HYDROLOGY OF THE UNCONFINED AQUIFER SYSTEM, MAURICE RIVER AREA: MAURICE AND COHANSEY RIVERS, NEW JERSEY, 1994-95

By Emmanuel G. Charles, Donald A. Storck, and Rick M. Clawges

ABSTRACT

The Maurice River study area consists principally of two surface-water drainage basins, the Maurice River and Cohansey River Basins, and the unconfined Kirkwood-Cohansey aquifer system that underlies them. In many parts of the study area, this aquifer system is hydraulically connected to overlying surficial deposits that can be as much as about 120 feet thick. A map of water levels in the unconfined ground-water system, constructed from water-level measurements made during April and May 1995 in 231 wells and at 304 stream sites, shows that water levels ranged from sea level to 140 feet above sea level. Seasonal fluctuations of water levels in 22 observation wells were as great as 5.5 feet. The horizontal hydraulic conductivities determined from aquifer tests range from 68 to 250 feet per day, the transmissivities range from 4,000 to 20,000 feet squared per day, and the storage coefficients range from 0.0001 to 0.044.

Approximately 35 percent of the study area is forested, 32 percent is used for agriculture, 16 percent is wetland, 12 percent is urban, 3 percent is water, and 2 percent is barren. The New Jersey Department of Environmental Protection has identified 166 contaminated sites in the study area. Chemical analyses of samples from 56 ground-water and 12 surface-water sites distributed throughout the study area were compiled and analyzed to document the quality of surface water and unconfined ground water. Results of analyses of samples from sites that may be affected by known sources of contamination were not reported. U.S. Environmental Protection Agency primary drinking-water regulations for nitrate plus nitrite were exceeded in 11 of 33 ground-water samples, and regulations for pesticides were exceeded in 1 of 44 ground-water samples. The pattern of ground- and surface-water quality in the study area reflects differences in land use.

Mean annual precipitation in the study area was 42.6 inches during 1932-94. Base-flow separation was used to divide total surface-water discharge in the Maurice River, Menantico Creek, West Branch Cohansey River, and the Cohansey River into base-flow and direct-runoff components. Mean annual base flow was 143 ft^3/s (cubic feet per second), or 87 percent of total flow, for the Maurice River during 1933-94; 32 ft^3/s, or 86 percent of total flow, for Menantico Creek during 1932-57 and 1978-84; 1.8 ft^3/s, or 83 percent of total flow, for West Branch Cohansey River during 1952-67; and 28 ft^3/s, or 80 percent of total flow, for the Cohansey River during 1977-88. In addition, low-flow correlation analyses were made, and mean discharge and base flow at 17 low-flow, partial-record gaging stations were estimated. Mean annual evapotranspiration, estimated from monthly potential evapotranspiration and precipitation, was 24.6 inches for the period 1985-94. Total consumptive water use in the study area from surface water and unconfined ground water was about 8,256 Mgal (million gallons) in 1994: 4,342 Mgal for irrigation, 1,801 Mgal for public and private domestic water supply, 1,952 Mgal for mining, 125 Mgal for industry, and 36 Mgal for commercial use. A water budget calculated for the study area shows that ground-water recharge is about 16 inches per year, or about 37 percent of mean annual precipitation.

INTRODUCTION

Unconfined (water-table) aquifer systems are present throughout most of the Coastal Plain of New Jersey. These aquifer systems are a major source of water supply in the Coastal Plain, and withdrawals from them are expected to increase. Detailed information about these aquifer systems, and the surface-water systems that are hydraulically connected to them, was needed as the basis for decisions that will ensure that the increasing demand for water from these aquifers will be met as the population grows. Therefore, in 1986 the U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection (NJDEP), began to compile data about selected ground- and surface-water systems in New Jersey. These ground- and surface-water systems coincide with Regional Water Resource Planning Areas, which are single drainage basins or groups of drainage basins delineated in the New Jersey Statewide Water Supply Master Plan (CH2M Hill; Metcalf and Eddy, Inc.; and New Jersey First, Inc.; 10 volumes with various publication dates)[1]. Information from this study of the Maurice and Cohansey River Basins can be used to plan for the optimal management of the surface water and unconfined ground water in the basins.

Purpose and Scope

This report presents the results of a 2-year study conducted during 1994-95 to investigate the hydrology of the surface-water and unconfined aquifer systems of the Maurice and Cohansey River Basins, New Jersey (fig. 1-1). The combined areas of these two basins plus the tidal areas and minor tributaries to the Delaware Bay (fig. 1-2), referred to as the Maurice River study area in this report, correspond to Regional Water Resource Planning Area 21, the Maurice River planning area, in the New Jersey Statewide Water Supply Master Plan (CH2M Hill; Metcalf and Eddy, Inc.; and New Jersey First, Inc.; 10 volumes with various publication dates). The extent of hydrogeologic units in the study area was approximated from published maps and reports. New data in this report include the results of water-level measurements in 231 wells and at 304 surface-water sites. Results of chemical analyses of water samples from 56 wells and 12 surface-water sites for selected inorganic and organic constituents are presented and interpreted. Results of base-flow-separation analyses of discharge measurements at 4 streamflow-gaging stations and results of low-flow correlations of streamflow records from 17 low-flow, partial-record stations in the study area are presented. Water budgets developed to estimate recharge in the study area also are presented; the budgets include measurements of precipitation and stream discharge, and estimates of evapotranspiration and water use.

Previous Investigations

County-wide studies of ground-water resources in the study area were authored by Rooney (1971) for Cumberland County, Hardt and Hilton (1969) for Gloucester County, and Rosenau and others (1969) for Salem County. Lacombe and Rosman (1995) describe the unconfined aquifer system in the upper Maurice River Basin and adjacent areas in Gloucester County and present a map of water levels in 1986. General investigations of the study area include water-resource studies by Barksdale and others (1958) and Parker and others (1964). Zapecza (1989) describes the hydrogeologic framework of the Coastal Plain, and Martin (1998) provides an analysis of ground-water flow in the Coastal Plain.

Well-Numbering System

The well-numbering system used in this report is based on the system used by the USGS in New Jersey since 1978. It consists of a county-code number and a sequence number of the well within the county. County codes used in this report are Atlantic (1), Cumberland (11), Gloucester (15), and Salem (33). For example, well number 11-761 represents the 761st well inventoried in Cumberland County. Construction details for wells with this type of identifier are stored in the USGS Ground Water Site Inventory (GWSI) database.

Acknowledgments

The authors acknowledge the cooperation of the many individuals and organizations who allowed us access to their observation, public supply, farm, commercial, industrial, or domestic wells for water-level measurements. We thank Lloyd Mullikin of the New Jersey Geological Survey for sharing his extensive knowledge of the geology in the study area.

Description of the Study Area

The Maurice River study area consists of two principal drainage basins and minor tributaries that together make up an area of approximately 602 mi^2 in parts of Atlantic, Cumberland, Gloucester, and Salem Counties (fig. 1-1, fig. 1-2) and that include all or parts of 27 municipalities (fig. 1-3). (Definitions of abbreviations and conversion factors for units used in the text are shown in table 1-1.) The study area and basin boundaries can be delineated by either topographic divides or ground-water-drainage divides, which are nearly coincident and, for the purposes of this report, are considered to be the same. The study area is a region of relatively low relief and elevation that slopes gently southwestward toward the Delaware Bay. Relatively level tidal marsh and lowland areas border the Delaware Bay and extend from 1 to 6 mi inland. Elevation of the land surface ranges from 160 ft in Washington Township, Gloucester County, to sea level along the Delaware Bay.

Geologic and Hydrogeologic Units

The Maurice River study area lies within the Coastal Plain physiographic province of New Jersey. The geologic units of the Coastal Plain consist of two types of unconsolidated sediments: (1) relatively flat-lying fluvial sediments, called "surficial geologic units," which consist of upper Holocene, Pleistocene, and upper Miocene deposits (younger than the Cohansey Sand) and (2) a seaward-dipping wedge of marine sediments that range in age from middle Miocene to lower Cretaceous (Cohansey Sand and older units). The flat-lying geologic units are present only at the surface and, where present, overlie the older, seaward-dipping geologic units. The interpretations in this report are based on geologic and hydrogeologic data from published maps and reports, three published geophysical-log interpretations (Zapecza, 1989), and two geophysical-log interpretations made as part of this study.

A hydrogeologic unit consists of one or more geologic units that have similar water-bearing and water-transmitting characteristics. Where ground water is present in sand or gravel that is not overlain by a confining unit, and the sand or gravel is sufficiently thick to provide useful quantities of water, that hydrogeologic unit is considered to be an unconfined aquifer. Where ground water is present in silt or clay, the hydrogeologic unit can be considered a "non-aquifer," or confining unit. In this report, a hydrogeologic unit is called "undifferentiated" if ground water is present in geologic material and the distribution, thickness, kind of material, and (or) hydraulic properties are too uncertain or variable to designate the unit as either an aquifer or a confining unit.

Lithologies interpreted from five geophysical well logs were used to construct a hydrogeologic section through the study area (fig. 1-4). Map boundaries of geologic units were used to approximate the boundaries of hydrogeologic units for this study (fig. 1-5, fig. 1-6).

The principal hydrogeologic unit in the Maurice River study area is the Kirkwood-Cohansey aquifer system, which in many areas includes overlying surficial geologic units. The surficial geologic units of Holocene and Pleistocene age that directly overlie the Kirkwood-Cohansey aquifer system are considered an undifferentiated hydrogeologic unit (table 1-2). In order of abundance, the Holocene-age tidal marsh and swamp deposits consist of organic matter, silt, and clay, and the alluvial deposits consist of silt, sand, gravel, and clay (Rooney, 1971). These deposits are relatively thin and are present in and adjacent to stream channels and adjacent to the Delaware Bay. The wetlands shown in figure 1-2 approximate the areal extent of the tidal marsh and swamp deposits. The Pleistocene-age Cape May Formation consists of interbedded sand and silt-clay layers and is present from the Delaware Bay to about 4 to 6 mi inland, and up the Maurice River valley to just across the Gloucester County border (fig. 1-5). Much of the Cape May Formation along the Delaware Bay is covered by Holocene-age tidal marsh and swamp deposits (Rooney, 1971). The extent of this geologic unit is shown in figure 1-5 and is from the map compilation of Johnson (1950). According to Rooney (1971), the Cape May Formation is as much as 120 ft thick in the study area, but is not an important source of ground-water supply.

The Kirkwood-Cohansey aquifer system supplies most of the ground water withdrawn in the study area and consists principally of the Cohansey Sand and the sandy part of the Kirkwood Formation, but locally includes the Bridgeton Formation and sand and gravel parts of the undifferentiated hydrogeologic unit. The Bridgeton Formation is a relatively flat-lying surficial geologic unit that is present over much of the uplands of the study area (fig. 1-5). It consists of sand, clayey sand, and clay-silt layers and can be as much as 50 ft thick in the study area (Owens and Minard, 1979). The Bridgeton Formation is hydraulically connected to the underlying Cohansey Sand. Rooney (1971) noted that few wells actually draw water directly from the Bridgeton Formation. The Cohansey Sand and sand of the Kirkwood Formation make up most of the Kirkwood-Cohansey aquifer system. The Cohansey Sand consists of fine- to coarse-grained, light-colored sand, pebbles, and interbedded clay (Rhodehamel, 1973) and overlies the Kirkwood Formation in the study area. The Kirkwood Formation consists of gray to tan, fine- to medium-grained, micaceous sand, and tan to dark-colored clayey silt (Zapecza, 1989). The Kirkwood-Cohansey aquifer system is underlain by a basal clayey silt that is equivalent to the Alloway Clay Member of the Kirkwood Formation. The altitude and thickness of the base of the Kirkwood-Cohansey aquifer system in the study area are shown in figures 1-6 and 1-7, respectively. In the extreme southeastern part of the study area, the thickness of the entire Kirkwood-Cohansey aquifer system reaches about 550 ft.

Confining units and confined ground water of at least local importance for water supply are present in the Kirkwood-Cohansey aquifer system in the study area; however, the exact extent of these confining units and of confined ground water has not been determined and is not within the scope of this study. Rooney (1971, table 14) reported that many wells screened in the Kirkwood-Cohansey aquifer system near the Delaware Bay and in the eastern part of Cumberland County flowed at the land surface when they were first drilled, indicating the presence of confined ground water. These wells typically were screened at depths of 200 to 370 ft. East of the study area lies a regionally important, thick confining unit within the Kirkwood-Cohansey aquifer system that contains two confined water-bearing units (table 1-2), the Rio Grande water-bearing zone and the Atlantic City 800-foot sand (Zapecza, 1989). The approximate western limit of this confining unit, defined by Zapecza (1989) from geophysical logs, is shown near the southeastern boundary of the study area (figs. 1-6 and 1-7).

Hydraulic Properties of the Unconfined Aquifer

Hydraulic properties of the Kirkwood-Cohansey aquifer system in and near the Maurice River study area were compiled from aquifer-test data. An aquifer test is the withdrawal of measured quantities of water from, or the addition of water to, a well and the measurement of the resulting changes in water levels at nearby locations in the aquifer both during and after the period of withdrawal (Bates and Jackson, 1987). The properties typically derived from aquifer-test results are transmissivity, hydraulic conductivity, and storage coefficient. Locations of aquifer-test sites are shown in figure 1-2.

Reported values of the horizontal hydraulic conductivity of unconfined aquifers in and near the Maurice River study area range from 68 to 250 ft/d (table 1-3). Reported transmissivities (aquifer thickness multiplied by hydraulic conductivity) in and near the study area range from 4,000 to 20,000 ft^2/d. Storage coefficient is a dimensionless value that represents the volume of water an aquifer will release per unit surface area per unit decrease in water level. Reported storage coefficients for aquifers in and near the study area range from 0.0001 to 0.044. Typical storage coefficients for unconfined aquifers (0.01-0.30 (Freeze and Cherry, 1979, p. 61)) are considerably different from most of those reported for aquifers in and near the study area, however. Thus the Kirkwood-Cohansey aquifer system, which is considered to be unconfined, appears to behave as a semiconfined aquifer during aquifer tests. This behavior probably is caused by the presence of discontinuous layers of silt and clay in the Cohansey Formation

[1] Available from the New Jersey Department of Environmental Protection, Trenton, N.J.

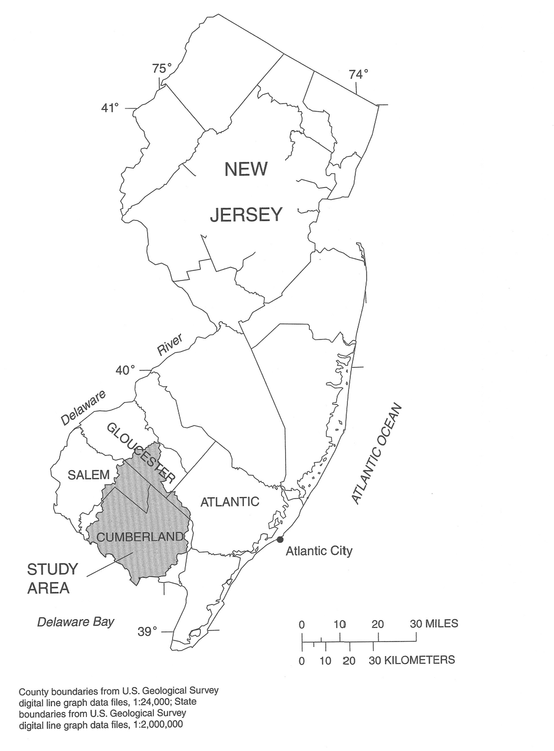

Figure 1-1. Location of the Maurice River study area, New Jersey.

Table 1-1. Conversion factors and vertical datum

Multiply	By	To obtain
	Length	
inch	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
foot per mile (ft/mi)	0.1894	meter per kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
million gallons (Mgal)	3,785	cubic meter
	Flow	
inch per year	2.54	centimeter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon per minute (gal/min)	0.06309	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
million gallons per day (Mgal/d)	0.04381	cubic meter per second
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	square meter per day
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day

Temperature conversion formula: °F = 1.8 × °C + 32

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

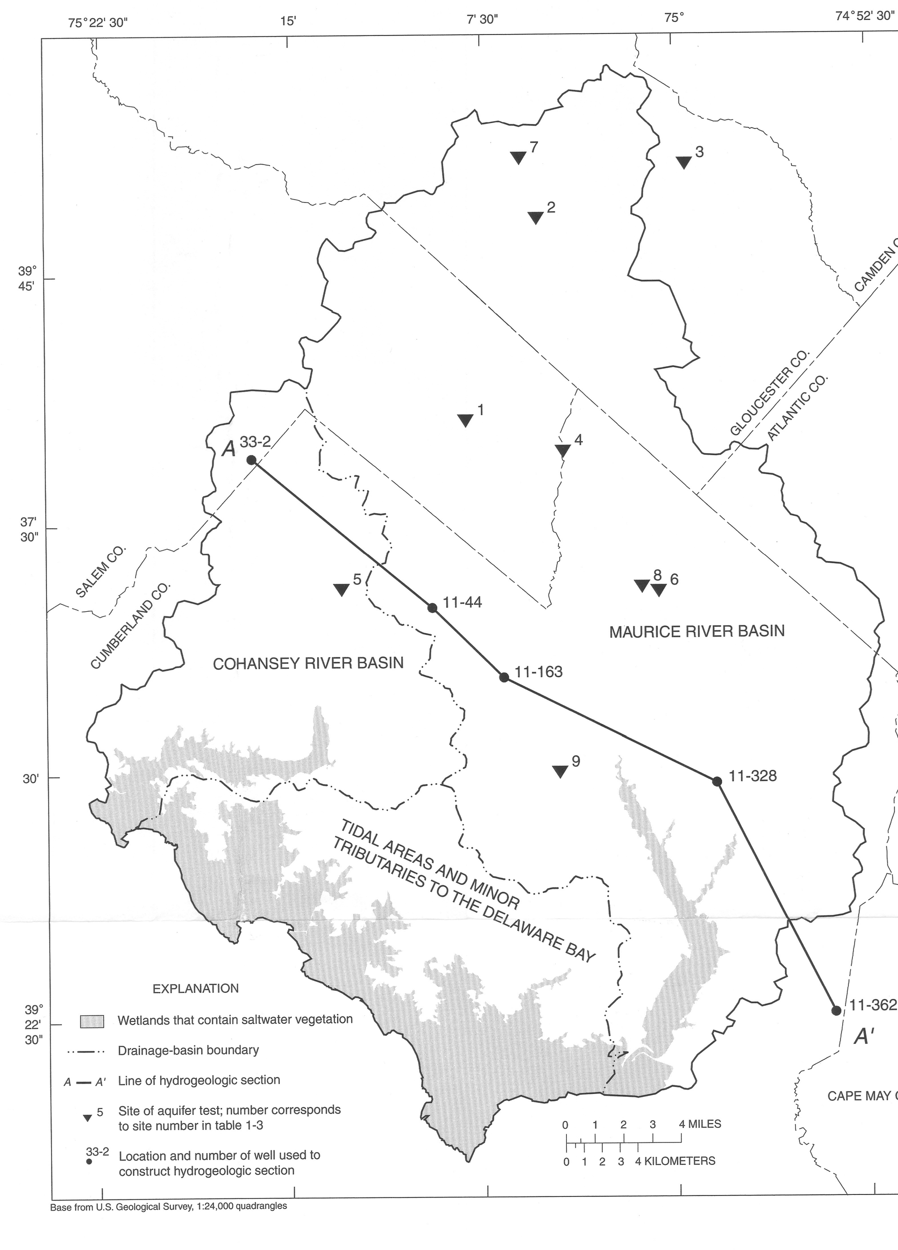

Figure 1-2. Major surface-water drainage basins, location of hydrogeologic section A-A'; sites of aquifer tests, and location of wetlands with saltwater-tolerant vegetation in the Maurice River study area, New Jersey.

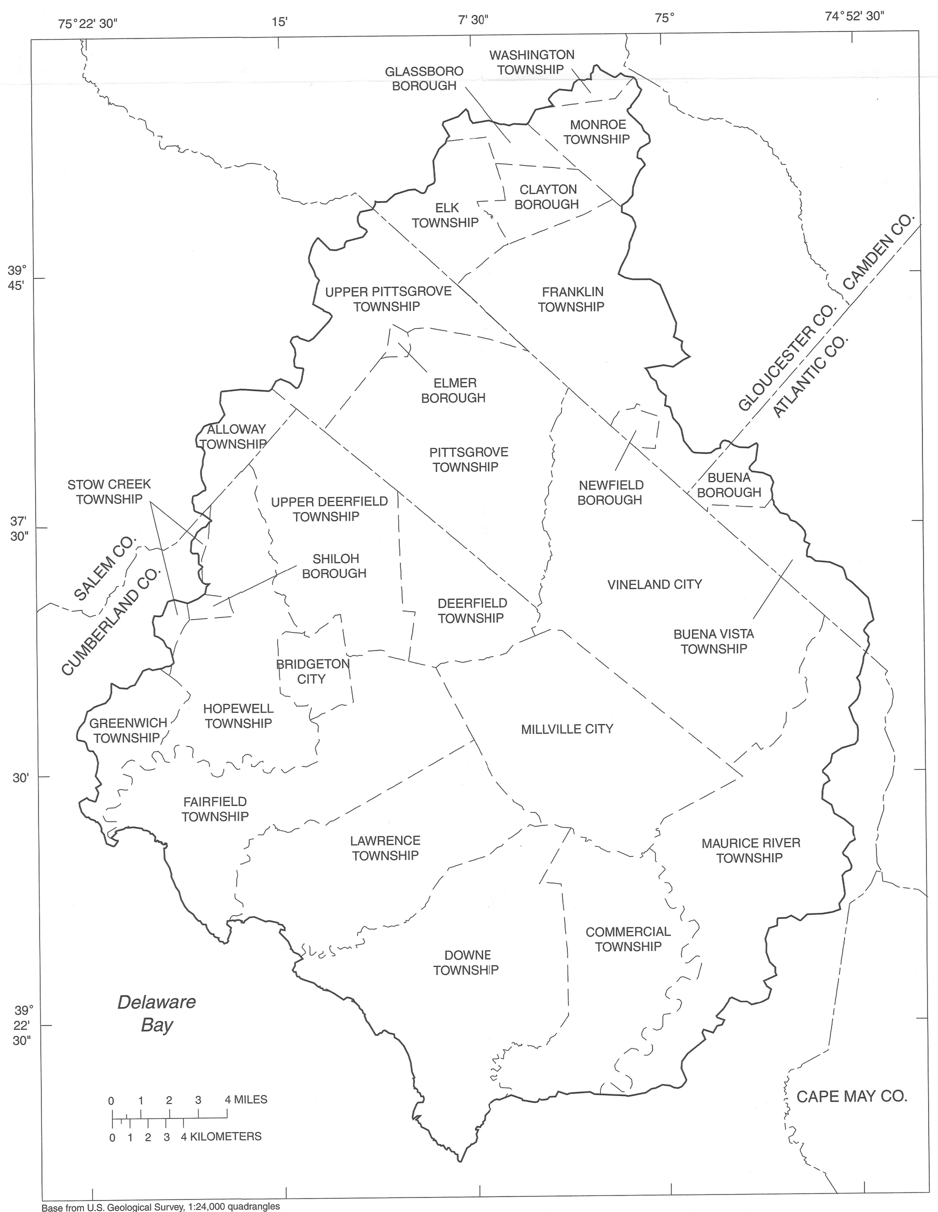

Figure 1-3. Municipalities in the Maurice River study area, New Jersey.

Table 1-2. Stratigraphy and hydrogeologic characteristics of geologic units in the Maurice River study area, New Jersey
[Modified from Zapecza, 1989, table 2]

SERIES	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT		HYDROLOGIC CHARACTERISTICS
Holocene	Tidal marsh and swamp deposits	Organic matter, silt, and clay	Undifferentiated		These fine- and coarse-grained sediments are commonly hydraulically connected to the underlying aquifer system. Locally some units may act as confining layers and others yield significant amounts of water where permeable and thick.
	Alluvial deposits	Silt, sand, gravel, and clay			
Pleistocene	Cape May Formation	Sand and clay-silt layers			
Miocene	Bridgeton Formation	Sand, clayey sand, brown clay-silt layers	Kirkwood-Cohansey aquifer system		These aquifers and confining units make up the major unconfined aquifer system. In some areas, clay and silt layers locally semi-confine the aquifer.
	Cohansey Sand	Sand, quartz, light-colored, fine- to coarse-grained, pebbly; interbedded clay layers			
	Kirkwood Formation	Sand, quartz, gray, tan, fine- to medium-grained, micaceous; tan to dark-colored clayey silt		Confining unit	These confining units, water-bearing zone, and aquifer are significant east of the study area, but the extent of significant thicknesses in the study area is unknown. The confining unit consists of thick, diatomaceous clay; the Rio Grande water-bearing zone is a thin sand within the middle of the clay; and the Atlantic City 800-foot sand is a major confined aquifer.
				Rio Grande water-bearing zone	
				Confining unit	
				Atlantic City 800-foot sand	
			Confining unit		The lower part of the Kirkwood Formation consists of the low-permeability Alloway Clay Member or equivalent.
Eocene	Piney Point Formation	Sand, quartz and glauconitic, fine- to coarse-grained	Piney Point aquifer		This confined aquifer yields moderate amounts of water.
	Manasquan Formation	Clay, silty and sandy, glauconitic, green, gray, and brown; fine-grained quartz sand	Confining unit		This confining unit consists of low-permeability sediments.

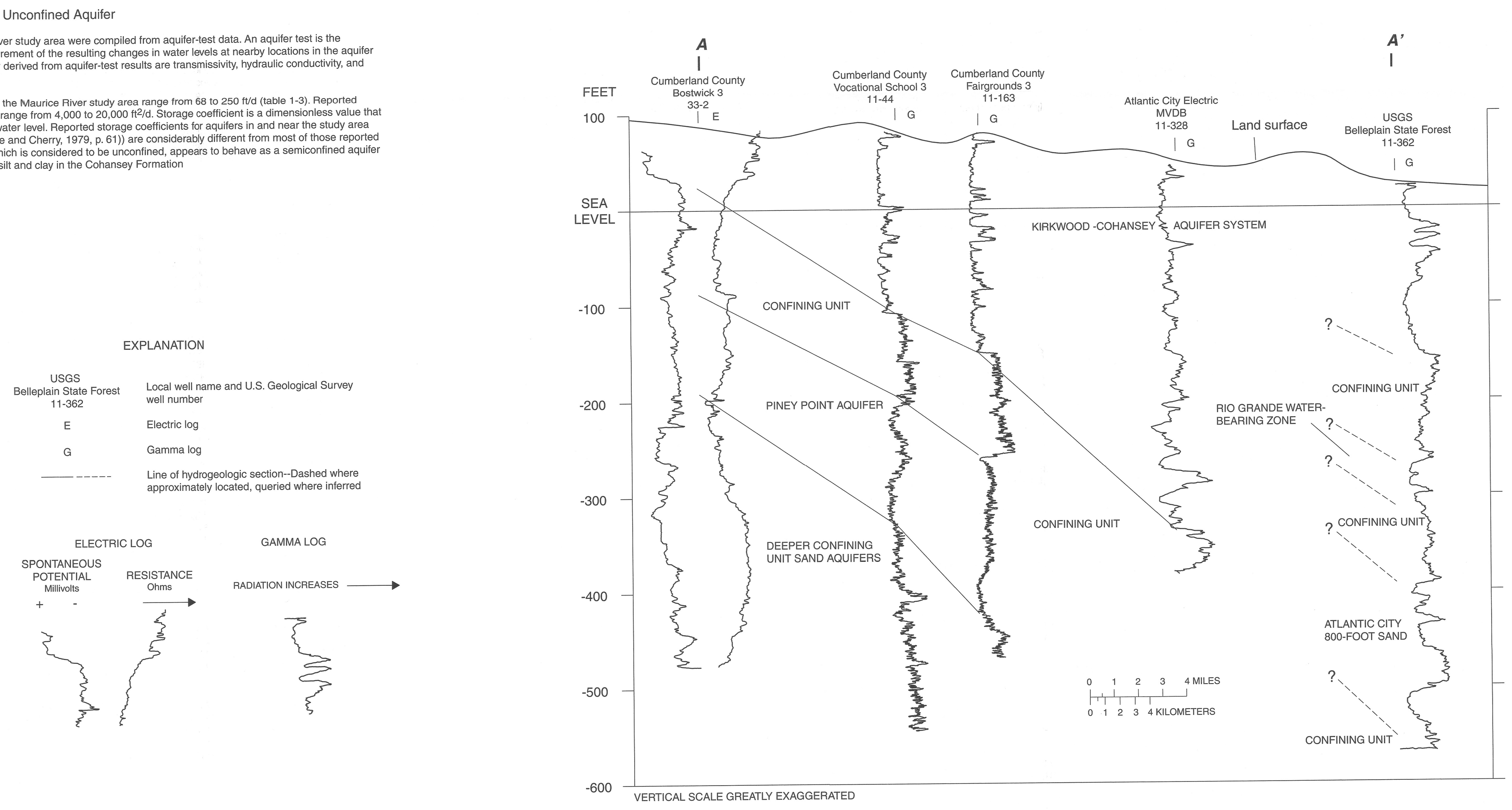

Figure 1-4. Hydrogeologic section A-A' through the Maurice River study area, New Jersey, based on gamma-ray logs and electric logs. (Lines of section shown in fig. 1-2, well-log interpretations for wells 11-44, 11-163, 11-328, 11-362, and 33-2 from Zapecza, 1989, table 4)

Table 1-3. Hydraulic properties of the unconfined Kirkwood-Cohansey aquifer system in and near the Maurice River study area, New Jersey
[ft/d, feet per day; ft^2/d, feet squared per day; --, missing data]

Site number (fig. 1-2)	Site location	Date of test	Method of evaluation[1]	Horizontal hydraulic conductivity (ft/d)	Transmissivity (ft^2/d)	Storage coefficient (dimensionless)	Reference
1	Peabody Farm, Elmer, Salem County	11/59	Theis, Hantush, Jacob	130	6,500	0.0003	Rhodehamel, 1973, p. 55
2	Clayton Borough, Gloucester County	11/6/56	Jacob	130	4,000	.0001	Rhodehamel, 1973, p. 55
2	Clayton Borough, Gloucester County	8/7/57	Jacob	250	7,500	--	Rhodehamel, 1973, p. 55
3	Williamstown, Gloucester County	11/12/51	Jacob	90	8,300	--	Rhodehamel, 1973, p. 55
4	Bronsonville, Salem County	1966	Theis	150	20,000	.044	Rhodehamel, 1973, p. 55
5	Upper Deerfield Township, Cumberland County	11/2/92	Hantush, Jacob	[2]68	[2]10,212	[2].00005	Data-base file number 4[3]
6	Vineland City, Cumberland County	6/22/88	Hantush, Jacob	99	19,800	.000448	Data base file number 6A[3]
7	Glassboro Borough, Gloucester County	7/13/90	Hantush, Jacob	[4]111	[4]5,803	[4].0006	Data-base file number 57[3]
8	Vineland City, Cumberland County	1963-64	Theis	170	10,000	--	Rhodehamel, 1973, p. 55
9	Millville City, Cumberland County	4/26/92	Hantush, Jacob	185	16,499	.00005	Data-base file number 5[3]

[1] Methods of evaluation explained in Driscoll (1986)
[2] Average value from three observation wells
[3] New Jersey Geological Survey Hydrogeometrics Database System (unpublished data on file at the New Jersey Geological Survey)
New Jersey Department of Environmental Protection, Trenton, N.J.
[4] Average value from two observation wells

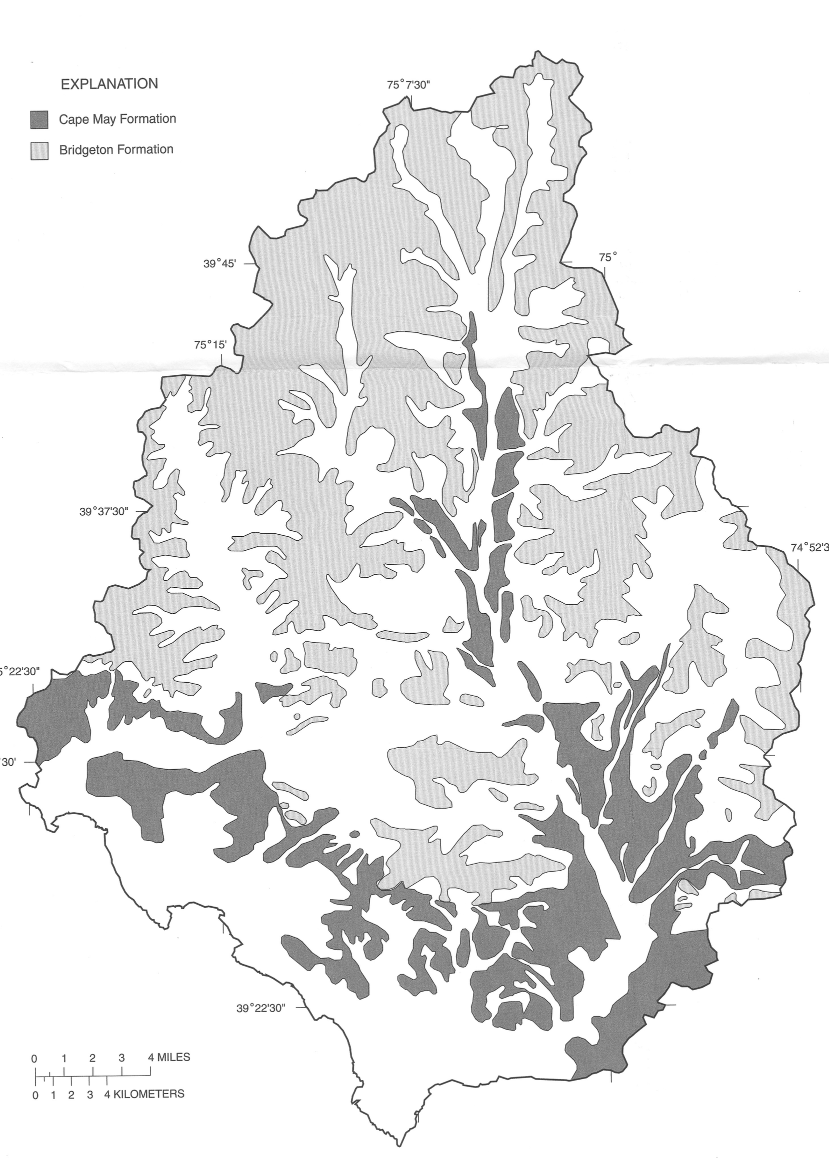

Figure 1-5. Surficial geologic units in the Maurice River study area, New Jersey. (Geology from Johnson, 1950)

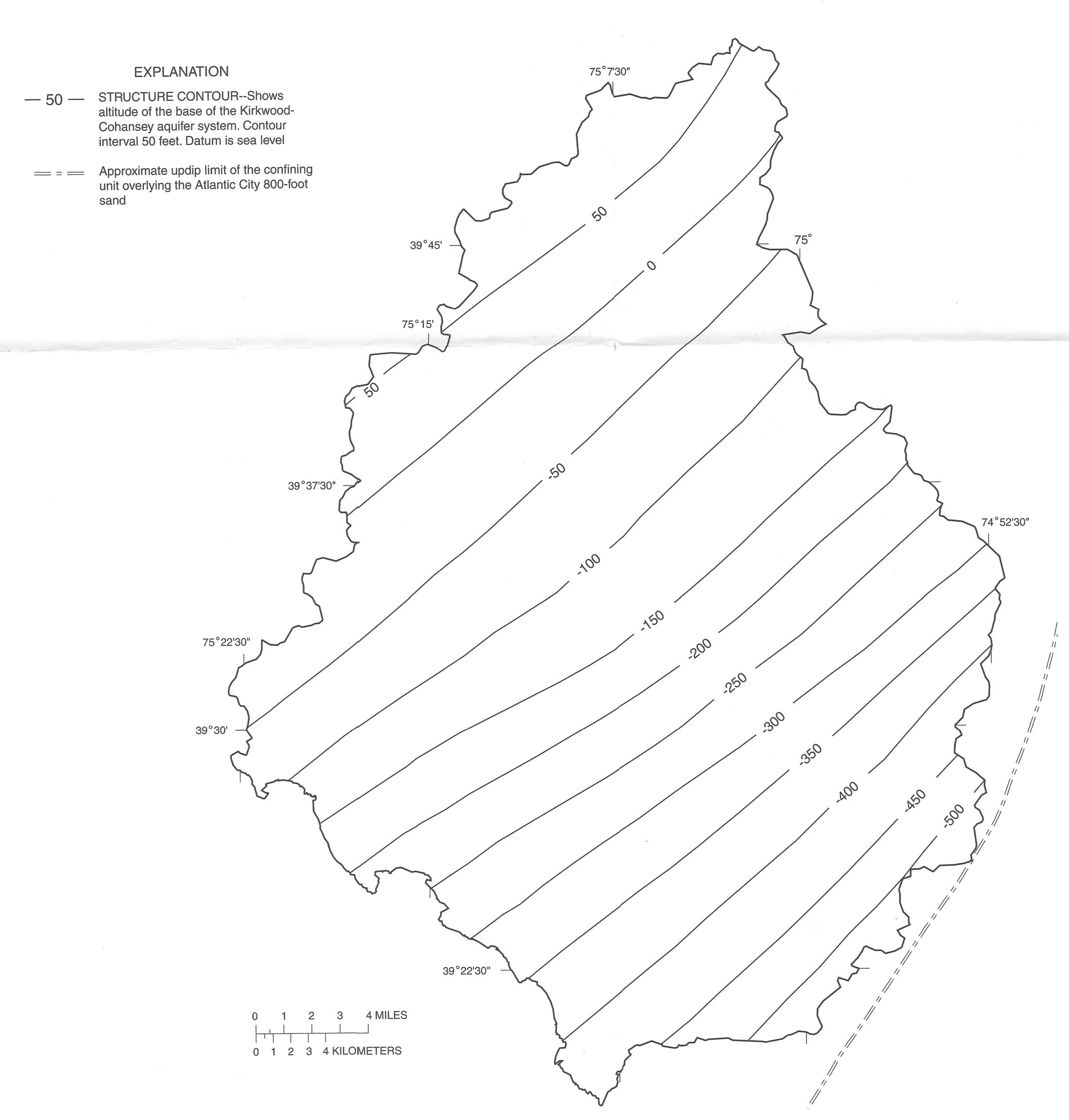

Figure 1-6. Altitude of the base of the Kirkwood-Cohansey aquifer system in the Maurice River study area, New Jersey. (Hydrogeology from Zapecza, 1989, pl. 23)

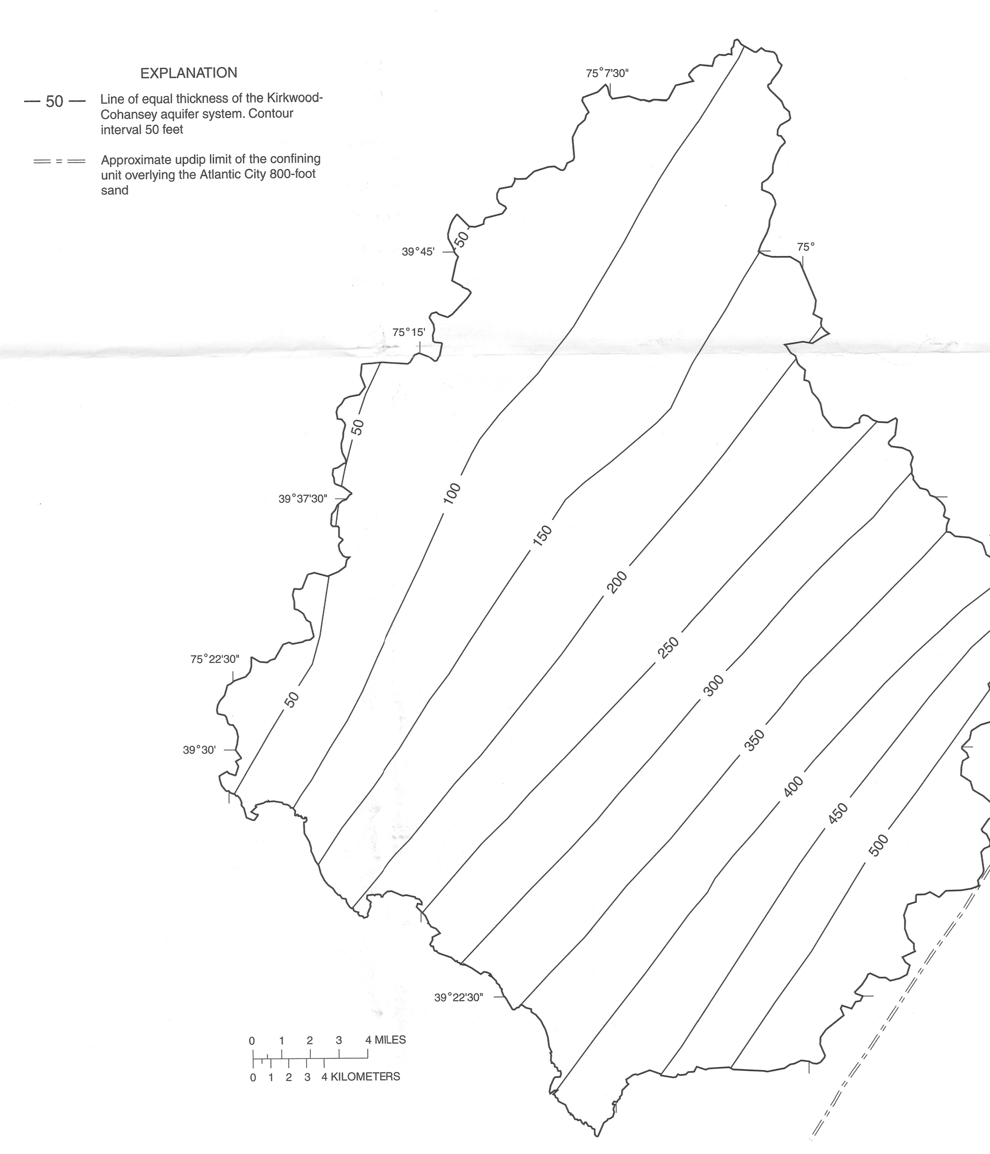

Figure 1-7. Thickness of the Kirkwood-Cohansey aquifer system in the Maurice River study area, New Jersey. (Hydrogeology from Zapecza, 1989, pl. 24)