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NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION AND ENERGY

WATER-RESOURCES INVESTIGATIONS REPORT 93-4110
SHEET 1 OF 5

HYDROLOGY OF THE UNCONFINED AQUIFER SYSTEM, TOMS RIVER, METEDECONK RIVER, AND KETTLE CREEK BASINS, NEW JERSEY, 1987-90

By Martha K. Watt, Melissa L. Johnson, and Pierre J. Lacombe

ABSTRACT

The Kirkwood-Cohansey aquifer system is the unconfined aquifer system that underlies the 330-square-mile study area in the Coastal Plain of New Jersey. The study area is composed of the Toms River, Metedeconk River, and Kettle Creek drainage basins. This aquifer system is a major source of water in these basins, and withdrawals from the Kirkwood-Cohansey aquifer system are expected to increase. A map of water levels in the Kirkwood-Cohansey aquifer system was constructed from water levels measured in 83 wells throughout the study area. Seasonal fluctuations of water levels in two observation wells typically range from less than 1 to 5 feet per year. The horizontal hydraulic conductivity of the aquifer system ranges from 9.0 to 140 feet per day, the transmissivity ranges from 1,900 to 25,000 feet squared per day, and the storage coefficient is 0.024.

A base-flow-separation technique was used to divide discharge data from two streamflow-gaging stations in the study area into base-flow and direct-runoff components. Annual base flow for the Toms River near Toms River, New Jersey, streamflow-gaging station during 1929-89 ranged from 112 to 269 cubic feet per second (80 to 89 percent of total flow). Annual base flow for the Metedeconk River near Lakewood, New Jersey, streamflow-gaging station during 1973-89 ranged from 26 to 63 cubic feet per second (63 to 79 percent of total flow). Mean discharge and base flow were determined, and low-flow-correlation analyses were made for seven low-flow partial-record sites. Mean annual precipitation in the study area was 47.3 inches during 1932-89, and annual potential evapotranspiration was estimated to be 27.0 inches.

Twenty-two ground-water-sampling sites distributed throughout the study area were selected for water-quality analysis. No constituents determined exceeded U.S. Environmental Protection Agency primary drinking-water regulations. In several samples, the U.S. Environmental Protection Agency secondary maximum contaminant levels for iron, manganese, and pH were exceeded. The predominant cations in the ground water are sodium plus potassium; the major anion is chloride. Sea salts from marine aerosols or saltwater intrusion and the effects of human activities, such as deicing of roads, industrial waste, and leachate from fertilized land contribute to the concentration of predominant ions. Water-quality data from one surface-water-quality site show that the predominant cations in the surface water are sodium plus potassium and calcium; the major anions are chloride and sulfate.

Consumptive water use in the study area in 1988 was 7,000 million gallons--5,900 million gallons from ground-water sources and 1,100 million gallons from surface-water sources. This total represents water used for public and private domestic water supply, irrigation, industry, and mining. Water budgets calculated for the Toms River Basin and the Metedeconk River Basin indicate that ground-water recharge is 15 inches per year in the Metedeconk River Basin and 19.4 inches per year in the Toms River Basin.

INTRODUCTION

The Kirkwood-Cohansey aquifer system is predominantly unconfined and underlies approximately 3,000 mi^2 of the Coastal Plain of New Jersey (Zapecza, 1989). (For definitions of abbreviations and conversion factors for units used in the text, see table 1-1.) This aquifer system is a major source of water in the Coastal Plain, and withdrawals from the Kirkwood-Cohansey aquifer system are expected to increase in the future. Rapid population growth coupled with restrictions on withdrawals from confined aquifers will result in increased demand for water from the unconfined aquifer system. In order to provide the information necessary to plan for the optimal use of this water and to meet the anticipated increased demand, the U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection and Energy (NJDEPE) (formerly the New Jersey Department of Environmental Protection (NJDEP)) is compiling water-resources information on the unconfined aquifer system and surface water in several river basins in the Coastal Plain of New Jersey. Information on the Toms River, Metedeconk River, and Kettle Creek Basins, which cover a 330-mi^2 area in the northern Coastal Plain, is compiled in this report.

Purpose and Scope

This report presents the results of a study conducted from 1987 through 1990 to compile information on the availability, use, and ambient quality of ground water in the Kirkwood-Cohansey aquifer system and of surface water in the Toms River, Metedeconk River, and Kettle Creek drainage basins. The report includes the results of water-level measurements in 83 wells. The results of analyses of samples collected from 22 wells and 1 surface-water site for selected inorganic and organic constituents also are included. Results of base-flow-separation analyses of discharge measurements from streamflow-gaging stations on the Toms River and Metedeconk River, and results of correlations of low flow at seven low-flow partial-record stations are presented. Hydrologic budgets for the two largest basins, the Toms River and Metedeconk River Basins, were calculated by using precipitation data, discharge data, estimates of actual evapotranspiration, and calculations of water use; these budgets were used to estimate ground-water recharge.

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 followed by a sequence number of the well within the county. County codes used in this report are 25 for Monmouth County and 29 for Ocean County. For example, well number 29-346 represents the 346th well inventoried in Ocean County. Construction details for wells with this type of identifier are stored in the USGS Ground-Water Site Inventory (GWSI) data base.

Acknowledgments

The authors gratefully acknowledge the cooperation of the well owners who allowed us access to their wells for water-level measurements and the collection of water-quality samples.

DESCRIPTION OF THE STUDY AREA

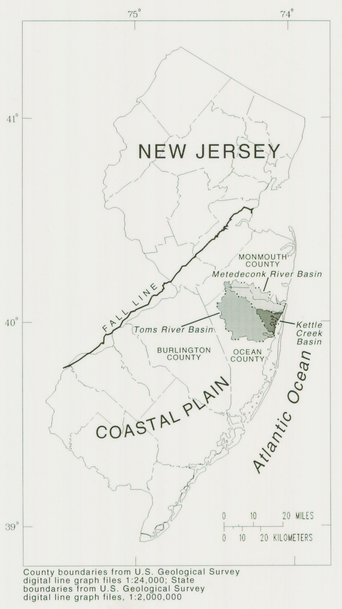
The study area consists of the three drainage basins of the Toms River, the Metedeconk River, and Kettle Creek, which together cover an area of approximately 330 mi^2 along the eastern coast of New Jersey (fig. 1-1). The three basins collectively are referred to in the rest of the report as the study area. The study area consists of part of southern Monmouth and northern Ocean Counties. The extent of the study area and the 24 municipalities that lie wholly or partly within it are shown in figure 1-2. In general, the study area is characterized by low relief. Elevations range from sea level along the coast to 320 ft in Millstone Township, Monmouth County. The study area is about 49 percent forest and about 24 percent urban land. The largest population centers are Lakehurst, Lakewood, and Toms River. Wetlands, surface-water bodies, and, to a lesser extent, agricultural and barren land comprise the other 28 percent of the study area. The distribution of land use is shown in figure 1-3.

Geologic and Hydrogeologic Units

The most recent geologic units that crop out in the study area, from oldest to youngest, are the Vincentown Formation, Kirkwood Formation, Cohansey Sand, and Beacon Hill Gravel of Tertiary age, and beach sands and gravels of Quaternary age (fig. 1-4, table 1-2). The Vincentown Formation and the Beacon Hill Gravel crop out only in small areas along the northwestern and southwestern boundaries of the study area. The Kirkwood Formation crops out predominantly in the northern and northwestern parts of the study area and, to a lesser extent, along the Toms River. The Cohansey Sand crops out in the southern and western parts of the study area, and the Quaternary beach sands crop out on the eastern edge of the study area. The Quaternary gravels are found in the east-central part of the study area, along Barnegat Bay. (See fig. 1-4.)

The hydrogeologic sections in figure 1-5 show the interpreted contacts between the hydrogeologic units (table 1-2). Interpreted contacts were determined on the basis of electric and gamma-ray geophysical logs. The Vincentown aquifer, which lies within the composite confining unit, is the oldest hydrogeologic unit that crops out in the study area. The composite confining unit is a complex series of geologic units that, depending on location, can include as many as nine distinct units. The part of the composite confining unit of interest in this study ranges in age from Paleocene to early Miocene and is made up of the Vincentown Formation, Manasquan Formation, Shark River Formation, Piney Point Formation, and basal clay of the Kirkwood Formation. Two minor aquifers are located in this part of the composite confining unit. One of these aquifers, the Vincentown aquifer, consists of that part of the Vincentown Formation that is composed of moderately permeable quartz sand. The Vincentown aquifer is used as a source of water only in and near the outcrop areas, which are located in the northwestern part of the study area. The other minor aquifer, the Piney Point aquifer, is present under confined conditions and is not discussed in this report. The Kirkwood Formation is the youngest unit included in the composite confining unit. Its lithology varies with depth from fine, gravelly sand to silty sand. The basal part of the Kirkwood Formation, which makes up the upper part of the composite confining unit, contains regionally extensive clay layers and is composed of clayey, micaceous, glauconitic, fine sand and clayey silt with beds of silty fine sand containing calcareous shell fragments. (See Owens and others, 1988, p. 17.)

The upper part of the Kirkwood Formation, which is hydraulically connected to the overlying Cohansey Sand and surficial deposits, is composed primarily of dark gray to yellowish-brown fine sand to fine gravel and diatomaceous silty clay containing fine wood fragments, shell and organic matter, and abundant pyrite. Minerals found in the Kirkwood Formation include zircon, tourmaline, rutile, hornblende, epidote, and potassium feldspar. (See Owens and others, 1988, p. 17.) The Cohansey Sand is predominantly a light-colored quartz sand, containing very fine- to coarse-grained sand, silty and clayey sand, and interbedded clay units (Zapecza, 1989, p. B19). The Kirkwood Formation, Cohansey Sand, and overlying deposits of Beacon Hill Gravel make up the Kirkwood-Cohansey aquifer system in the study area. Aquifer-system thickness is near zero in the northwestern part of the study area and increases about 5 to 30 ft/mi toward the southeastern part of the study area, to about 250 ft in Seaside Park Borough. The altitude of the base and the thickness of the Kirkwood-Cohansey aquifer system are shown in figures 1-6 and 1-7, respectively.



County boundaries from U.S. Geological Survey digital line graph files, 1:24,000; State boundaries from U.S. Geological Survey digital line graph files, 1:2,000,000

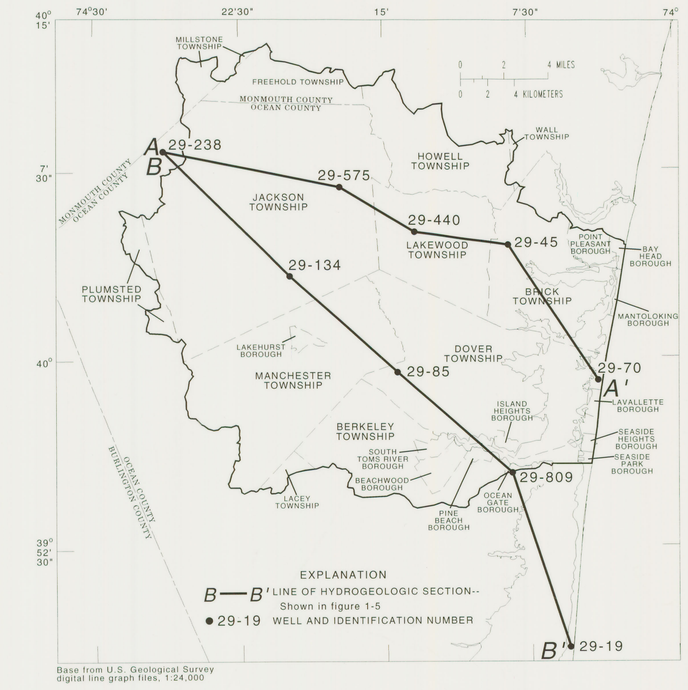
Figure 1-1.--Location of the Toms River, Metedeconk River, and Kettle Creek Basins.

Table 1-1.--Conversion factors and vertical datum

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
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 gallon (Mgal)	3,785	cubic meter
Flow		
inch per year (in/yr)	2.54	centimeter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter 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: $^{o}F = 1.8 \times {}^{o}C + 32$

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.



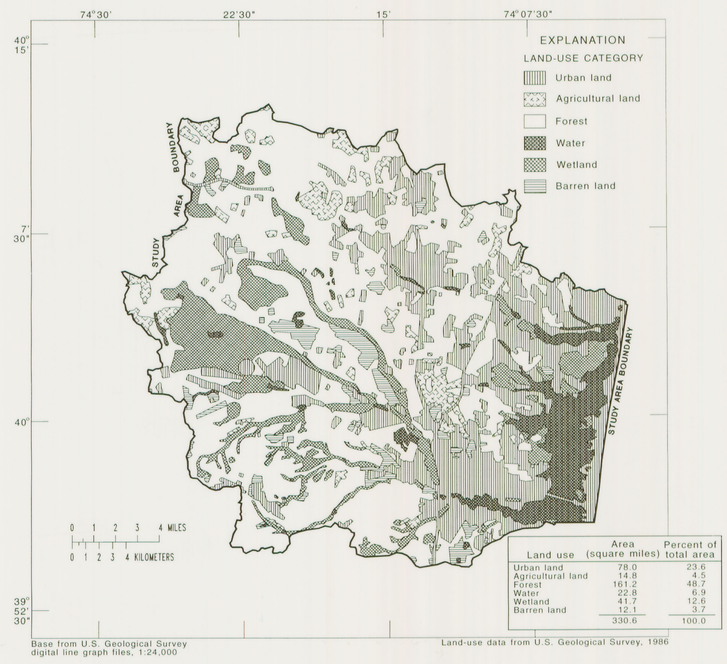
Base from U.S. Geological Survey digital line graph files, 1:24,000

Figure 1-2.--Municipalities in the study area and the location of hydrogeologic sections A-A' and B-B'.

Table 1-2.--Stratigraphy and hydrogeologic characteristics of late Paleocene to Holocene units in the study area

[Modified from Zapecza, 1989, table 2]

SYSTEM	SERIES	GEOLOGIC UNIT	LITHOLOGY	HYDROGEOLOGIC UNIT	HYDROLOGIC CHARACTERISTICS
Quaternary	Holocene	Alluvium deposits	Sand, silt, and black mud.	Undifferentiated	Surficial material, typically hydraulically connected to underlying aquifers. Locally some units may act as confining units. Thicker sands are capable of yielding large quantities of water.
		Beach sand and gravel	Sand and quartz, light-colored, medium- to coarse-grained, pebbly.		
	Pleistocene	Cape May Formation	Sand, quartz, light-colored, heterogeneous, clayey and pebbly.		
Tertiary	Miocene	Pensauken Formation			
		Bridgeton Formation			
		Beacon Hill Gravel	Gravel, quartz, light-colored, sandy.	Kirkwood-Cohansey aquifer system	Major aquifer system. Ground water generally occurs under water-table conditions.
		Cohansey Sand	Sand, quartz, light-colored, very fine- to coarse-grained, pebbly, local clay layers.		
		Kirkwood Formation	Sand, quartz, gray, tan, fine- to medium-grained, micaceous and dark diatomaceous clay.		
	Eocene	Piney Point Formation	Sand, quartz, and glauconite; fine- to coarse-grained.	Composite confining unit: Piney Point aquifer	Yields moderate quantities of water locally.
		Shark River Formation	Clay, silty and sandy, glauconitic, green, gray and brown; fine-grained quartz sand.	Composite confining unit	Low-permeability sediments
		Manasquan Formation			
	Paleocene	Vincentown Formation	Sand and quartz, gray and green, fine- to coarse-grained, glauconitic; and brown, clayey, very fossiliferous glauconite and quartz calcarenite.	Composite confining unit: Vincentown aquifer	Yields small to moderate quantities of water in and near its outcrop area.

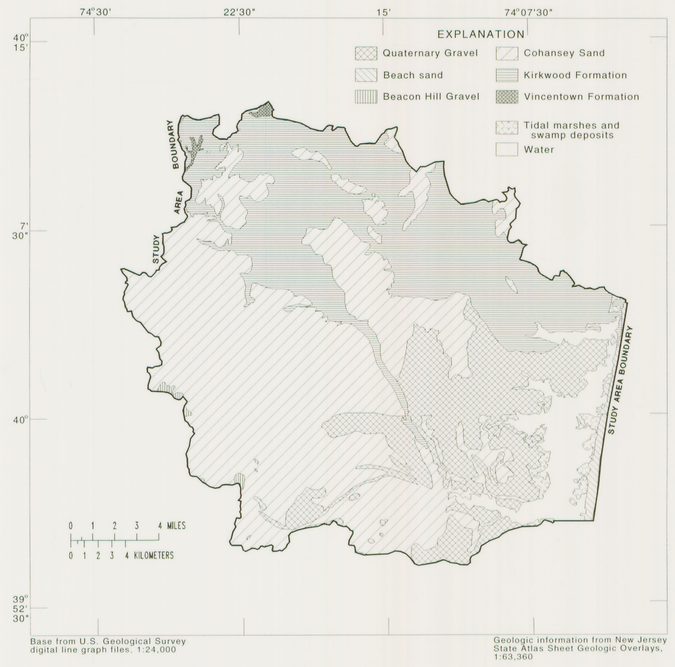


Land use	Area (square miles)	Percent of total area
Urban land	78.0	23.6
Agricultural land	14.8	4.5
Forest	161.2	48.7
Water	22.8	6.9
Wetland	41.7	12.6
Barren land	12.1	3.7
	330.6	100.0

Base from U.S. Geological Survey digital line graph files, 1:24,000

Land-use data from U.S. Geological Survey, 1986

Figure 1-3.--Land use in the study area.



Base from U.S. Geological Survey digital line graph files, 1:24,000

Geologic information from New Jersey State Atlas Sheet Geologic Overlays, 1:63,360

Figure 1-4.--Surficial geology in the study area.

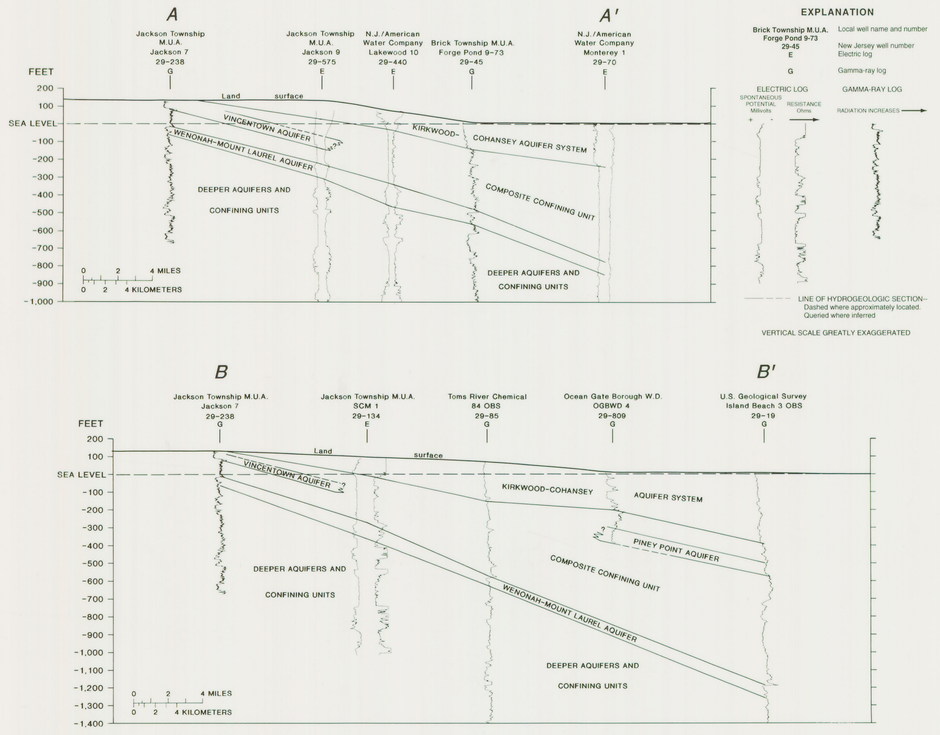
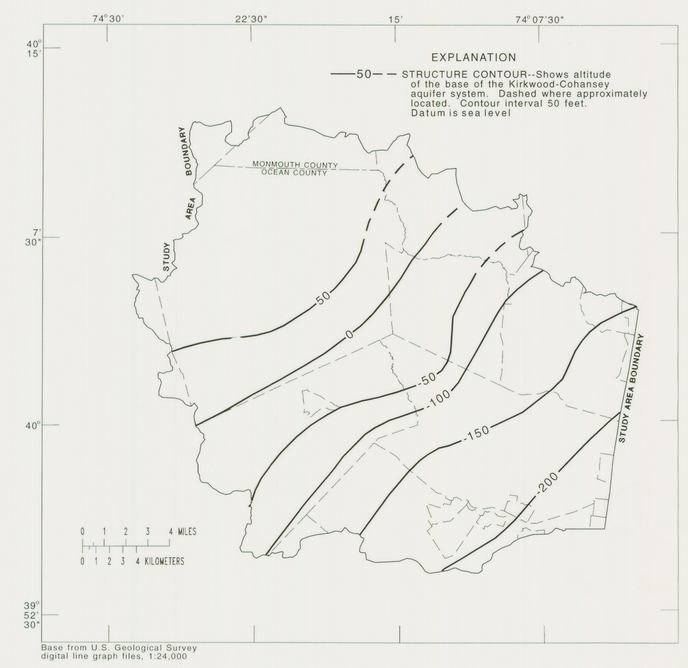


Figure 1-5.--Hydrogeologic sections A-A' and B-B', based on gamma-ray and electric logs; lines of section shown in figure 1-2. (Hydrogeologic sections from Zapecza, 1989, pl. 3)



Base from U.S. Geological Survey digital line graph files, 1:24,000

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

Hazardous-Waste Sites and Sanitary Landfills

Fourteen hazardous-waste sites have been identified in the study area by the NJDEPE. All information on these sites in this report is found in the status and site-status reports prepared in October 1989 as part of the NJDEPE Hazardous Waste Management Program (New Jersey Department of Environmental Protection, 1989a and 1989b).

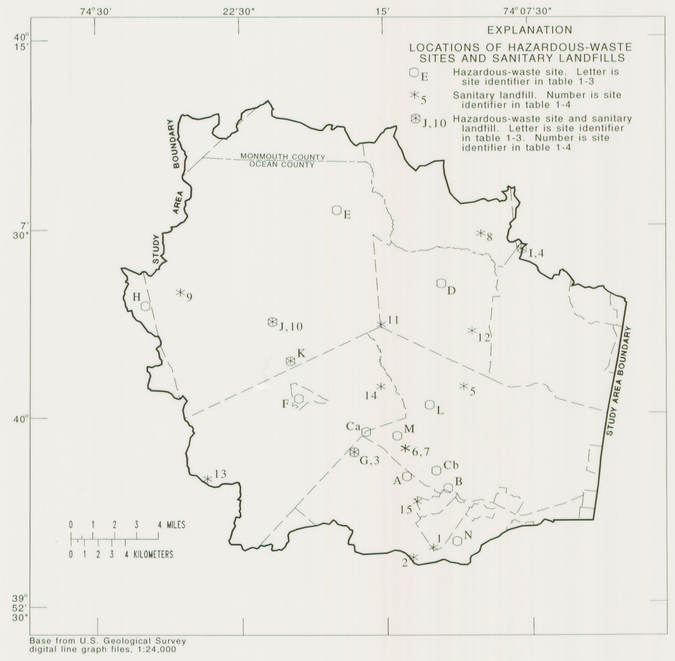
All of the hazardous-waste sites in the study area are located in Ocean County (fig. 1-8). Table 1-3 lists information about the sites. The column labeled "N.J. Superfund rank" lists the relative positions of the 7 hazardous-waste sites among the 109 U.S. Environmental Protection Agency (USEPA) Superfund sites in the State of New Jersey that are also Superfund sites. The "funding" column indicates whether the funds used for site investigation and remediation are private or public. Public funding is derived from State or Federal sources, whereas private funding is provided by the responsible parties[1]. Activities at 9 of the 14 hazardous-waste sites in the study area are privately funded. The "lead agency" column lists the agency that oversees site investigation and remediation at each of the sites. In New Jersey, investigations and cleanup at most hazardous-waste sites are overseen by the NJDEPE, whereas similiar activities at Superfund sites are overseen by the NJDEPE in conjunction with the USEPA. Investigation and remediation at site K, however, is conducted jointly by the NJDEPE, the USEPA, and the U.S. Department of Defense. The "status" column in table 1-3 shows the stage that has been reached in the investigation and remediation process at each site as of June 30, 1989. For example, a site at which the initial investigation was completed and possible remediation methods were being negotiated is characterized as "C,P" for "completed" and "pending."

[1] Responsible party is defined as any person who has discharged a hazardous substance or is in any way responsible for any hazardous substance which the NJDEPE has removed or is removing pursuant to the NJDEPE Spill Compensation and Control Act, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the New Jersey Water Pollution Control Act (New Jersey Department of Environmental Protection, 1989b).

Seven of the 14 hazardous-waste sites in the study area are not Superfund sites. As of 1989, orders had been issued by the NJDEPE for initial investigations to begin at three of these sites--A, B, and C. Site C is a 6.5-mi-long stretch of highway along Route 37. Points "Ca" and "Cb" mark the site limits. In 1989, the investigation phase was underway at site D and, at site E, contaminated soil had been removed, monitoring wells had been installed, and ground-water samples had been collected. At site F, contaminated soil had been excavated and disposed of, underground storage tanks had been removed, and monitoring wells had been installed. Plans for site F included installation of an air-stripping system and a vacuum-extraction system, and capping of the excavated tank area. At site G, the initial site investigation had been completed and six recovery systems had been installed, but part of the site was still under study.

The remaining seven hazardous-waste sites in the study area are Superfund sites. As of 1989, site H was actively being studied, and the investigation at site I had been partially completed; funds were being sought to complete the work. The preliminary investigation at site J had been completed, and an agreement had been reached to conduct additional work at the site. At site K, the first phase of a confirmation study (a study to determine the nature and extent of the problem and establish remediation alternatives) as well as a program of soil-gas and ground-water sampling had been completed. The second phase, which was to include installation of monitoring wells, test pits, or soil borings, was underway. At site L, the initial investigation was completed; both buried and above-ground drums and contaminated soil had been removed, and it was determined that additional investigation and remediation was necessary. Initial studies at site M had been completed, ground-water remediation was about to begin, and work plans for additional remediation had been submitted for public review. At site N, investigations designed to identify the problem had been completed and solutions had been proposed.

In addition to the 14 hazardous-waste sites, 15 sanitary landfills are present in the study area. The location of each site is shown in figure 1-8; table 1-4 lists information about each of these sites. Four of the landfills are located at or near hazardous-waste sites (fig. 1-8). The ownership of each site is listed in table 1-4 as private, municipal or State-owned, and the "status" column lists whether the sites are open or closed. Only 2 of the 15 landfills in the study area were open as of 1989.



Base from U.S. Geological Survey digital line graph files, 1:24,000

Figure 1-8.--Locations of hazardous-waste sites and sanitary landfills in the study area. (Locations of hazardous-waste sites and sanitary-landfill sites from New Jersey Department of Environmental Protection, 1989.)

Table 1-3.--Hazardous-waste sites in the study area

[Fig., figure; Twp, Township; USEPA, U.S. Environmental Protection Agency; NJ, New Jersey; --, data unavailable; NJDEPE, N.J. Department of Environmental Protection and Energy; DOD, Department of Defense; N/A, not applicable; P, pending; U, underway; C, completed]

Site identifier (fig. 1-8)	Site name[1]	County	Municipality	USEPA number	NJ Superfund rank[3]	Lead agency	Latitude	Longitude	Funding	Status[4]
A	Holiday City - Berkeley	Ocean	Berkeley Twp	NJD981143043	N/A	NJDEPE	395736	741357	Private	P
B	JCP&L - Toms River Coal Gas	Ocean	Dover Twp	NJD000000214	N/A	NJDEPE	395707	741150	Private	U,P
C a.	RT 37 - Starting Coordinates	Ocean	Various Twps	NJD000000419	N/A	NJDEPE	395923	741602	Private	P
b.	RT 37 - Ending Coordinates	Ocean	Various Twps	NJD000000419	N/A	NJDEPE	395749	741226	Private	P
D	JCP&L - Lakewood Coal Gas	Ocean	Lakewood Twp	NJD000000212	N/A	NJDEPE	400517	741205	Private	U,P
E	Powers Farm	Ocean	Jackson Twp	NJD981134455	N/A	NJDEPE	400813	741727	Private	C,U
F	Lakehurst Exxon	Ocean	Lakehurst Borough	--	N/A	NJDEPE	400044	741931	Public	C,U,P
G	Holiday City - Silverton	Ocean	Dover Twp	NJD981562630	N/A	NJDEPE	395833	741640	Private	C,U,P
H[2]	Wilson Farm	Ocean	Plumsted Twp	--	88	NJDEPE	400430	742725	Public	C,U
I[2]	Brick Twp Landfill	Ocean	Brick Twp	NJD981173347	12	NJDEPE	400639	740751	Public	U
J[2]	Jackson Twp Landfill	Ocean	Jackson Twp	NJD078254455	67	NJDEPE	400346	742052	Private	U,P
K[2]	Lakehurst Naval Air Engineering Center	Ocean	Lakehurst Borough Manchester Twp Jackson Twp	NJ7170023744	26	USEPA/ DOD	400213	741955	Private	U
L[2]	Reich Farm	Ocean	Dover Twp	NJD980529713	18	USEPA/ NJDEPE	400025	741243	Public	C,P
M[2]	Toms River Chemical /Ciba-Geigy	Ocean	Dover Twp	NJD001502517	27	USEPA/ NJDEPE	395913	741424	Private	C,U,P
N[2]	Beachwood/Berkeley wells	Ocean	Beachwood Borough Berkeley Twp	NJD980654123	57	NJDEPE	395501	741124	Public	C

[1] The use of industry or firm names in this report is for location purposes only and does not impute responsibility for any present or potential effects on the natural resources.
[2] USEPA Superfund site
[3] This number indicates the relative position of hazardous-waste sites among the 109 U.S. Environmental Protection Agency Superfund sites in the State of New Jersey.
[4] Additional site-specific information can be found in the above text or referenced text.

Table 1-4.--Sanitary landfills in the study area

[Fig., figure; Twp, Township; Boro, Borough; So., South; --, data unavailable; NJPDES, New Jersey Pollution Discharge Elimination System; M, Municipal; P, Private; S, State; C, Closed; O, Open; N/A, not applicable]

Site identifier (fig. 1-8)	Landfill name	County	Municipality	NJPDES[1] permit number	Ownership	Acres	Status	Year closed
1	Beachwood	Ocean	Beachwood Boro	53376	M	150	C	1983
2	Berkeley Twp	Ocean	Berkeley Twp	51977	M	330	C	1982
3	Holiday City West	Ocean	Berkeley Twp	--	P	200	C	1982
4	Ridge Road	Ocean	Brick Twp	61719	M	300	C	1979
5	Dover Twp	Ocean	Dover Twp	50946	M	220	C	1980
6	Toms River Chemical	Ocean	Dover Twp	--	P	--	C	--
7	Toms River Chemical	Ocean	Dover Twp	--	P	--	O	N/A
8	Waste Disposal Inc.	Monmouth	Howell Twp	98515	P	800	C	1987
9	Colliers Mills	Ocean	Jackson Twp	59773	S	--	C	--
10	Jackson Twp Sanitary Landfill	Ocean	Jackson Twp	51985	M	--	C	--
11	Lakehurst Boro	Ocean	Lakehurst Boro	61778	M	300	C	1976
12	Lakewood Twp Old	Ocean	Lakewood Twp	55166	M	620	C	1984
13	Manchester Twp	Ocean	Manchester Twp	51896	M	200	C	1985
14	Ocean County Landfill Corporation	Ocean	Manchester Twp	51128	P	450	O	N/A
15	South Toms River	Ocean	So. Toms River	56910	M	700	C	1985

[1] A program implemented by the N.J. Department of Environmental Protection and Energy, which issues permits to regulate discharges to surface water, ground water, and publically owned water treatment plants.

Watt, M.K., Johnson, M.L., and Lacombe, P.J., 1994, Hydrology of the unconfined aquifer system, Toms River, Metedeconk River, and Kettle Creek Basins, New Jersey, 1987-90: U.S. Geological Survey Water-Resources Investigations Report 93-4110

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