	Newark East	Campbell, William	--	1949	W	H	140	S
Cc12-02	394439	0753900	Newark East	Comoletti, Donald	--	1950	W	H	162	S
Cc12-06	394417	0753811	Newark East	Manning, Bob	--	--	U	U	112	S
Cc21-02	394358	0753917	Newark East	Stark, Warren	--	1849	U	U	119	S

Table 26.--Records of selected wells in Delaware--Continued

Hydro-geologic unit	Depth of well (feet)	Casing: Depth (feet)	Casing: Diameter (feet)	Depth to water-bearing zone(s) (feet)	Water level (feet)	Date water level measured	Reported yield (gal/min)	Measured yield: Specific capacity (gal/min)/ft	Measured yield: Dis-charge (gal/min)	Measured yield: Pumping period (hours)	DGS well number
300WSCK	590	41	6	327/459/575	58.8	08-14-89	--	0.03	5	3.4	Bc42-13
300WSCK	705	--	--	--	60.25	09-14-89	--	.01	5	1	Bc42-15
300WSCK	400	--	--	--	38.35	08-14-89	20	--	--	--	Bc42-16
300WSCK	--	--	--	--	53.25	07-25-89	--	--	--	--	Bc42-17
300WSCK	143	45	6	80	38.77	07-25-89	6	--	--	--	Bc42-18
300WSCK	265	--	--	--	17.26	08-01-89	--	--	--	--	Bc42-19
300WSCK	182	--	--	--	42.6	08-14-89	2	--	--	--	Bc42-20
300WSCK	60	--	--	--	21.65	08-14-89	7	--	--	--	Bc42-21
300WSCK	175	64	6	--	19.60	07-25-89	--	.06	6	4	Bc42-22
300WSCK	--	--	--	--	34.42	03-14-90	--	--	--	--	Bc42-23
300WSCK	500	27	6	--	28.09	10-04-89	--	<.01	1	4	Bc42-24
300WSCK	241	40	6	--	53	08-14-89	7	--	--	2	Bc42-25
300WSCK	--	--	--	--	16.60	08-14-89	--	--	--	--	Bc42-26
300WSCK	165	--	--	--	29.92	01-18-56	--	--	--	--	Bc43-01
300WSCK	205	45	6	--	25.20	10-17-89	--	.49	30	1	Bc43-08
300WSCK	--	--	--	--	9.22	10-17-89	--	--	--	--	Bc43-09
300WSCK	--	--	--	--	73.80	08-21-89	--	--	--	--	Bc43-10
300WSCK	120	80	6	--	36.35	08-21-89	45	--	--	4	Bc43-11
300WSCK	220	49	6	--	17.57	08-21-89	--	.03	5	4	Bc43-12
300WSCK	--	--	6	--	26.85	08-22-89	--	--	--	--	Bc43-13
300WLMG	250	--	--	--	38.45	08-14-89	8	--	--	--	Bc43-14
300WLMG	200	33	6	--	41.43	08-21-89	--	.08	8	1	Bc43-15
300WLMG	--	--	--	--	18.10	11-04-88	--	--	--	--	Bc43-16
300WLMG	--	--	--	--	14.65	08-23-89	--	--	--	--	Bc43-17
300WSCK	247	--	6	--	120	08-21-89	40	--	--	--	Bc44-05
300WSCK	32	--	--	--	19.3	09-29-89	--	--	--	--	Bc51-09
300WSCK	100	--	--	--	27.66	03-14-90	--	--	--	--	Bc52-30
300WSCK	--	--	--	--	27.34	03-14-90	--	--	--	--	Bc52-31
300WLMG	19	--	--	--	9.3	10-03-89	--	--	--	--	Bc53-06
300WLMG	41	--	--	--	15	10-17-89	--	--	--	--	Bc53-07
300WLMG	28	--	--	--	20.40	10-11-89	--	--	--	--	Cc11-13
300WLMG	100	--	--	--	5.71	10-03-89	30	--	--	--	Cc11-16
300WLMG	68	--	--	--	11.5	10-03-89	7	--	--	--	Cc12-02
300WLMG	20	--	--	--	16.65	07-29-89	--	--	--	--	Cc12-06
300WLMG	--	--	--	--	11.35	10-03-89	--	--	--	--	Cc21-02

Table 27.--Red Clay Creek seepage investigation, October 31-November 2, 1990

[Measurement sites are shown on plate 1. Lat., latitude; long., longitude; --, no data; ft^3/s, cubic feet per second; +, gain of water; -, loss of water]

West Branch Red Clay Creek from headwaters to confluence with East Branch, October 31, 1990

Stream mile	Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary [1]	Gain or loss in Red Clay Creek [1]	Total gain or loss in Red Clay Creek [1]
21.1	1	West Branch Red Clay Creek	Lat. 39°53′09″, long. 75°44′30″, at Mill Road	--	0.72	--	--	--
21.0	2	Tributary to West Branch Red Clay Creek	Lat. 39°53′07″, long. 75°44′30″, at Mill Road	0.56	--	--	--	--
20.1	5	West Branch Red Clay Creek [2]	Lat. 39°52′31″, long. 75°44′00″, near Wollaston Road	--	2.19	--	+ 0.91	+ 0.91
19.6	6	West Branch Red Clay Creek	Lat. 39°52′08″, long. 75°44′16″, south of Street Road	--	3.30	--	+ 1.11	+ 2.02
19.5	6A	Tributary to West Branch Red Clay Creek	Lat. 39°52′08″, long. 75°44′17″, downstream of Mill Road	.32	--	--	--	--
19.5	7	West Branch Red Clay Creek	Lat. 39°52′06″, long. 75°44′16″, south of Street Road	--	2.84	--	- .78	+1.24
19.3	8	Tributary to West Branch Red Clay Creek	Lat. 39°51′59″, long. 75°44′04″, downstream of Wollaston Road	.06	--	--	--	--
19.2	10	West Branch Red Clay Creek	Lat. 39°51′56″, long. 75°44′08″, south of Street Road	--	3.33	--	+ .43	+ 1.67
19.2	9	Tributary to West Branch Red Clay Creek	Lat. 39°51′55″, long. 75°44′10″, downstream of Mill Road	.04	--	--	--	--
--	12	South Brook (1.8 miles above mouth)	Lat. 39°51′43″, long. 75°45′51″, at Landhope Farm	.31	--	--	--	--
--		Discharge, New Bolton Center [3] (1.2 miles above mouth)	Lat. 39°51′38″, long. 75°45′16″	.04	--	--	--	--
--	13	South Brook (1.0 miles above mouth)	Lat. 39°51′41″, long. 75°45′15″, at New Bolton Center	.37	--	+ 0.02	--	--
18.9	14	South Brook	Lat. 39°51′40″, long. 75°44′15″, at Mill Road at mouth	.63	--	+ .26	--	--
18.8	11	West Branch Red Clay Creek	Lat. 39°51′35″, long. 75°44′03″, below confluence with South Brook	--	4.38	--	+ .38	+2.05
18.1	16	Tributary to West Branch Red Clay Creek	Lat. 39°51′01″, long. 75°44′04″, near Pemberton Road	.09	--	--	--	--
17.9	17	West Branch Red Clay Creek	Lat. 39°50′58″, long. 75°43′30″, at Pemberton Road	--	5.24	--	+ .77	+2.82
17.5	18	West Branch Red Clay Creek	Lat. 39°50′44″, long. 75°43′18″, at Baltimore Pike	--	5.66	--	+ .42	+3.24
17.3		Discharge, Seneca-Kennett Foods [3]	Lat. 39°50′36″, long. 75°43′17″	.04	--	--	--	--
16.8	19	Tributary to West Branch Red Clay Creek	Lat. 39°50′15″, long. 75°43′30″, near Quarry Road	.38	--	--	--	--
16.7	20	West Branch Red Clay Creek	Lat. 39°50′13″, long. 75°43′33″, at Kennett Square (01479680)	--	6.05	--	- .03	+3.21
16.5		Discharge, Kennett Square Sewage Treatment Plant [3]	Lat. 39°50′03″, long. 75°43′29″	1.18	--	--	--	--

Table 27.--Red Clay Creek seepage investigation, October 31-November 2, 1990--Continued

Stream mile	Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary [1]	Gain or loss in Red Clay Creek [1]	Total gain or loss in Red Clay Creek [1]
West Branch Red Clay Creek from headwaters to confluence with East Branch, October 31, 1990								
--	22	Toughkenamon Tributary (1.4 miles above mouth)	Lat. 39°50′12″, long. 75°44′54″, at Baltimore Pike	0.52	--	--	--	--
--	23	Toughkenamon Tributary (1.2 miles above mouth)	Lat. 39°50′10″, long. 75°44′43″, at Chambers Road	.56	--	+0.04	--	--
--	25	Tributary to Toughkenamon Tributary (1.1 miles above mouth)	Lat. 39°50′04″, long. 75°44′41″, at Chambers Road	.46	--	--	--	--
16.4	27	Toughkenamon Tributary	Lat. 39°50′00″, long. 75°43′34″, at Scarlett Road near mouth	1.14	--	+ .12	--	--
16.2	28	West Branch Red Clay Creek	Lat. 39°49′53″, long. 75°43′24″, at Hillendale Road	--	9.94	--	+1.57	+4.78
--	32	Bucktoe Creek (0.9 miles from mouth)	Lat. 39°49′03″, long. 75°43′53″, north of Bucktoe Road	.72	--	--	--	--
--	33	Tributary to Bucktoe Creek (0.4 miles from mouth)	Lat. 39°48′53″, long. 75°43′24″, east of Sharp Road	.22	--	--	--	--
14.7	34	Bucktoe Creek	Lat. 39°48′49″, long. 75°43′10″, near Bucktoe Road near mouth	.99	--	+ .05	--	--
14.5	31	West Branch Red Clay Creek	Lat. 39°48′40″, long. 75°42′48″, at Chandler Mill and Bucktoe Roads	--	10.52	--	-.41	+ 4.37
14.3	35	Tributary to West Branch Red Clay Creek	Lat. 39°48′34″, long. 75°42′39″, at Chandler Mill and Kaolin Roads	.24	--	--	--	--
13.1	36	West Branch Red Clay Creek	Lat. 39°49′04″, long. 75°41′35″, at Marshalls Bridge Road	--	10.80	--	+ .04	+ 4.41
East Branch Red Clay Creek from headwaters to confluence with West Branch, November 1, 1990 Stream mile measured from confluence of East and West Branches Red Clay Creek								
5.7	37	East Branch Red Clay Creek	Lat. 39°52′30″, long. 75°42′46″, at Street Road	--	.33	--	--	--
--	39	Red Clay Creek (0.6 miles above mouth)	Lat. 39°52′32″, long. 75°42′05″, at Street Road	.15	--	--	--	--
5.1	41	Tributary to East Branch Red Clay Creek [2]	Lat. 39°52′07″, long. 75°42′17″, at Walnut Street near mouth	.37	--	+ .22	--	--
5.0	38	East Branch Red Clay Creek	Lat. 39°52′03″, long. 75°42′20″, at East Locust Street	--	.71	--	+ .01	+ .01
3.5	42	Tributary to East Branch Red Clay Creek	Lat. 39°51′04″, long. 75°42′29″, at Walnut Street, Kennett Square	.23	--	--	--	--

Table 27.--Red Clay Creek seepage investigation, October 31-November 2, 1990--Continued

East Branch Red Clay Creek from headwaters to confluence with West Branch, November 1, 1990
Stream mile measured from confluence of East and West Branches Red Clay Creek

Stream mile	Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary [1]	Gain or loss in Red Clay Creek [1]	Total gain or loss in Red Clay Creek [1]
3.4	43	East Branch Red Clay Creek	Lat. 39°50′53″, long. 75°42′24″, at Baltimore Pike	--	1.99	--	+ 1.05	+ 1.06
3.1	44	East Branch Red Clay Creek	Lat. 39°50′39″, long. 75°42′21″, at Kennett Square Fire Station	--	1.93	--	- .06	+1.00
2.4		Discharge, Mushroom Co-op [3]	Lat. 39°50′35″, long. 75°42′00″	0.11	--	--	--	--
2.4	45	East Branch Red Clay Creek	Lat. 39°50′28″, long. 75°41′58″, north of Route 82	--	2.03	--	- .01	+ .99
1.2	46	East Branch Red Clay Creek	Lat. 39°49′46″, long. 75°41′21″, north of Old Kennett Road	--	2.86	--	+ .83	+1.82
--	47	Longwood Tributary (2.4 miles above mouth)	Lat. 39°51′31″, long. 75°40′41″, at Orchard Valley Development	.72	--	--	--	--
--	48	Longwood Tributary (1.9 miles above mouth)	Lat. 39°51′07″, long. 75°40′35″, at Bayard Road	.93	--	+0.21	--	--
--	49	Longwood Tributary (1.6 miles above mouth)	Lat. 39°50′50″, long. 75°40′37″, at Rosedale and Bayard Roads	1.27	--	+ .34	--	--
--	50	Tributary to Longwood Tributary (0.8 miles above mouth)	Lat. 39°50′38″, long. 75°41′18″, at Rosedale Road	.33	--	--	--	--
--	51	Longwood Tributary (0.7 miles above mouth)	Lat. 39°50′22″, long. 75°41′16″, at Hillendale Road	1.55	--	- .05	--	--
--	52	Longwood Tributary (0.4 miles above mouth)	Lat. 39°50′05″, long. 75°41′19″, east of McFarland Road above unmeasured tributary	1.73	--	+ .18	--	--
--	53	Longwood Tributary [2] (0.3 miles above mouth)	Lat. 39°50′03″, long. 75°41′19″, east of McFarland Road below unmeasured tributary	2.03	--	+ .30	--	--
1.1	54A	Longwood Tributary	Lat. 39°49′48″, long. 75°41′20″, off Old Kennett Road above Pond tributary at mouth	1.92	--	- .11	--	--
1.1	54B	Tributary to Longwood Tributary	Lat. 39°49′46″, long. 75°41′19″, off Old Kennett Road	.26	--	--	--	--
.1	55	East Branch Red Clay Creek	Lat. 39°49′11″, long. 75°41′29″, near Five Point near Kennett Square (01479800)	--	5.48	--	+ .44	+2.26
12.9	56B	Red Clay Creek	Lat. 39°49′00″, long. 75°41′31″, near Kennett Square, (01479820)	--	16.8	--	--	--
12.9	56A	Tributary to Red Clay Creek	Lat. 39°48′57″, long. 75°41′31″, at Marshalls Bridge Road	.39	--	--	--	--
12.3		Diversion, National Vulcanized Fiber Company [3]	Lat. 39°48′46″, long. 75°40′55″	-2.78	--	--	--	--

Table 27.--Red Clay Creek seepage investigation, October 31-November 2, 1990–Continued

Stream mile	Site number	Stream	Location	Discharge (ft³/s) Tributary	Main stream	Gain or loss in tributary [1]	Gain or loss in Red Clay Creek [1]	Total gain or loss in Red Clay Creek [1]
East Branch Red Clay Creek from headwaters to confluence with West Branch, November 1, 1990. Stream mile measured from confluence of East and West Branches Red Clay Creek								
11.3	57	Red Clay Creek	Lat. 39°48'27", long. 75°40'30", at National Vulcanized Fiber	--	16.3	--	+1.89	+1.89
11.2	58	Tributary to Red Clay Creek	Lat. 39°48'17", long. 75°40'35", at National Vulcanized Fiber	0.23	--	--	--	--
11.2		Discharge, National Vulcanized Fiber [3]	Lat. 39°48'25", long. 75°40'27"	1.50	--	--	--	--
11.1	62	Tributary to Red Clay Creek	Lat. 39°48'36", long. 75°40'23", at Yorklyn	.88	--	--	--	--
11.0	63	Red Clay Creek	Lat. 39°48'32", long. 75°40'17", at Yorklyn below National Vulcanized Fiber	--	18.6	--	-.31	+1.58
10.3	65	Tributary to Red Clay Creek	Lat. 39°48'10", long. 75°39'42", at Route 82 and Sharp Road	.02	--	--	--	--
10.2	64	Red Clay Creek	Lat. 39°48'07", long. 75°39'43", at Route 82 and Sharp Road	--	17.9	--	-.72	+.86
10.1	66A	Tributary to Red Clay Creek	Lat. 39°47'59", long. 75°39'47", at Delaware Nature Society	.18	--	--	--	--
10.0	66C	Tributary to Red Clay Creek	Lat. 39°47'55", long. 75°39'44", at Delaware Nature Society	.07	--	--	--	--
9.8	66B	Tributary to Red Clay Creek	Lat. 39°47'49", long. 75°39'34", at Delaware Nature Society	.14	--	--	--	--
9.7	66D	Tributary to Red Clay Creek	Lat. 39°47'50", long. 75°39'25", south of Barley Mill Road	.05	--	--	--	--
9.0	67	Red Clay Creek	Lat. 39°47'54", long. 75°38'57", above Burroughs Run	--	18.8	--	+.46	+1.32
3.6	68	Burroughs Run	Lat. 39°50'24", long. 75°39'09", north of Spring Mill Road	1.22	--	--	--	--
3.5	69	Tributary to Burroughs Run	Lat. 39°50'21", long. 75°39'05", northeast of Spring Mill Road	.39	--	--	--	--
3.0	71	Tributary to Burroughs Run	Lat. 39°49'50", long. 75°39'16", at Norway Road	.40	--	--	--	--
2.9	70	Burroughs Run	Lat. 39°49'51", long. 75°39'03", at Burnt Mill Road	2.31	--	+0.30	--	--
2.7	72	Burroughs Run [2]	Lat. 39°49'45", long. 75°38'48", at Center Mill Road	2.35	--	+.04	--	--
2.6	73	Tributary to Burroughs Run	Lat. 39°49'44", long. 75°38'40", at Burnt Mill Road	.22	--	--	--	--

Table 27.--Red Clay Creek seepage investigation, October 31-November 2, 1990–Continued

East Branch Red Clay Creek from headwaters to confluence with West Branch, November 1, 1990
Stream mile measured from confluence of East and West Branches Red Clay Creek

Stream mile	Site number	Stream	Location	Discharge (ft^3/s) Tributary	Main stream	Gain or loss in tributary [1]	Gain or loss in Red Clay Creek [1]	Total gain or loss in Red Clay Creek [1]
2.4	74	Tributary to Burroughs Run	Lat. 39°49′35″, long. 75°38′29″, at Hermitage Development	0.17	--	--	--	--
1.9	75	Tributary to Burroughs Run	Lat. 39°49′12″, long. 75°38′39″, south of Snuff Mill Road	.32	--	--	--	--
1.8	76	Burroughs Run	Lat. 39°49′06″, long. 75°38′35″, at Old Kennett Road	3.58	--	+ 0.52	--	--
1.5	77	Tributary to Burroughs Run	Lat. 39°49′02″, long. 75°38′20″, at Old Kennett Road	.14	--	--	--	--
.1	78	Burroughs Run	Lat. 39°47′56″, long. 75°39′01″, at Route 82 near mouth	4.19	--	+ .47	--	--
8.9	78	Burroughs Run	Lat. 39°47′56″, long. 75°39′01″, at Route 82	4.26	--	--	--	--
8.7	79	Tributary to Red Clay Creek	Lat. 39°47′42″, long. 75°38′44″, at Route 82 and Walnut Green Road	.92	--	--	--	--
7.7	80	Red Clay Creek at Mt. Cuba and Hillside Mill Roads	Lat. 39°47′12″, long. 75°38′25″	--	27.1	--	+ 3.12	+ 4.44
7.4	81	Tributary to Red Clay Creek	Lat. 39°47′09″, long. 75°38′15″, at Hillside Mill Road	.19	--	--	--	--
7.2	82	Tributary to Red Clay Creek	Lat. 39°46′53″, long. 75°38′29″, at Mt. Cuba Road	.23	--	--	--	--
6.7	83	Tributary to Red Clay Creek	Lat. 39°46′30″, long. 75°38′31″, at Spring Valley Road	.31	--	--	--	--
6.2	84	Tributary to Red Clay Creek	Lat. 39°46′15″, long. 75°38′09″, below Hoopes Reservoir	.08	--	--	--	--
6.1	85	Tributary to Red Clay Creek	Lat. 39°46′09″, long. 75°38′02″, at Rolling Mill and Barley Mill Roads	.38	--	--	--	--
4.8	86	Red Clay Creek	Lat. 39°45′52″, long. 75°38′08″, at Wooddale, Del., (01480000)	--	25.5	--	- 2.79	+ 1.65
3.3	87	Red Clay Creek	Lat. 39°44′39″, long. 75°38′05″, above mouth of Hyde Run	--	24.9	--	- .60	+1.05
--	88	Hyde Run (2.0 miles above mouth)	Lat. 39°45′29″, long. 75°39′20″, near Heritage and Amblerside Roads	.48	--	--	--	--
3.2	89	Hyde Run	Lat. 39°44′37″, long. 75°38′06″, at B & O Railroad, Brandywine Springs Park at mouth	.96	--	+ .48	--	--
1.6	90	Red Clay Creek	Lat. 39°43′28″, long. 75°38′03″, at Kiaminski Road	--	27.8	--	+ 1.94	+ 2.99
.8	91	Red Clay Creek	Lat. 39°42′55″, long. 75°38′28″, near Stanton, Del., (01480015)	--	29.8	--	+ 2.0	+ 4.99

Table 27.--Red Clay Creek seepage investigation, October 31-November 2, 1990--Continued

East Branch Red Clay Creek from headwaters to confluence with West Branch, November 1, 1990
Stream mile measured from confluence of East and West Branches Red Clay Creek

				Discharge (ft³/s)				
Stream mile	Site number	Stream	Location	Tributary	Main stream	Gain or loss in tributary [1]	Gain or loss in Red Clay Creek [1]	Total gain or loss in Red Clay Creek [1]
0.5	92	Tributary to Red Clay Creek	Lat. 39°42′51″, long. 75°38′40″, at Route 4	0.26	--	--	--	--
.1	93	Red Clay Creek	Lat. 39°42′27″, long. 75°38′40″, near mouth at Wilmington Suburban Water Company	--	32.7	--	+ 2.64	+ 7.63

[1] Includes possible measurement error.
[2] Increase in flow may be due to small unmeasured tributary flowing into stream above this station.
[3] Reported.

Table 28.--Results of chemical analysis for organochlorine insecticides, organophosphorus insecticides, polychlorinated biphenols, and polychlorinated naphthalenes

[ND, not detected, detection limit unknown; µg/L, micrograms per liter; --, no data; <, less than; PCB, polychlorinated biphenols; PCN, polychlorinated naphthalenes]

Well number	Date of sample	Aldrin, total (µg/L)	Lindane, total (µg/L)	Chlordane, total (µg/L)	DDD, total (µg/L)	DDE, total (µg/L)	DDT, total (µg/L)	Dieldrin, total (µg/L)	Endosulfan, total (µg/L)	Endrin, total (µg/L)	Toxaphene total (µg/L)	Heptachlor, total (µg/L)	Perthane, total (µg/L)
CH-31	07-07-83	<0.010	<0.010	<0.1	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<1	<0.010	<0.1
31	05-16-84	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
45	06-16-82	--	--	--	--	--	--	--	--	--	--	--	--
45	08-04-82	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
69	06-03-80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
69	05-07-81	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<.1	<.010	<.1
69	05-16-84	<.001	<.001	<.1	<.001	<.001	<.001	<.001	<.001	<.001	<1	<.001	<.1
69	07-06-88	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
71	07-21-86	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
2015	08-30-89	<.010	.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
2061	06-24-82	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
2414	08-26-80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2414	05-07-81	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<.1	<.010	<.1
2586	08-08-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
2591	08-05-87	<.010	.020	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	.010	<.1
3084	08-05-87	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3130	09-02-87	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3293	06-02-88	<.010	.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3307	06-30-88	--	--	--	--	--	--	--	--	--	--	--	--
3308	06-30-88	<.010	.010	<.1	<.010	<.010	<.010	.010	<.010	<.010	<1	<.010	<.1
3310	07-06-88	<.010	.020	<.1	<.010	<.010	.040	<.010	<.010	<.010	<1	<.010	<.1
3310	06-02-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3310	07-19-90	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3323	08-15-88	<.010	.030	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3356	06-02-89	<.010	--	--	<.010	<.010	--	--	--	--	--	<.010	--
3458	08-03-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3467	08-09-89	<.010	<.010	<.1	.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3468	08-14-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3469	08-15-89	<.010	<.010	<.1	<.010	<.010	.021	<.010	<.010	<.010	<1	<.010	<.1
3470	08-16-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3471	08-16-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3472	08-17-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3473	08-23-89	<.010	<.010	<.1	<.010	<.010	<.010	.021	<.010	<.010	<1	<.010	<.1
3474	08-24-89	<.010	.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3478	09-01-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
3539	08-30-89	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
4004	08-01-90	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
4005	08-14-90	<.010	<.010	<.1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1
4023	09-04-90	<.010	<.010	< 1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	< 1
4024	09-04-90	<.010	<.010	< 1	<.010	<.010	<.010	<.010	<.010	<.010	<1	<.010	<.1

Table 28.--Results of chemical analysis for organochlorine insecticides, organophosphorus insecticides, polychlorinated biphenols, and polychlorinated naphthalenes--Continued

Hepta-chlor epoxide, total (µg/L)	Meth-oxy-chlor, total (µg/L)	Mirex, total (µg/L)	Di-syston, total (µg/L)	Phorate, total (µg/L)	DEF, total (µg/L)	Ethion, total (µg/L)	Mala-thion, total (µg/L)	Mala-thion, dis-solved (µg/L)	Para-thion, total (µg/L)	Para-thion, dis-solved (µg/L)	Di-azinon, total (µg/L)	Date of sample	Well number
<0.01	<0.01	<0.01	--	--	--	--	--	--	--	--	--	07-07-83	CH- 31
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	05-16-84	31
--	--	--	--	--	--	--	--	--	--	--	--	06-16-82	45
.010	<.01	<.01	--	--	--	--	--	--	--	--	--	08-04-82	45
ND	ND	ND	--	--	--	--	--	--	--	--	--	06-03-80	69
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	07-07-81	69
<.001	<.01	<.01	--	--	--	<0.01	<0.01	--	<0.01	--	<0.01	05-16-84	69
<.010	<.01	<.01	--	--	--	--	--	0.01	--	<0.01	--	07-06-88	69
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	07-21-86	71
<.010	<.01	<.01	<0.01	<0.01	<0.01	<.01	<.01	--	<.01	--	<.01	08-30-89	2015
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	06-24-82	2061
ND	ND	ND	--	--	--	--	--	--	--	--	--	08-26-80	2414
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	05-07-81	2414
<.010	<.01	<.01	--	--	--	<.01	<.01	--	<.01	--	<.01	08-08-89	2586
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	08-05-87	2591
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	08-05-87	3084
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	09-02-87	3130
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	06-02-88	3293
--	--	--	--	--	--	--	--	--	--	--	--	06-30-88	3307
<.010	.01	<.01	--	--	--	--	--	--	--	--	--	06-30-88	3308
<.010	.11	<.01	--	--	--	--	--	--	--	--	--	07-06-88	3310
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	06-02-89	3310
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	07-19-90	3310
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	08-15-88	3323
--	--	<.01	--	--	--	<.01	<.01	--	<.01	--	.01	06-02-89	3356
<.010	<.01	<.01	--	--	--	<.01	<.01	--	<.01	--	.01	08-03-89	3458
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	.01	--	<.01	08-09-89	3467
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	.03	08-14-89	3468
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	08-15-89	3469
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	08-16-89	3470
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	08-16-89	3471
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	08-17-89	3472
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	08-23-89	3473
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	08-24-89	3474
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	09-01-89	3478
<.010	<.01	<.01	<.01	.02	<.01	<.01	<.01	--	<.01	--	<.01	08-30-89	3539
<.010	<.01	<.01	--	--	--	--	--	--	--	--	--	08-01-90	4004
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	08-14-90	4005
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	09-04-90	4023
<.010	<.01	<.01	<.01	<.01	<.01	<.01	<.01	--	<.01	--	<.01	09-04-90	4024

Table 28.--Results of chemical analysis for organochlorine insecticides, organophosphorus insecticides, polychlorinated biphenols, and polychlorinated naphthalenes--Continued

Well number	Date of sample	Di-azinon, dis-solved, total (µg/L)	Methyl para-thion, total (µg/L)	Methyl para-thion, dis-solved (µg/L)	Tri-thion, total (µg/L)	Tri-thion, dis-solved (µg/L)	Methyl tri-thion, total (µg/L)	Methyl tri-thion, dis-solved (µg/L)	Ethion, dis-solved (µg/L)	PCB, total (µg/L)	PCN, total (µg/L)
CH-31	07-07-83	--	--	--	--	--	--	--	--	<0.1	<0.10
31	05-16-84	--	--	--	--	--	--	--	--	<.1	<.10
45	06-16-82	--	--	--	--	--	--	--	--	--	--
45	08-04-82	--	--	--	--	--	--	--	--	<.1	<.10
69	06-03-80	--	--	--	--	--	--	--	--	0	0.0
69	05-07-81	--	--	--	--	--	--	--	--	<.1	<.10
69	05-16-84	--	<0.01	--	<0.01	--	<0.01	--	--	<.1	<.10
69	07-06-88	2.6	--	<0.01	--	<0.01	--	<0.01	<0.01	<.1	<.10
71	07-21-86	--	--	--	--	--	--	--	--	<.1	<.10
2015	08-30-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
2061	06-24-82	--	--	--	--	--	--	--	--	<.1	<.10
2414	08-26-80	--	--	--	--	--	--	--	--	0	0.0
2414	05-07-81	--	--	--	--	--	--	--	--	<.1	<.10
2586	08-08-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
2591	08-05-87	--	--	--	--	--	--	--	--	<.1	<.10
3084	08-05-87	--	--	--	--	--	--	--	--	<.1	<.10
3130	09-02-87	--	--	--	--	--	--	--	--	<.1	<.10
3293	06-02-88	--	--	--	--	--	--	--	--	<.1	<.10
3307	06-30-88	<.01	--	<.01	--	<.01	--	<.01	<.01	--	--
3308	06-30-88	--	--	--	--	--	--	--	--	<.1	<.10
3310	07-06-88	--	--	--	--	--	--	--	--	<.1	<.10
3310	06-02-89	--	--	--	--	--	--	--	--	<.1	<.10
3310	07-19-90	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3323	08-15-88	--	--	--	--	--	--	--	--	<.1	<.10
3356	06-02-89	--	<.01	--	<.01	--	<.01	--	--	<.1	--
3458	08-03-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3467	08-09-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3468	08-14-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3469	08-15-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3470	08-16-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3471	08-16-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3472	08-17-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3473	08-23-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3474	08-24-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3478	09-01-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
3539	08-30-89	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
4004	08-01-90	--	--	--	--	--	--	--	--	<.1	<.10
4005	08-14-90	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10
4023	09-04-90	--	<.01	--	.01	--	<.01	--	--	<.1	<.10
4024	09-04-90	--	<.01	--	<.01	--	<.01	--	--	<.1	<.10

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Table 29.--Results of chemical analysis for volatile organic compounds, base neutral compounds, and phenols

[ND, not detected, detection limit unknown; µg/L, micrograms per liter; --, no data; <, less than]

Well number	Date of sample	Di-chloro-bromo-methane, total (µg/L)	Carbon tetra-chlo-ride, total (µg/L)	1,2-di-chloro-ethane, total (µg/L)	Bromo-form, total (µg/L)	Chloro-di-bromo-methane, total (µg/L)	Chloro-form, total (µg/L)	Toluene, total (µg/L)	Benzene, total (µg/L)	Chloro-benzene, total (µg/L)	Chloro-ethane, total (µg/L)	Ethyl-benzene, total (µg/L)
CH- 31	07-07-83	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	--	<1.0
31	05-16-84	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0
45	06-16-82	--	--	--	--	--	--	--	--	--	--	--
45	08-04-82	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
69	06-03-80	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
69	05-07-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
69	05-16-84	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--	<3.0
69	07-06-88	--	--	--	--	--	--	--	--	--	--	--
71	07-21-86	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
2061	06-24-82	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.0	<1.0	<1.0	<1.0
2414	08-26-80	ND	ND	ND	ND	ND	ND	7.0	ND	ND	ND	ND
2414	05-07-81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2586	08-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
2591	08-05-87	--	--	--	--	--	--	--	--	--	--	--
3084	08-05-87	--	--	--	--	--	--	--	--	--	--	--
3110	08-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
3130	09-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
3321	08-15-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
4004	08-01-90	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
4005	08-14-90	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
4023	09-04-90	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0

Table 29.--Results of chemical analysis for volatile organic compounds, base neutral compounds, and phenols--Continued

Methyl bromide, total (µg/L)	Methyl chlo-ride, total (µg/L)	Methyl-ene chlo-ride, total (µg/L)	Tetra-chloro-ethyl-ene, total (µg/L)	Tri-chloro-fluoro-methane, total (µg/L)	1,1-Di-chloro-ethane, total (µg/L)	1,1-Di-chloro-ethyl-ene, total (µg/L)	1,1,1-Tri-chloro-ethane, total (µg/L)	1,1,2-Tri-chloro-ethane, total (µg/L)	1,1,2,2-Tetra-chloro-ethane, total (µg/L)	Date of sample	Well number
--	--	<1.0	400	--	<1.0	<1.0	<1.0	<1.0	<1.0	07-07-83	CH- 31
--	--	<3.0	290	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	05-16-84	31
--	--	--	--	--	--	--	--	--	--	06-16-82	45
<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	08-04-82	45
ND	--	ND	ND	ND	ND	ND	ND	ND	ND	06-03-80	69
ND	--	ND	ND	ND	ND	ND	ND	ND	ND	05-07-81	69
--	--	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	05-16-84	69
--	--	--	--	--	--	--	--	--	--	07-06-88	69
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	07-21-86	71
<1.0	--	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	06-24-82	2061
ND	--	ND	ND	ND	ND	ND	ND	ND	ND	08-26-80	2414
ND	--	ND	ND	ND	ND	ND	ND	ND	ND	05-07-81	2414
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	08-08-89	2586
--	--	--	--	--	--	--	--	--	--	08-05-87	2591
--	--	--	--	--	--	--	--	--	--	08-05-87	3084
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	08-25-87	3110
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	09-02-87	3130
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	08-15-88	3321
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	08-01-90	4004
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	08-14-90	4005
<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	09-04-90	4023

Table 29.--Results of chemical analysis for volatile organic compounds, base neutral compounds, and phenols--Continued

Well number	Date of sample	1,2-Di-chloro-benzene, total (µg/L)	1,2-Di-chloro-propane, total (µg/L)	Trans-1,2-di-chloro-ethene, total (µg/L)	1,3-Di-chloro-propene, total (µg/L)	1,3-Di-chloro-benzene, total (µg/L)	1,4-Di-chloro-benzene, total (µg/L)	2-Chloro-ethyl-vinyl-ether, total (µg/L)	Di-chloro-di-fluoro-methane, total (µg/L)	Trans-1,3-di-chloro-propene, total (µg/L)	Cis-1,3-di-chloro-propene total (µg/L)	Penta-chloro-phenol, total (µg/L)
CH- 31	07-07-83	--	<1.0	<1.0	<1.0	--	--	<1.0	--	--	--	<1.0
31	05-16-84	<1.0	<3.0	<3.0	--	<1.0	<1.0	--	<3.0	--	--	<1.0
45	06-16-82	--	--	--	--	--	--	--	--	--	--	--
45	08-04-82	--	<1.0	<1.0	<1.0	--	--	<1.0	<1.0	--	--	--
69	06-03-80	--	ND	ND	ND	--	--	ND	ND	--	--	--
69	05-07-81	--	ND	ND	ND	--	--	ND	ND	--	--	--
69	05-16-84	<1.0	<3.0	<3.0	--	<1.0	<1.0	--	<3.0	--	--	<1.0
69	07-06-88	<5.0	--	--	--	<5.0	<5.0	--	--	--	--	--
71	07-21-86	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
2061	06-24-82	--	<1.0	<1.0	<1.0	--	--	<1.0	<1.0	--	--	--
2414	08-26-80	--	ND	ND	ND	--	--	ND	ND	--	--	--
2414	05-07-81	--	ND	ND	ND	--	--	ND	ND	--	--	--
2586	08-08-89	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
2591	08-05-87	--	--	--	--	--	--	--	--	--	--	--
3084	08-05-87	--	--	--	--	--	--	--	--	--	--	--
3110	08-25-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
3130	09-02-87	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
3321	08-15-88	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
4004	08-01-90	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
4005	08-14-90	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--
4023	09-04-90	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	--

Table 29.--Results of chemical analysis for volatile organic compounds, base neutral compounds, and phenols--Continued

1,2-Dibromo ethylene, total (µg/L)	Vinyl chloride, total (µg/L)	Trichloroethylene, total (µg/L)	Hexachlorobenzene, total (µg/L)	Hexachlorobutadiene, total (µg/L)	Styrene, total (µg/L)	1,2-Dibromoethane, total (µg/L)	Xylene, total (µg/L)	Phenols, total (µg/L)	Date of sample	Well number
--	--	8.0	--	--	--	--	--	<1	07-07-83	CH- 31
--	--	5.1	<1.0	<1.0	--	--	--	<1	05-16-84	31
--	--	--	--	--	--	--	--	--	06-16-82	45
--	<1.0	<1.0	--	--	--	--	--	<1	08-04-82	45
--	ND	1.0	--	--	--	--	--	ND	06-03-80	69
--	ND	ND	--	--	--	--	--	ND	05-07-81	69
--	--	<3.0	<1.0	<1.0	--	--	--	<1	05-16-84	69
--	--	--	<5.0	<5.0	--	--	--	--	07-06-88	69
<3.0	<3.0	<3.0	<5.0	<5.0	<3.0	--	--	<1	07-21-86	71
--	<1.0	<1.0	--	--	--	--	--	2	06-24-82	2061
--	ND	ND	--	--	--	--	--	ND	08-26-80	2414
--	ND	ND	--	--	--	--	--	ND	05-07-81	2414
--	<1.0	<3.0	--	--	<3.0	<3.0	<3.0	8	08-08-89	2586
--	--	--	--	--	--	--	--	1	08-05-87	2591
--	--	--	--	--	--	--	--	1	08-05-87	3084
<3.0	<3.0	<3.0	--	--	<3.0	--	<3.0	3	08-25-87	3110
<3.0	<3.0	<3.0	--	--	<3.0	--	<3.0	2	09-02-87	3130
<3.0	<3.0	<3.0	--	--	<3.0	--	<3.0	--	08-15-88	3321
--	<1.0	<3.0	--	--	<3.0	<3.0	<3.0	<1	08-01-90	4004
--	<1.0	<3.0	--	--	<3.0	<3.0	<3.0	<1	08-14-90	4005
--	<1.0	<3.0	--	--	<3.0	<3.0	<3.0	2	09-04-90	4023

Table 30.--Results of chemical analyes for nutrients

[ND, not detected, detection limit unknown; mg/L, milligrams per liter; --, no data; <, less than; dis, dissolved]

Well number	Date of sample	Nitrogen, organic, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Phosphate, ortho, dissolved (mg/L as PO_4)	Phosphate, ortho, dissolved (mg/L as P)	Nitrogen, ammonia, dissolved (mg/L as NH_4)
CH-21	04-15-58	--	--	--	1.80	--	--	--	--	--
30	04-14-58	--	--	--	19.0	--	--	--	--	--
30	05-22-59	--	--	--	17.0	--	--	--	--	--
31	07-07-83	--	<0.010	<0.010	--	--	7.80	--	--	--
35	04-14-58	--	--	--	9.70	--	--	--	--	--
35	05-12-58	--	--	--	9.50	--	--	--	--	--
35	05-22-59	--	--	--	8.60	--	--	--	--	--
41	05-22-59	--	--	--	1.80	--	--	--	--	--
43	04-14-58	--	--	--	7.70	--	--	--	--	--
43	05-25-59	--	--	--	8.60	--	--	--	--	--
44	05-22-59	--	--	--	12.0	--	--	--	--	--
45	08-08-58	--	--	--	2.50	--	--	--	--	--
45	05-22-59	--	--	--	3.40	--	--	--	--	--
45	06-16-82	--	.010	<.010	--	--	3.90	--	--	0.01
46	04-15-58	--	--	--	3.60	--	--	--	--	--
47	04-15-58	--	--	--	6.30	--	--	--	--	--
48	05-22-59	--	--	--	4.50	--	--	--	--	--
52	05-25-59	--	--	--	3.20	--	--	--	--	--
54	05-25-59	--	--	--	.070	--	--	--	--	--
69	06-03-80	--	.020	.010	2.99	--	3.00	--	--	.03
69	05-07-81	--	.050	<.010	--	--	3.20	--	--	.06
69	05-16-84	--	<.010	<.010	--	--	5.70	--	--	--
69	07-06-88	--	.020	<.010	--	--	.700	--	--	.03
459	09-25-25	--	--	--	.340	--	--	--	--	--
468	09-25-25	--	--	--	.40	--	--	--	--	--
1943	10-22-74	ND	.070	<.010	.110	0.07	.110	0.12	0.040	.09
2015	08-30-89	--	.010	.060	2.84	--	2.90	--	--	.01
2061	06-24-82	--	.010	<.010	--	--	7.80	--	--	.01
2414	08-26-80	--	.010	.00	7.50	--	7.50	--	--	.01
2414	05-07-81	--	.040	<.010	--	--	5.30	--	--	.05

Table 30.--Results of chemical analyes for nutrients--Continued

Well number	Date of sample	Nitrogen, organic, dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, ammonia + organic dis. (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Phosphate, ortho, dissolved (mg/L as PO_4)	Phosphate, ortho, dissolved (mg/L as P)	Nitrogen, ammonia, dissolved (mg/L as NH_4)
CH- 2586	08-08-89	--	0.010	<0.010	--	--	4.70	--	--	0.01
2591	08-05-87	--	<.010	<.010	--	0.90	6.80	--	<0.010	--
3084	08-05-87	--	.010	<.010	--	<.20	.970	0.06	.020	.01
3110	08-25-87	--	<.010	<.010	--	--	6.50	--	--	--
3130	09-02-87	--	<.010	<.010	--	2.2	14.0	--	<.010	--
3293	06-02-88	0.77	.030	<.010	--	.80	17.0	--	<.010	.04
3307	06-30-88	--	.020	<.010	--	--	6.40	--	--	.03
3308	06-30-88	--	.020	<.010	--	--	15.0	--	--	.03
3310	07-06-88	--	.010	<.010	--	--	14.0	--	--	.01
3310	06-02-89	--	<.010	<.010	--	--	12.0	--	--	--
3312	07-07-88	--	.010	<.010	--	--	14.0	--	--	.01
3313	07-08-88	--	.020	<.010	--	--	13.0	--	--	.03
3314	07-11-88	--	.010	<.010	--	--	3.20	--	--	.01
3318	08-08-88	--	<.010	<.010	--	--	.720	--	--	--
3321	08-15-88	--	<.010	<.010	--	.40	6.50	.06	.020	--
3323	08-15-88	--	.100	.010	1.79	--	1.80	--	--	.13
3356	06-02-89	--	<.010	<.010	--	--	6.90	--	--	--
3458	08-03-89	--	<.010	.020	5.28	--	5.30	--	--	--
3467	08-09-89	--	<.010	<.010	--	--	15.0	--	--	--
3468	08-14-89	--	<.010	<.010	--	--	8.60	--	--	--
3469	08-15-89	--	<.010	<.010	--	--	1.60	--	--	--
3470	08-16-89	--	<.010	<.010	--	--	2.70	--	--	--
3471	08-16-89	--	<.010	<.010	--	--	1.30	--	--	--
3472	08-17-89	--	<.010	<.010	--	--	4.90	--	--	--
3473	08-23-89	--	.030	<.010	--	--	1.30	--	--	.04
3474	08-24-89	--	<.010	<.010	--	--	6.00	--	--	--
3478	09-01-89	--	.020	<.010	--	--	<.100	--	--	.03
3539	08-30-89	--	.010	<.010	--	--	<.100	--	--	.01
4004	08-01-90	--	.050	<.010	--	--	.400	--	--	.06
4005	08-14-90	--	<.010	<.010	--	--	.700	--	--	--
4023	09-04-90	--	<.010	<.010	--	--	1.30	--	--	--
4024	09-04-90	--	<.010	<.010	--	--	3.80	--	--	--

Table 31.--Results of chemical analyses for metals and other trace constituents

[µg/L, micrograms per liter; --, no data; ND, not detected, detection limit unknown; <, less than]

Well number	Date of sample	Arsenic, dis-solved (µg/L as As)	Barium, dis-solved (µg/L as Ba)	Boron, dis-solved (µg/L as B	Cadmium, dis-solved (µg/L as Cd)	Chro-mium, dis-solved (µg/L as Cr)	Cobalt, dis-solved (µg/L as Co)	Copper, dis-solved (µg/L as Cu)	Iron, dis-solved (µg/L as Fe)	Lead, dis-solved (µg/L as Pb)
CH-31	07-07-83	1	--	--	<1.0	<1	--	7	3	4
45	08-08-58	--	--	--	--	--	--	--	40	--
45	08-04-82	1	--	--	<1.0	<1	--	8	4	1
46	04-15-58	--	--	--	--	--	--	--	230	--
69	06-03-80	1	--	--	4.0	1	--	--	10	ND
69	05-07-81	ND	--	--	<1.0	ND	--	--	<10	ND
69	07-06-88	<1	--	--	<1.0	<1	--	11	3	<5
71	07-21-86	<1	--	--	<1.0	<10	--	2	--	<5
459	09-25-25	--	--	--	--	--	--	--	310	--
468	09-25-25	--	--	--	--	--	--	--	50	--
1943	10-22-74	<1	<100	<20	ND	ND	<2	ND	120	2
2015	08-30-89	--	--	--	--	--	--	--	20	--
2061	06-24-82	1	--	--	1.0	1	--	60	10	<1
2062	10-22-87	--	120	--	--	--	--	--	7	--
2414	08-26-80	1	--	--	ND	2	--	--	10	ND
2414	05-07-81	ND	--	--	<1.0	ND	--	--	<10	ND
2586	08-08-89	<1	--	--	<1.0	<1	--	200	36	2
3110	08-25-87	1	--	--	<1.0	20	--	24	7	<5
3129	09-02-87	--	82	--	--	--	--	--	70	--
3310	06-02-89	--	--	--	--	--	--	--	40	--
3310	07-19-90	--	--	--	--	--	--	--	10	--
3356	06-02-89	<1	--	--	<1.0	<1	--	37	15	2
3458	08-03-89	--	--	--	--	--	--	--	<10	--
3467	08-09-89	--	--	--	--	--	--	--	20	--
3468	08-14-89	--	--	--	--	--	--	--	20	--
3469	08-15-89	--	--	--	--	--	--	--	10	--
3470	08-16-89	--	--	--	--	--	--	--	30	--
3471	08-16-89	--	--	--	--	--	--	--	180	--
3472	08-17-89	--	--	--	--	--	--	10	--	--
3473	08-23-89	--	--	--	--	--	--	--	20	--
3474	08-24-89	--	--	--	--	--	--	--	10	--
3478	09-01-89	--	--	--	--	--	--	--	10	--
3539	08-30-89	--	--	--	--	--	--	--	4,000	--
4004	08-01-90	--	--	--	--	--	--	--	50	--
4005	08-14-90	<1	--	--	<1.0	<1	--	2	280	<1
4023	09-04-90	<1	--	--	<1.0	<1	--	180	10	1
4024	09-04-90	--	--	--	--	--	--	--	10	--

Table 31.--Results of chemical analysis for metals and other trace constituents--Continued

Manganese, dissolved (µg/L as Mn)	Nickel, dissolved (µg/L as Ni)	Silver, dissolved (µg/L as Ag)	Zinc, dissolved (µg/L as Zn)	Aluminum, dissolved (µg/L as Al)	Lithium, dissolved (µg/L as Li)	Selenium, dissolved (µg/L as Se)	Mercury, dissolved (µg/L as Hg)	Date of sample	Well number
<1	1	--	51	--	--	1	<0.1	07-07-83	CH- 31
70	--	--	--	ND	--	--	--	08-08-58	45
4	1	--	7	--	--	<1	.1	08-04-82	45
70	--	--	--	--	--	--	--	04-15-58	46
30	ND	--	--	--	--	--	.1	06-03-80	69
10	ND	--	--	--	--	--	<.1	05-07-81	69
1	--	--	140	--	--	--	1.1	07-06-88	69
--	1	--	--	--	--	--	--	07-21-86	71
--	--	--	--	--	--	--	--	09-25-25	459
--	--	--	--	--	--	--	--	09-25-25	468
<10	3	ND	20	10	<10	<2	<.5	10-22-74	1943
60	--	--	--	--	--	--	--	08-30-89	2015
2	<1	--	16	--	--	<1	<.1	06-24-82	2061
<1	--	--	--	--	--	--	--	10-22-87	2062
10	1	--	--	--	--	--	<.1	08-26-80	2414
<1	ND	--	--	--	--	--	<.1	05-07-81	2414
11	--	--	35	--	--	--	<.1	08-08-89	2586
3	--	--	34	--	--	--	--	08-25-87	3110
5	--	--	--	--	--	--	--	09-02-87	3129
10	--	--	--	--	--	--	--	06-02-89	3310
10	--	--	--	--	--	--	--	07-19-90	3310
4	--	--	90	--	--	--	<.1	06-02-89	3356
<10	--	--	--	--	--	--	--	08-03-89	3458
<10	--	--	--	--	--	--	--	08-09-89	3467
<10	--	--	--	--	--	--	--	08-14-89	3468
10	--	--	--	--	--	--	--	08-15-89	3469
20	--	--	--	--	--	--	--	08-16-89	3470
<10	--	--	--	--	--	--	--	08-16-89	3471
<10	--	--	--	--	--	--	--	08-17-89	3472
<10	--	--	--	--	--	--	--	08-23-89	3473
<10	--	--	--	--	--	--	--	08-24-89	3474
<10	--	--	--	--	--	--	--	09-01-89	3478
80	--	--	--	--	--	--	--	08-30-89	3539
20	--	--	--	--	--	--	--	08-01-90	4004
67	--	--	<3	--	--	--	<.1	08-14-90	4005
6	--	--	20	--	--	--	<.1	09-04-90	4023
10	--	--	--	--	--	--	--	09-04-90	4024

Table 32.--Results of chemical analyses for physical properties, selected common ions, and radionuclides

[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; pCi/L, picocuries per liter; µg/L, micrograms per liter; --, no data; <, less than]

Well number	Date of sample	Temperature, water (°C)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, standard units	Alkalinity, field (mg/L as $CaCO_3$)	Hardness, total (mg/L as $CaCO_3$)	Solids, residue at 180°C, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium + potassium, dissolved (mg/L as Na)
CH-21	04-15-58	--	115	--	6.2	23	42	--	--	--	--	5.3
30	04-14-58	16.0	464	--	5.8	15	180	--	--	--	--	18
30	05-22-59	16.0	448	--	7.0	13	200	--	--	--	--	7.6
31	07-07-83	14.0	575	--	7.1	200	--	--	--	--	--	--
31	05-16-84	14.0	555	--	6.8	218	--	--	--	--	--	--
35	04-14-58	13.5	321	--	7.1	101	160	--	--	--	--	1.8
35	05-12-58	13.5	--	--	--	--	--	--	--	--	--	--
35	05-22-59	--	325	--	7.7	117	150	--	--	--	--	4.4
41	05-22-59	10.5	210	--	6.1	25	62	--	--	--	--	11
43	04-14-58	13.5	490	--	7.4	189	250	--	--	--	--	8.0
43	05-25-59	--	502	--	8.1	200	250	--	--	--	--	11
44	05-22-59	13.0	101	--	6.1	19	36	--	--	--	--	16
45	08-08-58	12.0	278	--	7.8	121	140	174	31	14	3.7	5.4
45	05-22-59	13.0	285	--	7.8	129	140	--	--	--	--	6.0
45	06-16-82	13.0	355	--	7.3	--	--	--	--	--	--	--
45	08-04-82	12.0	320	--	7.4	--	--	--	--	--	--	--
46	04-15-58	13.5	128	--	6.6	32	39	104	2	2.2	5.5	7.5
47	04-15-58	9.5	217	--	6.2	35	76	--	--	--	--	10
48	05-22-59	13.5	752	--	7.6	258	360	--	--	--	--	6.9
52	05-25-59	--	81	--	6.3	21	24	--	--	--	--	7.1
54	05-25-59	--	224	--	7.3	81	90	--	--	--	--	7.8
69	06-03-80	14.0	850	--	7.0	--	--	--	--	--	--	--
69	05-07-81	15.0	950	--	7.3	--	--	--	--	--	--	--
69	05-16-84	14.0	835	--	7.2	288	--	--	--	--	--	--
69	07-06-88	18.0	850	--	6.9	312	--	528	--	--	--	--
71	07-21-86	13.0	550	--	7.5	152	--	397	--	--	--	--
459	09-25-25	--	--	--	--	25	21	67	4.7	2.3	4.3	5.2
468	09-25-25	12.0	--	--	--	210	250	271	2	29	8.9	10
1943	10-22-74	--	140	--	8.2	40	35	91	13	.60	9.0	10
2015	08-30-89	13.5	331	0.2	6.8	73	--	190	--	--	--	--
2061	06-24-82	16.0	240	--	6.1	--	--	--	--	--	--	--
2062	10-22-87	14.0	270	10.7	6.3	38	88	163	23	7.5	9.6	--
2414	08-26-80	15.5	560	--	7.5	--	--	--	--	--	--	--
2414	05-07-81	13.5	540	--	7.8	--	--	--	--	--	--	--
2586	08-08-89	16.0	208	4.1	5.5	15	--	127	--	--	--	--

Table 32.--Results of chemical analysis for physical properties, selected common ions, and radionuclides--Continued

Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L SiO_2)	Radon-222, total (pCi/L)	Radium-228, dissolved (pCi/L as Ra-228)	Radium-226, dissolved, radon method (pCi/L)	Uranium, natural, dissolved (µg/L as U)	Gross beta, dissolved (pCi/L as Cs-137)	Gross alpha, dissolved (pCi/L as U-nat)	Date of sample	Well number
--	4.0	18	--	--	--	--	--	--	--	--	04-15-58	CH- 21
--	32	92	--	--	--	--	--	--	--	--	04-14-58	30
--	26	100	--	--	--	--	--	--	--	--	05-22-59	30
--	--	--	--	--	--	--	--	--	--	--	07-07-83	31
--	--	--	--	--	--	--	--	--	--	--	05-16-84	31
--	10	10	--	--	--	--	--	--	--	--	04-14-58	35
--	--	--	--	--	--	--	--	--	--	--	05-12-58	35
--	6.0	8.3	--	--	--	--	--	--	--	--	05-22-59	35
--	8.0	42	--	--	--	--	--	--	--	--	05-22-59	41
--	18	25	--	--	--	--	--	--	--	--	04-14-58	43
--	16	20	--	--	--	--	--	--	--	--	05-25-59	43
--	1.0	7.1	--	--	--	--	--	--	--	--	05-22-59	44
1.7	5.8	4.6	0.10	22	--	--	--	--	--	--	08-08-58	45
--	4.0	4.7	--	--	--	--	--	--	--	--	05-22-59	45
--	--	--	--	--	--	--	--	--	--	--	06-16-82	45
--	--	--	--	--	--	--	--	--	--	--	08-04-82	45
2.0	4.3	6.3	.0	23	--	--	--	--	--	--	04-15-58	46
--	10	26	--	--	--	--	--	--	--	--	04-15-58	47
--	35	45	--	--	--	--	--	--	--	--	05-22-59	48
--	2.0	4.3	--	--	--	--	--	--	--	--	05-25-59	52
--	6.0	17	--	--	--	--	--	--	--	--	05-25-59	54
--	--	--	--	--	--	--	--	--	--	--	06-03-80	69
--	--	--	--	--	--	--	--	--	--	--	05-07-81	69
--	--	--	--	--	--	--	--	--	--	--	05-16-84	69
--	48	59	--	--	--	--	--	--	--	--	07-06-88	69
--	24	70	--	--	--	--	--	--	--	--	07-21-86	71
.90	2.1	3.7	--	31	--	--	--	--	--	--	09-25-25	459
1.4	17	13	--	22	--	--	--	--	--	--	09-25-25	468
1.4	2.4	13	.20	22	--	--	--	--	--	--	10-22-74	1943
--	18	33	--	--	530	--	--	--	--	--	08-30-89	2015
--	--	--	--	--	--	--	--	--	--	--	06-24-82	2061
2.7	13	34	.10	23	--	--	--	--	--	--	10-22-87	2062
--	--	--	--	--	--	--	--	--	--	--	08-26-80	2414
--	--	--	--	--	--	--	--	--	--	--	05-07-81	2414
--	15	27	--	--	680	--	--	--	--	--	08-08-89	2586

Table 32.--Results of chemical analyses for physical properties, selected common ions, and radionuclides--Continued

Well number	Date of sample	Temperature, water (°C)	Specific conductance (µS/cm)	Oxygen, dissolved (mg/L)	pH, standard units	Alkalinity, field (mg/L as $CaCO_3$)	Hardness, total (mg/L as $CaCO_3$)	Solids, residue at 180°C, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium + potassium, dissolved (mg/L as Na)
CH-2591	08-05-87	16.0	560	--	7.6	212	--	354	--	--	--	--
3084	08-05-87	14.0	135	--	6.1	28	--	87	--	--	--	--
3110	08-25-87	13.0	270	--	6.1	30	--	173	--	--	--	--
3129	09-02-87	14.5	122	9.3	5.4	13	37	68	3.0	3.5	4.2	--
3130	09-02-87	15.0	310	--	6.2	75	--	215	--	--	--	--
3293	06-02-88	14.5	500	--	6.1	46	--	370	--	--	--	--
3307	06-30-88	14.5	112	7.0	6.1	14	--	93	--	--	--	--
3308	06-30-88	14.0	450	3.2	5.8	57	--	327	--	--	--	--
3310	07-06-88	14.0	320	--	5.5	18	--	225	--	--	--	--
3310	06-02-89	15.5	309	12.6	5.5	14	--	178	--	--	--	--
3310	07-19-90	12.5	290	9.7	5.6	18	--	187	--	--	--	--
3312	07-07-88	14.5	610	--	5.8	40	--	469	--	--	--	--
3313	07-08-88	15.0	620	--	6.3	82	--	418	--	--	--	--
3314	07-11-88	15.0	330	--	6.1	52	--	190	--	--	--	--
3318	08-08-88	15.5	480	--	6.3	68	--	296	--	--	--	--
3321	08-15-88	14.0	140	--	6.1	32	--	109	--	--	--	--
3323	08-15-88	14.0	320	--	6.4	72	--	199	--	--	--	--
3356	06-02-89	15.5	220	7.0	5.8	32	--	123	--	--	--	--
3458	08-03-89	13.5	268	2.2	7.8	52	--	169	--	--	--	--
3467	08-09-89	13.5	360	4.4	6.0	30	--	263	--	--	--	--
3468	08-14-89	16.0	248	10.2	5.7	13	--	196	--	--	--	--
3469	08-15-89	17.5	198	2.8	6.4	41	--	133	--	--	--	--
3470	08-16-89	15.5	132	8.1	6.1	21	--	77	--	--	--	--
3471	08-16-89	13.0	169	5.7	5.8	18	--	86	--	--	--	--
3472	08-17-89	14.0	320	9.9	6.1	26	--	153	--	--	--	--
3473	08-23-89	15.0	220	4.6	6.2	32	--	139	--	--	--	--
3474	08-24-89	16.5	502	4.9	7.7	171	--	263	--	--	--	--
3478	09-01-89	14.0	224	1.0	9.5	79	--	123	--	--	--	--
3539	08-30-89	14.0	20	0	6.3	41	--	118	--	--	--	--
4004	08-01-90	19.0	137	4.9	7.2	57	--	78	--	--	--	--
4005	08-14-90	13.5	152	6.0	6.7	28	--	86	--	--	--	--
4023	09-04-90	15.5	249	7.0	5.6	18	--	156	--	--	--	--
4024	09-04-90	13.5	222	7.1	5.9	39	--	137	--	--	--	--

Table 32.--Results of chemical analysis for physical properties, selected common ions, and radionuclides--Continued

Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L SiO_2)	Radon-222, total (pCi/L)	Radium-228, dissolved (pCi/L as Ra-228)	Radium-226, dissolved, radon method (pCi/L)	Uranium, natural, dissolved (µg/L as U)	Gross beta, dissolved (pCi/L as Cs-137)	Gross alpha, dissolved (pCi/L as U-nat)	Date of sample	Well number
--	23	53	--	--	--	--	--	--	--	--	08-05-87	CH-2591
--	8.7	18	--	--	--	--	--	--	--	--	08-05-87	3084
--	21	39	--	--	--	--	--	--	--	--	08-25-87	3110
2.7	6.6	18	<0.10	18	900	<0.40	0.20	<0.05	3.1	1.3	09-02-87	3129
--	13	9.8	--	--	--	--	--	--	--	--	09-02-87	3130
--	17	110	--	--	--	--	--	--	--	--	06-02-88	3293
--	4.6	5.6	--	--	--	--	--	--	--	--	06-30-88	3307
--	49	38	--	--	--	--	--	--	--	--	06-30-88	3308
--	27	29	--	--	--	--	--	--	--	--	07-06-88	3310
--	26	34	--	--	240	--	--	--	--	--	06-02-89	3310
--	18	32	--	--	--	--	--	--	--	--	07-19-90	3310
--	90	64	--	--	--	--	--	--	--	--	07-07-88	3312
--	27	140	--	--	--	--	--	--	--	--	07-08-88	3313
--	41	33	--	--	--	--	--	--	--	--	07-11-88	3314
--	76	54	--	--	--	--	--	--	--	--	08-08-88	3318
--	5.5	5.1	--	--	--	--	--	--	--	--	08-15-88	3321
--	39	27	--	--	--	--	--	--	--	--	08-15-88	3323
--	10	25	--	--	4,200	--	--	--	--	--	06-02-89	3356
--	14	24	--	--	640	--	--	--	--	--	08-03-89	3458
--	29	17	--	--	2,700	--	--	--	--	--	08-09-89	3467
--	14	43	--	--	97	--	--	--	--	--	08-14-89	3468
--	15	15	--	--	2,500	--	--	--	--	--	08-15-89	3469
--	3.3	16	--	--	690	--	--	--	--	--	06-16-89	3470
--	9.6	30	--	--	490	--	--	--	--	--	08-16-89	3471
--	11	49	--	--	510	--	--	--	--	--	08-17-89	3472
--	11	37	--	--	2,900	--	--	--	--	--	08-23-89	3473
--	15	29	--	--	240	--	--	--	--	--	08-24-89	3474
--	6.4	15	--	--	320	--	--	--	--	--	09-01-89	3478
--	6.1	42	--	--	180	--	--	--	--	--	08-30-89	3539
--	3.9	6.0	--	--	280	--	--	--	--	--	08-01-90	4004
--	4.4	30	--	--	1,600	--	--	--	--	--	08-14-90	4005
--	38	27	--	--	330	--	--	--	--	--	09-04-90	4023
--	13	34	--	--	2,700	--	--	--	--	--	09-04-90	4024