WITHDRAWALS OF GROUND WATER AND SURFACE WATER IN NEW JERSEY, 1989-90

By John P. Nawyn and Rick M. Clawges

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ABSTRACT

Data on withdrawals of ground water and surface water in New Jersey during 1989-90 were compiled from monthly withdrawal data provided to the New Jersey Department of Environmental Protection by water users with pumping equipment capable of producing 100,000 gallons per day or greater. The categories of water use presented include public supply, domestic supply, commercial, irrigation, industrial, mining, and thermoelectric power. Withdrawals by domestic-supply users and small community public-supply systems were estimated as the product of the population of users and the per capita coefficient of 75 gallons per day.

Withdrawals in New Jersey in 1989 totaled about 2,350 Mgal/d (million gallons per day)--about 570 Mgal/d of ground water and about 1,780 Mgal/d of surface water. In 1990, withdrawals totaled nearly 2,170 Mgal/d--about 557 Mgal/d of ground water and about 1,610 Mgal/d of surface water. Withdrawals for public supply averaged about 1,030 Mgal/d and served 6.8 million residents of New Jersey. Withdrawals of ground water for domestic supply averaged 70 Mgal/d and supplied about 972,000 residents of the State. Withdrawals for commercial use, chiefly ground water, averaged 16 Mgal/d. Withdrawals for irrigation use, consisting mostly of surface water used for cranberry production, averaged 109 Mgal/d. Average withdrawals for industrial and thermoelectric-power use were 287 Mgal/d and 660 Mgal/d, respectively. Withdrawals by mining facilities totaled 111 Mgal/d in 1989 and 56 Mgal/d in 1990; the 50-percent decrease in withdrawals is attributed to reduced production at one mining facility.

INTRODUCTION

New Jersey is the most densely populated (886 persons per square mile) and the most highly urbanized State in the Nation. About 33 percent of the land area in New Jersey is defined as urban by the U.S. Bureau of the Census (Morgan and others, 1992, p. 174, 354). The five northeastern counties--Bergen, Essex, Hudson, Passaic, and Union--contain about 40 percent of the population of New Jersey and 9 percent of the land area in the State (U.S. Bureau of the Census, 1991b). The chief source of potable water for this urban area is surface water, which is transported from reservoirs in rural, upland watersheds in Morris, Passaic, and Sussex Counties (fig. 1).

One of the effects of the rapid industrial and population growth of New Jersey in the late 19th century was local degradation of the quality of surface water and shortages of potable water (Vermeule, 1894; Capen, 1937; New Jersey Commission on Efficiency and Economy in State Government, 1967). By 1900, most communities with a population of 1,000 or greater were served by public-supply systems, which used chiefly surface water (Vermeule, 1894, p. 320).

To safeguard the quality and quantity of potable-water supplies, laws were promulgated by New Jersey legislators to regulate the disposal of sewage in streams and the withdrawal of surface water for public supply. Throughout the past century, New Jersey has provided comprehensive management of its water resources, including monitoring the withdrawals of surface water for public supply (since 1907) and the withdrawals of ground water for public supply (since 1910); registering the drilling of all new wells and permitting withdrawals of 100,000 gal or greater during a 24-hour period (since 1947); and regulating the withdrawals of surface water by non-public-supply users (since 1963) (Capen, 1937; New Jersey Commission on Efficiency and Economy in State Government, 1967; Goldshore, 1983; Deitch, 1992).

This report is a product of a cooperative water-use program of the U.S. Geological Survey (USGS) and the New Jersey Department of Environmental Protection (NJDEP). The study was conducted as part of this water-use program for which water-use data are compiled and stored in the Site Specific Water-Use Data System (SSWUDS) and the Aggregate Water-Use Data System (AWUDS) data bases of the Water-Use Data System component of the National Water Information System, the USGS National water- data storage and retrieval system.

Purpose and Scope

This report presents data on the withdrawals of ground water and surface water in New Jersey during 1989-90. All withdrawal data are presented by county, type of water (ground water or surface water), and water-use category (public supply, domestic supply, commercial, industrial, irrigation, mining, and thermoelectric power). Data on small public-supply-system, domestic-supply, and irrigation users include estimated withdrawal data and were not included in compilations by hydrologic cataloging unit, aquifer, and physiographic province.

Description of Study Area

New Jersey is a mid-Atlantic State consisting of 7,419 mi^2 of land area and 1,303 mi^2 of water area (Horner, 1992, p. 243). The State has 7.7 million residents (Morgan and others, 1992, p. 168, 335) and is divided into 21 counties (fig. 1). New Jersey is an important center for commerce, recreation, manufacturing, and scientific research and is one of the most frequently travelled transportation corridors for rail and motor vehicles in the United States.

Hydrogeology

The Coastal Plain, Piedmont, Highlands, and Valley and Ridge are the physiographic provinces in New Jersey (fig. 2; table 1). The Fall Line (fig. 2) separates the Coastal Plain, an area of about 4,200 mi^2, from the consolidated rocks of the three northern provinces, an area of about 3,300 mi^2 (Qualls and Horn, 1990, p. 368).

The Coastal Plain (fig. 2; table 1) is underlain by stratified, unconsolidated sediments consisting of sand, gravel, silt, and clay (Gill and Farlekas, 1976). The most productive aquifers in the Coastal Plain are the Potomac-Raritan-Magothy aquifer system, Kirkwood-Cohansey aquifer system, Atlantic City 800-foot sand, Englishtown aquifer system, and Wenonah-Mount Laurel aquifer (Qualls and Horn, 1990, p. 368).

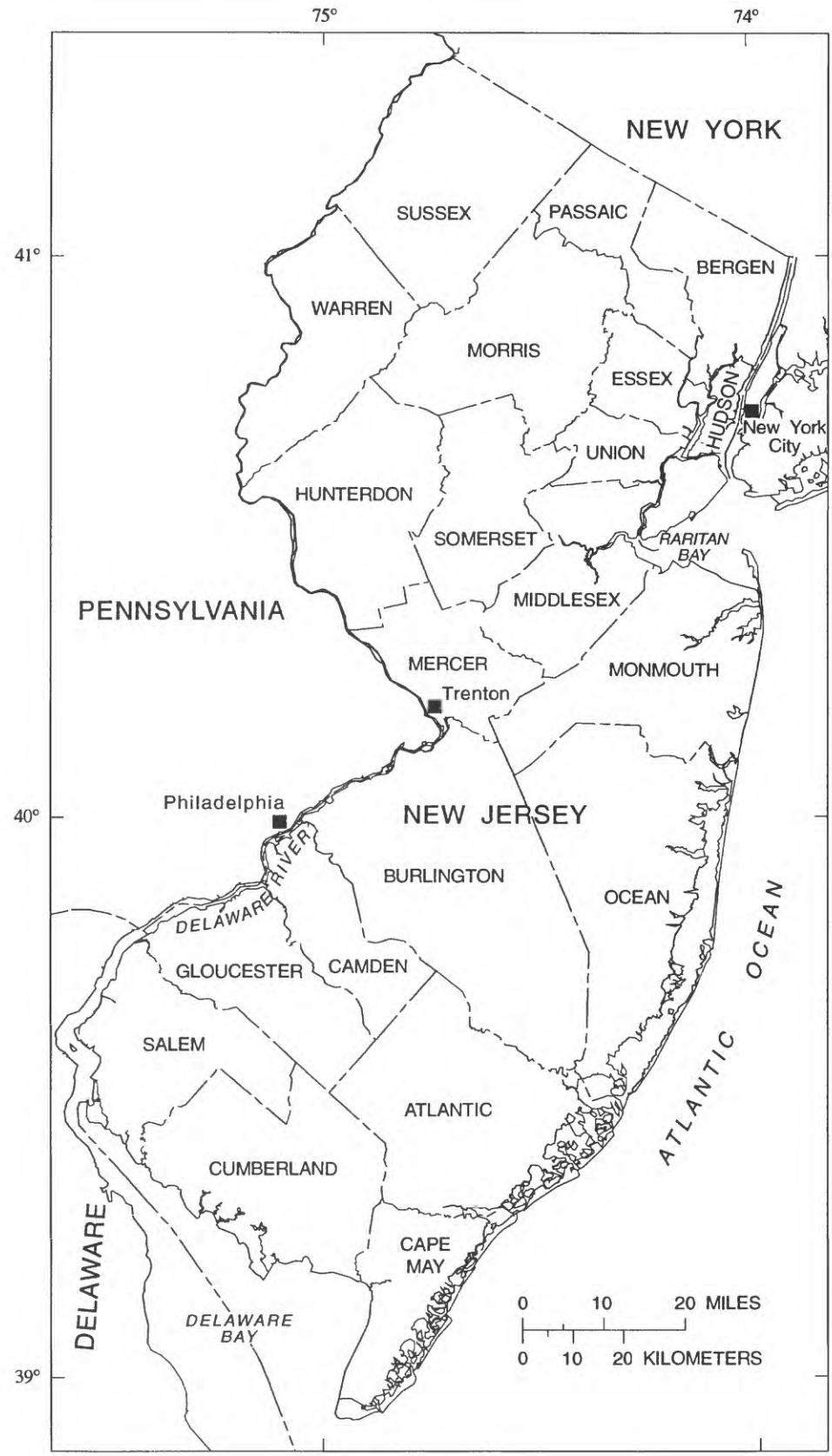

Figure 1. Counties in New Jersey.

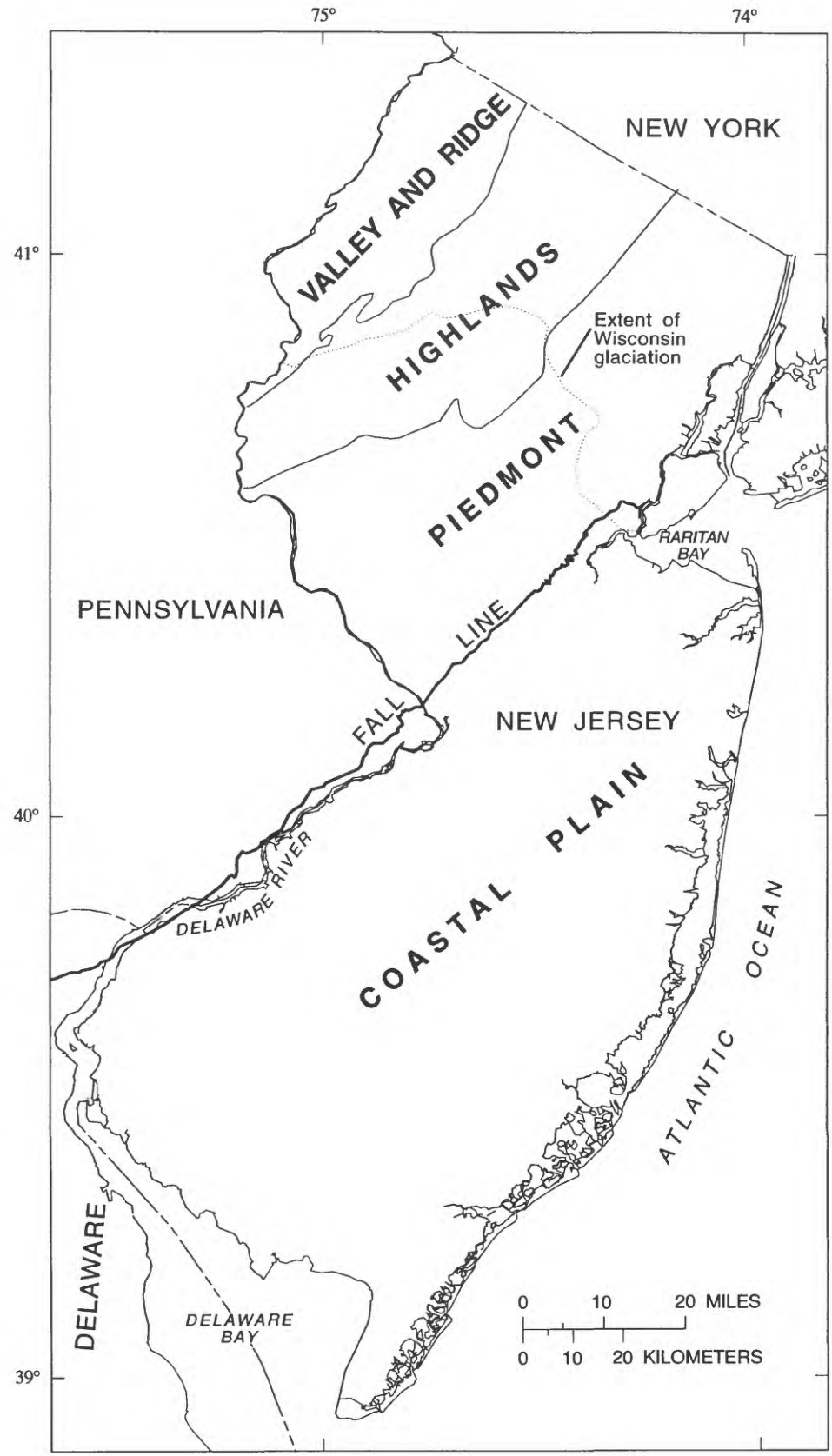

Figure 2. Physiographic provinces in New Jersey.

Directly north of the Fall Line is the Piedmont Province, which occupies about one-fifth of the area of the State (fig. 2). The area is underlain by Jurassic/Triassic fractured shales and sandstones of the Newark Supergroup. Ridges composed of basalt flows or diabase (trap rock) intrusions also are found throughout the Piedmont Province (Lyttle and Epstein, 1987). To the northwest of the Piedmont Province is the Highlands Province, which is an upland plateau that has been eroded by streams into a series of ridges (fig. 2). Fractured crystalline rocks of Precambrian age are most prevalent in this province. The Valley and Ridge Province is located in the northwestern corner of the State (fig. 2). The Kittatinny Mountain range, part of the Appalachian Mountain system, and the Kittatinny Valley of Paleozoic sedimentary rocks (limestone, dolomite, shale, and sandstone) define the Valley and Ridge Province in New Jersey (Salisbury, 1898; Lewis and Kummel, 1940; Drake, 1969; Miller, 1974).

Significant thicknesses of unconsolidated glacial sediments overlie the fractured rock formations north of the Wisconsin terminal moraine (fig. 2). Glacial aquifers are the most productive aquifers north of the Fall Line (Sargent and others, 1985, p. 312).

Characteristics of aquifers and wells in New Jersey are summarized in table 1. Salisbury (1898) and Lewis and Kummel (1940) provide detailed information on the topography and geology of New Jersey. Zapecza (1989) presents a detailed description of the aquifer systems in the Coastal Plain.

Hydrologic Cataloging Units

Seaber and others (1987) designated 13 hydrologic cataloging units (HUC's) that lie either partly or entirely within the borders of New Jersey (fig. 3; table 2). The HUC is a geographic area that represents the drainage basin of a surface-water body, such as the Raritan River, or a distinct hydrologic feature, such as the Delaware Bay. The 8-digit HUC code and name associated with each unit are part of the national system for locating, storing, retrieving, and exchanging hydrologic data. Streams that flow within the major HUC's are listed in table 2. In this study, withdrawals in three HUC's--02030101, Lower Hudson; 02040104, Middle Delaware-Mongaup-Broadhead; and 02040202, Delaware Bay--were less than 1 Mgal/d; consequently, these HUC's are not included in tables presenting data by HUC.

The Delaware River has the largest drainage area of the streams in New Jersey and delineates the 254-mi western border of the State (Schopp and Bauersfeld, 1986). The Raritan, Passaic, and Hackensack Rivers are other major rivers in New Jersey. Most of the water-supply reservoirs are located in the northern and central regions of the State (fig. 4). The Hackensack-Passaic HUC contains many public-supply reservoirs that serve the urban areas of northeastern New Jersey (fig. 4) (Schopp and Bauersfeld, 1986). Two water-supply reservoirs lie within the Raritan HUC, and five reservoirs lie in HUC's located in the Coastal Plain.

Climate

The climate of New Jersey varies as a result of differences in topography and the presence or absence of water bodies. The average annual precipitation in New Jersey during 1951-80 was 45 in. (National Climatic Center, 1990; 1991) and ranged from 40 in. in the southeast to 52 in. in the northwest (Bauersfeld, Schopp, and Shulman, 1991). Precipitation is nearly uniform throughout the year. In 1989 and 1990, the annual precipitation was 55 in. and 48 in., respectively (fig. 5A).

Table 1. Characteristics of aquifers and wells in New Jersey

[Modified from Zapecza, 1989; Lyttle and Epstein, 1987; Sargent and others, 1985; Miller,1974; and Vecchioli and Palmer, 1962; Mgal/d, million gallons per day; gal/min, gallons per minute; ft, feet]

Physiographic province Aquifer and aquifer characteristics	Well characteristics Depth (ft) (Common range)	 Yield (gal/min) (Common range)	Remarks
		Coastal Plain aquifers	
Coastal Plain			
Kirkwood-Cohansey aquifer system: Sand, quartz, fine- to coarse-grained, pebbly; local clay beds. Unconfined.	20 - 350	500 - 1,000	Major withdrawals are for public supply in Cumberland, Ocean, and Atlantic Counties. Chief source of water for agricultural and domestic-supply users in the Coastal Plain.
Rio Grande water-bearing zone: Medium- to coarse-grained sand. Thin aquifer within confining unit that overlies the Atlantic City 800-foot sand. Confined.	240 - 650	100 - 1,000	Most withdrawals are for public supply in southern Cape May County. Also present in coastal areas of southern Ocean and Atlantic Counties.
Atlantic City 800-foot sand: Sand, quartz, medium- to coarse-grained; gravel, with considerable amount of fragmented shell material. Confined.	450 - 950	600 - 800	Major confined aquifer along the barrier beaches in Ocean, Atlantic, and Cape May Counties.
Piney Point aquifer: Glauconitic quartz sand and shell beds, fine- to coarse-grained. Confined.	200 - 1,000	50 - 800	Locally important aquifer in the Coastal Plain. The aquifer does not crop out, but is extensive in the subsurface and extends from Salem and Cumberland Counties to Ocean County.
Vincentown aquifer: Sand, quartz, gray and green, fine- to coarse-grained, glauconitic. Chiefly confined.	20 - 250	10 - 900	Yields small to moderate quantities of water in or near the outcrop area. The aquifer extends from northeastern Monmouth County to the Delaware River adjacent to Salem County.
Wenonah-Mount Laurel aquifer: Sand, quartz, slightly glauconitic, very fine to coarse grained. Confined.	50 - 600	50 - 250	Most withdrawals are for public supply in Burlington and Ocean Counties.
Englishtown aquifer system: Sand, quartz, fine- to medium-grained, local clay beds. Confined.	50 - 1,000	300 - 500	Locally important aquifer. Withdrawals are used for public supply in Monmouth and Ocean Counties.
Potomac-Raritan-Magothy aquifer system: Three units (upper, middle, and lower aquifers) recognized in Delaware River Valley. In the deep subsurface, the unit below the upper aquifer is undifferentiated. Light-gray sand and quartz with interbedded material (clay, silt, or gravel) in areas. Confined and unconfined.	20 - 1,700	20 - 2,000	The most heavily pumped aquifer system in New Jersey. Extends from Raritan Bay to Delaware Bay. Present in all counties in the Coastal Plain except Atlantic and Cape May.
Upper aquifer	20 - 1,500	20 - 1,500	The most extensive unit of the aquifer system and the source of the largest withdrawals of ground water for public supply in the Coastal Plain. Also known as the Old Bridge aquifer in Middlesex and Monmouth Counties.

Table 1. Characteristics of aquifers and wells in New Jersey--Continued

[Modified from Zapecza, 1989; Lyttle and Epstein, 1987; Sargent and others, 1985; Miller,1974; and Vecchioli and Palmer, 1962; Mgal/d, million gallons per day; gal/min, gallons per minute; ft, feet]

Physiographic province Aquifer and aquifer characteristics	Well characteristics Depth (ft) (Common range)	Well characteristics Yield (gal/min) (Common range)	Remarks
Middle aquifer	20 - 1,700	20 - 1,500	Major source of public-supply withdrawals in northwestern Burlington and Gloucester Counties. Major source of industrial withdrawals in the Coastal Plain. Also known as the Farrington aquifer in Middlesex and Monmouth Counties.
Lower aquifer	60 - 1,110	50 - 2,000	The most limited in extent of the three aquifers of the Potomac-Raritan-Magothy aquifer system. Major source of public-supply withdrawals in northwestern Camden, Gloucester, and Burlington Counties.
Non-Coastal Plain aquifers			
Piedmont Province, Highlands Province, and Valley and Ridge Province			
Glacial-deposit aquifers: Wisconsin and pre-Wisconsin glacial deposits consisting of sand and gravel with interbedded silt and clay. Unconfined except where overlain by lake silt and clay or till.	10 - 300	100 - 1,000	Includes glacial buried-valley aquifer in northern New Jersey. Productive and widely used aquifers in Morris and Warren Counties.
Piedmont Province			
Aquifers of the Brunswick Group: Very fine- to coarse-grained sandstone, shale, siltstone, and red-matrix conglomerate, and fine-grained rock in extensive flows (basalt). Unconfined to partially confined in upper 200 ft; confined at greater depths.	30 - 1,500	10 - 500	The most heavily pumped of the consolidated-rock aquifers in New Jersey. Part of the Passaic Formation previously known as the Brunswick Formation. Low yields from the basalt, suitable for domestic-supply withdrawals.
Locatong Formation: Gray and black siltstone and shale; argillite.	50 - 500	2 - 250	Generally, wells have low yields and are used for domestic-supply withdrawals.
Stockton Formation: Arkosic sandstone, siltstone, shale, conglomerate.	15 - 500	15 - 900	Highest yields of rock aquifers in Mercer County. Not extensive in New Jersey.
Highlands Province and Valley and Ridge Province			
Aquifers of the Kittatinny Supergroup: Dolomite, limestone. Unconfined and semiconfined.	20 - 700	5 - 2,000	Ground water is present along bedding surfaces, joints, faults, solution cavities, intergranular space, and other openings. Yields are variable.
Franklin Limestone: Coarse white marble, crystalline limestone, magnesian in part.	35 - 500	15 - 800	Present in Sussex and Warren Counties. Wells with largest yields intersect caverns.
Precambrian crystalline-rock aquifers: Complex igneous and metamorphic rocks; gneiss.	35 - 400	10 - 150	Most water obtained from upper 300 ft of weathered and fractured rock; highest yields in or near major fault zones.

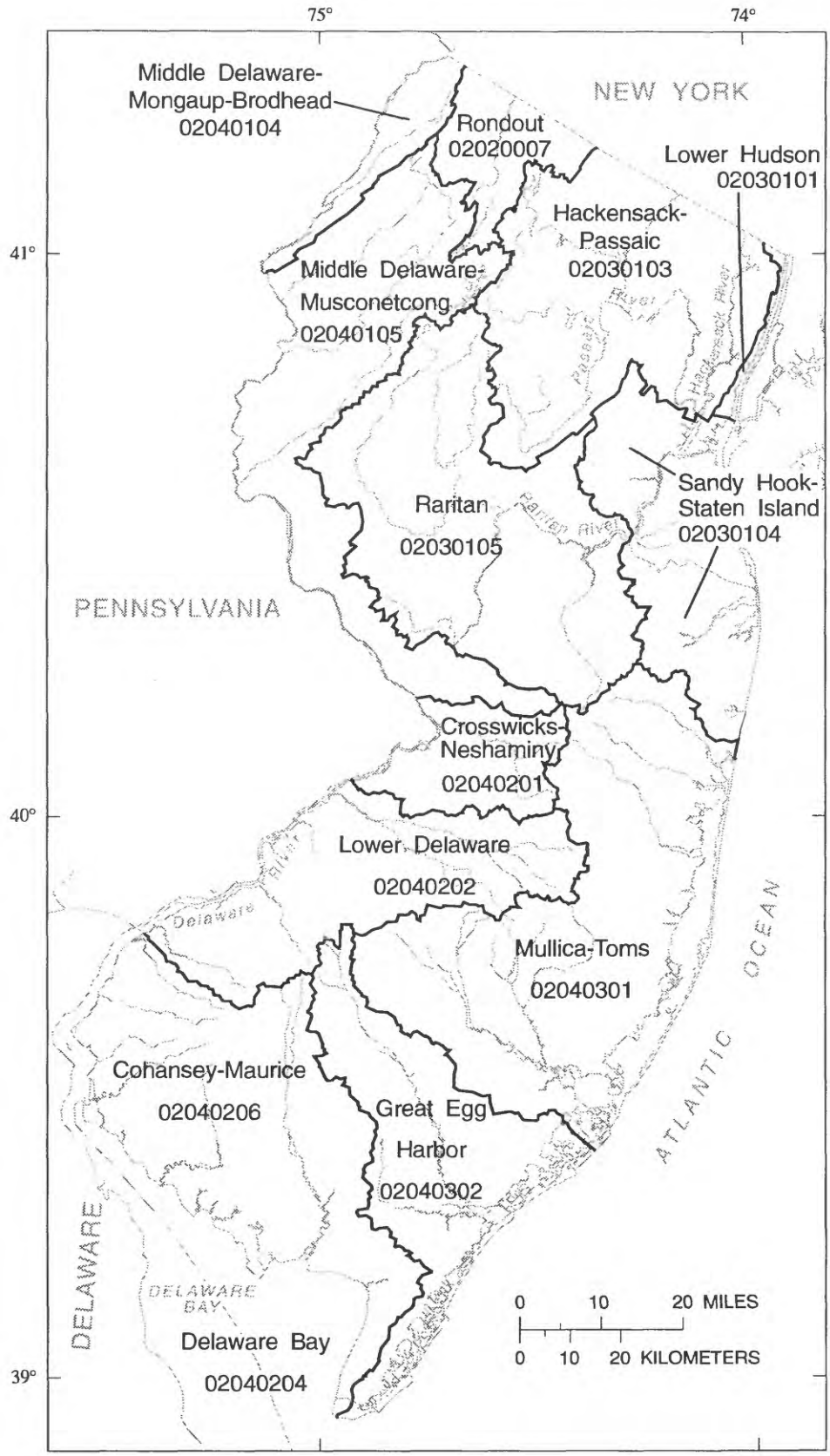

Figure 3. Hydrologic cataloging units and codes in New Jersey. (Modified from Seaber and others, 1987)

Table 2. Streams in New Jersey by hydrologic cataloging unit

[Modified from Seaber and others, 1987; mi^2, square miles]

Hydrologic cataloging unit (Drainage area)	Hydrologic unit code	Stream		Hydrologic cataloging unit (Dradinage area)	Hydrologic unit code	Stream	
Rondout[1] ($1,190 mi^2$)	02020007	Papakating Creek	Wallkill River	Lower Delaware[2] ($1,050 mi^2$)	02040202	Delaware River	Newton Creek
		Pochuck Creek				Baldwin Run	Pennsauken Creek
						Big Timber Creek	Pompeston Creek
Hackensack-Passaic[1] ($1,120 mi^2$)	02030103	Hackensack River	Rockaway River			Coopers Creek	Raccoon Creek
		Passaic River	Ramapo River			Mantua Creek	Rancocas Creek
		Pascack Brook	Saddle River			Maple Swamp	Repaupo Creek
		Pequannock River	Wanaque River			Mill Creek	Woodbury Creek
		Pompton River	Whippany River				
				Cohansey-Maurice ($1,060 mi^2$)	02040206	Cohansey River	Menantico Creek
Sandy Hook-Staten Island[1] ($679 mi^2$)	02030104	Rahway River	Shark River			Maurice River	Oldmans Creek
		Elizabeth River	Shrewsbury River			Alloway Creek	Salem River
		Matawan Creek	Woodbridge Creek			Dennis Creek	Sleeper Branch
		Moses Creek	Whale Pond Brook			Dividing Creek	Stow Creek
		Navesink River	Wreck Pond Brook			Mamumuskin Creek	Whooping Creek
Raritan ($1,080 mi^2$)	02030105	Raritan River	Middle Brook	Mullica-Toms ($1,350 mi^2$)	02040301	Mullica River	Manasquan River
		Green Brook	Millstone River			Toms River	Metedeconk River
		Lamington River	Stony Brook			Batsto River	Nescochague
Creek							
		Lawrence Brook	South River			Cedar Creek	Oswego River
						Doughty Creek	Wading River
Middle Delaware-Musconetcong[2] ($1,330 mi^2$)	02040105	Delaware River	Lockatong Creek			Kettle Creek	
		Musconetcong River	Lopatcong Creek				
		Assunpink Creek	Paulins Kill	Great Egg Harbor ($717 mi^2$)	02040302	Great Egg Harbor River	
		Delawanna Creek	Pequest River			Absecon Creek	
						Jones Creek	
Crosswicks-Neshaminy[2] ($521 mi^2$)	02040201	Crosswicks Creek	Blacks Creek			Patcong Creek	
		Assiscunk Creek	Crafts Creek			Tuckahoe River	

[1] Includes drainage area in New York

[2] Includes drainage area in Pennsylvania

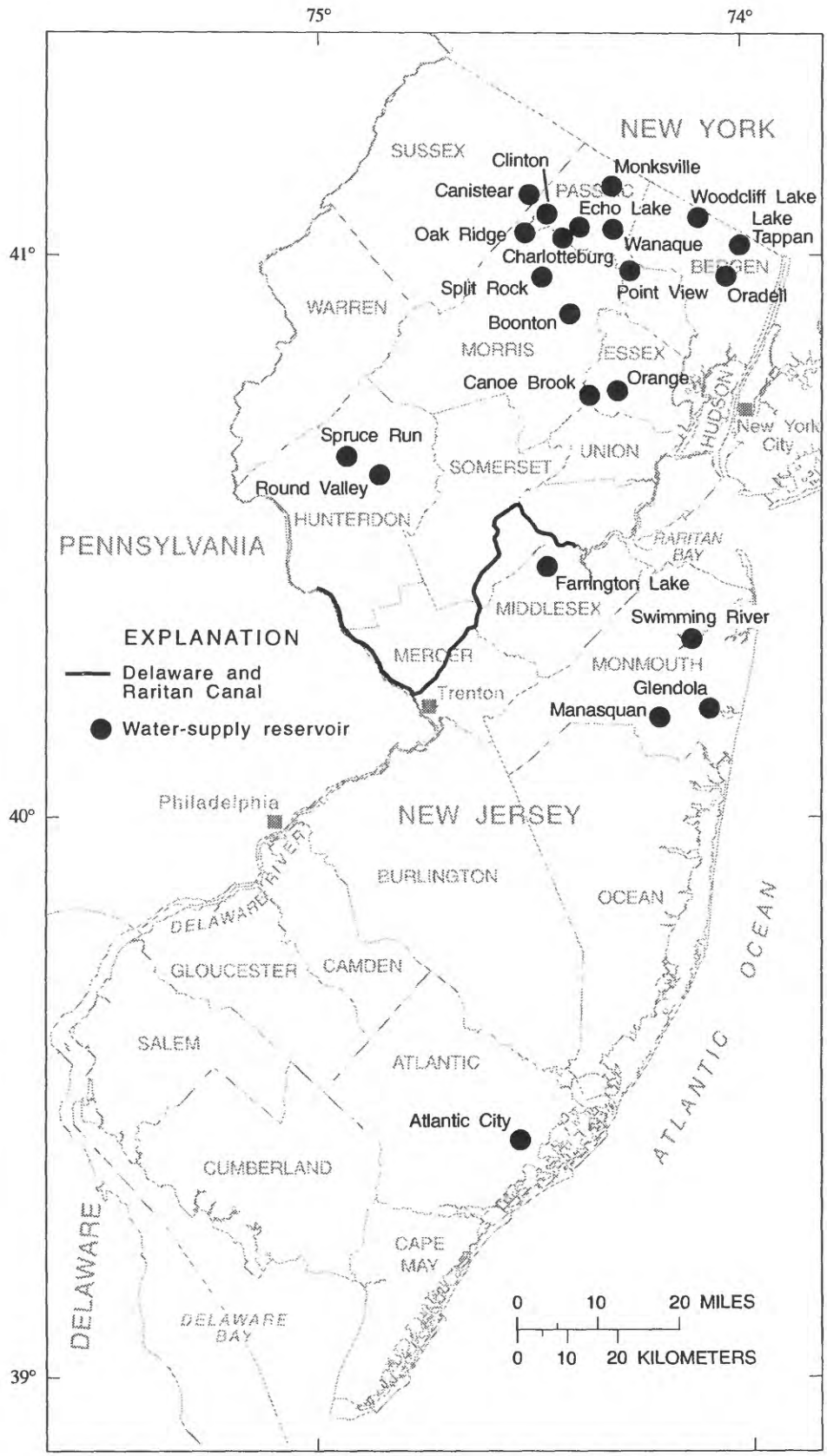

Figure 4. Water-supply reservoirs and the Delaware and Raritan Canal in New Jersey.

The average annual temperature in New Jersey during 1951-80 was 53°F and was 3°F greater in the south than in the north. The average annual temperature was 53°F in 1989 and 55° F in 1990. In 1990, average temperatures during the winter months throughout New Jersey exceeded the 30-year average monthly temperatures for this season by 6°F (fig. 5B) (National Climatic Data Center, 1990; 1991).

The agricultural community monitors soil-moisture conditions to determine the amount of supplemental water needed to maintain plant growth. Greater-than-average temperatures or below-average precipitation will result in low soil-moisture levels; therefore, withdrawals of water must be increased to provide adequate irrigation. In addition, household use of water for lawns, gardens, and outdoor recreation can be affected by the amount and frequency of precipitation (S.C. Danos, Littleton Light and Water Department, Littleton, Mass., oral commun., 1992).

Collection of Withdrawal Data

By the 1890's, rapid urban and industrial growth in New Jersey had resulted in local degradation of water quality and insufficient water supplies (Capen, 1937; New Jersey Commission on Efficiency and Economy in State Government, 1967). The State government responded to these problems by initiating water regulations and water-resources-management programs. The current water-allocation program is a comprehensive system for monitoring withdrawals of water.

Data Sources and Compilation

The 1981 Water Supply Management Act authorizes the NJDEP to monitor withdrawals of ground water and surface water in New Jersey (Saarela, 1992, p. 6). This legislation requires that all water users with the capacity to withdraw 100,000 gal/d or greater of ground water or surface water must (1) obtain permission from the NJDEP for withdrawals, (2) report monthly withdrawals, and (3) install in-line flow meters (except agricultural/horticultural users). During a 24-hour period, the amount of water withdrawn by pumping equipment producing at least 70 gal/min is about 100,000 gal.

Water users must obtain permission in the form of a permit, registration, or certification. Water-allocation permits are issued to users who withdraw 100,000 gal/d or more. Permit holders must submit quarterly reports of monthly withdrawal data and must recalibrate in-line flow meters every 5 years. Well registrants, a class of water users who use pumping equipment capable of producing 70 gal/min, but withdraw less than 100, 000 gal, must submit annual reports of monthly withdrawals.

An agricultural/horticultural certification is issued through the County Agricultural Agent, who collects information from the water user on the proposed crop type and the amount of irrigated acreage. The County Agricultural Agent determines and recertifies the maximum monthly withdrawals for each applicant; however, the NJDEP reviews site and withdrawal data for accuracy and completeness. Withdrawals for agricultural/horticultural purposes rarely are metered; water users report monthly withdrawal data that are estimated by multiplying the number of hours of use by the pump capacity. Monthly withdrawals are reported annually.

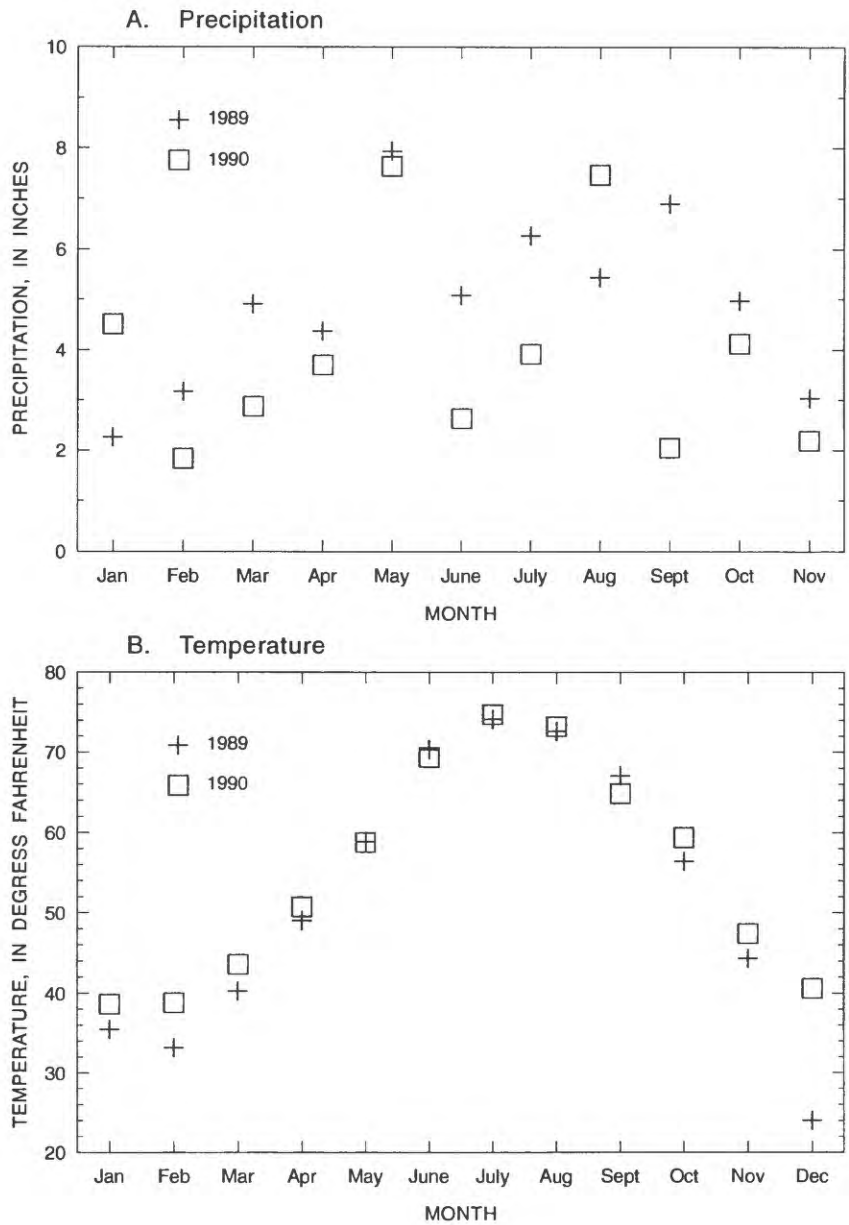

Figure 5. Average monthly precipitation and temperature in New Jersey, 1989-90: (A) precipitation and (B) temperature. (Modified from National Climatic Data Center, 1990, 1991)

Users of water for non-agricultural irrigation purposes, such as golf courses, must obtain a water-allocation permit or well registration. These users must meter their withdrawals and report them monthly according to their permit or registration requirements.

NJDEP personnel entered monthly withdrawal data into computer files for each withdrawal site and reviewed them. To identify inconsistencies, annual withdrawal data (1989 and 1990) on each water-allocation permit were compared with the annual withdrawal data for the preceding 5 years. Original paper files containing the withdrawal data were checked when errors in the computer file were suspected.

Computerized water-withdrawal information was provided by the NJDEP to the USGS as part of the Cooperative Water-Use Program. USGS personnel reconfigured and tested the withdrawal and site data before entering them into the Site-Specific Water-Use Data System (SSWUDS) data base. The USGS software was used to compare site characteristics and annual withdrawal values in the NJDEP and the SSWUDS data bases by using the NJDEP water-allocation identifier (permit, registration, or certification number) of the water user and the NJDEP well-permit number of the ground-water site and the NJDEP identifier of the surface-water site. The annual withdrawal value reported by the NJDEP was compared with the annual value that was entered for the preceding year in the SSWUDS data base for the site; values that differed by less than 1 percent were considered to match.

Data-collection forms and diagnostic messages were generated for unmatched site and withdrawal data. Unmatched data included (1) a miscoded NJDEP water-allocation identifier, well-permit number, or surface-water identifier; or (2) a change in withdrawals greater than 1 percent; or (3) a new withdrawal site or disaggregation of previously combined withdrawal data. When site and withdrawal data in the NJDEP data base and SSWUDS data base matched, the USGS software was used to reformat the withdrawal data into standard SSWUDS input configuration. Unmatched site and withdrawal data generated on data-collection forms were compared with the NJDEP paper files; corrected information was entered into the SSWUDS data base.

Methods Used to Estimate Water Withdrawals

Withdrawals by domestic-supply users and small community public-supply systems in New Jersey are unreported. Although domestic- supply wells drilled since 1947 are registered with the NJDEP (Principi, 1991), withdrawals by these low-capacity pumps (less than 70 gal/min) are not reported (Merend, 1989; Saarela, 1992).

In this study, the number of domestic-supply users in New Jersey was estimated by updating NJDEP estimates. Saarela (1992) began with the number of self-supplied residents in 1980, as reported by the U.S. Bureau of the Census, and estimated the number of new domestic-supply users by multiplying the number of domestic-well permits (by county) issued since 1980 by the average household size in 1980 (by county), as reported by the U.S. Bureau of the Census.

The number of domestic-supply users in 1989 and 1990 was estimated as the sum of the domestic-supply population reported by Saarela (1992) and the number of new well permits issued during the 2 years (Principi, 1991, p. 33) multiplied by the average county household size in 1990, as reported by the U.S. Bureau of the Census (unpublished data on computer files at

New Jersey Department of Labor, Trenton, N.J.). Withdrawals were estimated to be the product of the number of domestic-supply users and the per capita water-use coefficient of 75 gal/d (Solley and others, 1988, p. 17).

Withdrawals by small community public-supply systems, such as mobile-home parks and homeowner associations, with pumping equipment with a capacity of less than 70 gal/min were estimated by multiplying the population served by the public supplier by the per capita water-use coefficient of 75 gal/d. The population data were compiled from the Federal Reporting Data System data base of the U.S. Environmental Protection Agency (unpublished data for 1990 are on file at U.S. Geological Survey, Branch of Water Use, Reston, Va.). Withdrawals by other water users with pumping equipment with a capacity of less than 70 gal/min were not included in this compilation of withdrawal data.

Data on withdrawals for agricultural and non-agricultural irrigation were compiled from monthly withdrawal data submitted to the NJDEP; however, agricultural irrigation withdrawal data were compiled independently of the SSWUDS data base. Data on non-agricultural irrigation withdrawals, such as those for golf courses, were compiled from the SSWUDS data base. Withdrawals for livestock, usually associated with agricultural water use, are not included in this study.

Reliability of Data

Non-agricultural withdrawal data compiled by the NJDEP are highly reliable because the withdrawals are metered, and many of the in-line flow meters were recalibrated periodically. In addition, NJDEP and USGS personnel reviewed withdrawal data annually for consistency. Summaries of aggregated data (by aquifer, county, HUC, and water-use category) were checked by USGS personnel for consistency with previously reported information; inconsistencies were investigated by contacting the NJDEP or the water user.

Agricultural withdrawal data include non-metered values that were estimated by the water user and reported to the NJDEP. The reliability of the withdrawal data varies depending on the accuracy of the determination of the pump capacity and the number of hours of pumping. Pump capacity can decrease when pumping equipment ages or when water levels are lowered as a result of regional water-level changes (Eckel and Walker, 1983). Pumping time can be determined from time-totalizing meters attached to discharge pipes, running-time meters on gas- or diesel-powered generators or tractors, and electric-utility records.

During 1989, the USGS conducted a field study to verify withdrawals for irrigation use reported by 10 agricultural/horticultural users. Eighteen digital vibration-time totalizers that measure the time of pump operation were attached to irrigation pipes. Withdrawal data calculated from vibration-time-totalizer readings and estimated data reported by the water user to the NJDEP were found to have a positive correlation ($r = 0.905$). At one site, the volume determined from vibration-time-totalizer readings was compared with the volume determined from in-line flow-meter readings, and both volumes were consistent (Clawges and Titus, 1993).

Withdrawal data on domestic-supply users and small community public-supply systems are subject to the largest error of all the types of data included in this study. Both population and water-use coefficients were estimated. Population data were compared with the most recent

U.S. Bureau of the Census (1991a; 1991b) data to identify any large errors. The water-use coefficient used in this study represents the best documented and most recent estimate of per capita water use (Solley and others, 1993).

Presentation of Data

This report includes metered and estimated withdrawal data compiled from the SSWUDS and NJDEP data bases. Metered withdrawal data were compiled from the SSWUDS data base and are presented by the type of water (ground water or surface water), water-use category, county, HUC, and aquifer. Metered ground-water-withdrawal data are presented also by physiographic province.

Tables 3, 4, and 5 include estimated data on public-supply, domestic-supply, and irrigation water users. Estimated data are presented only by county and type of water; consequently, county and State totals presented in tables 3, 4 and 5 may not equal the totals shown in other tables. All withdrawal data are reported in million gallons per day and rounded to nearest whole number. Estimated population data are shown to the nearest thousand.

Previous Investigations

Vermeule (1894) discussed withdrawals for public supply in the first comprehensive report on withdrawals of ground water and surface water in the State. Hazen, Wipple, and Fuller (1922) and the New Jersey Water Policy Commission (1926) described sources, consumption, and development of potable water supplies in New Jersey. Tippetts-Abbett-McCartney-Stratton (1955) compiled public-supply withdrawal data for the New Jersey Legislative Commission on Water Supply. Major withdrawals of surface water for public supply in New Jersey are presented in the annual surface-water data reports prepared since 1961 by the USGS (Bauersfeld and others, 1990a, 1990,1992; Bauersfeld, Moshinsky, and Pustay, 1991). Agricultural water demand in New Jersey was estimated by Titus and others (1990) for field-grown crops, and by Clawges and Titus (1993) for crops, livestock, and selected sectors of the food-processing industry.

Most studies of withdrawals in New Jersey investigated the ground-water resources of the Coastal Plain. Withdrawal data on the Coastal Plain are summarized in reports by Vowinkel (1984) and Vowinkel and Foster (1981). Horn and Bratton (1991) compiled historical (1901-85) withdrawal data on Middlesex and Monmouth Counties. Earlier studies of the Coastal Plain presented withdrawal data on individual counties, aquifers, or local areas. Water-resources investigations that include ground-water withdrawal data on counties in the Coastal Plain include Clark and others (1968), Atlantic County; Rush (1968), Burlington County; Farlekas and others (1976), Camden County; Gill (1962), Cape May County; Rooney (1971), Cumberland County; Hardt and Hilton (1969), Gloucester County; Vecchioli and Palmer (1962), Mercer County; Barksdale and others (1943), Middlesex County; Jablonski (1968), Monmouth County; Anderson and Appel (1969), Ocean County; and Rosenau and others (1969), Salem County.

Reports in which results of ground-water-flow simulation are described and ground-water-withdrawal data are presented for aquifers in the Coastal Plain include reports on the Potomac-Raritan-Magothy aquifer system (Luzier, 1980), the Farrington aquifer (Farlekas, 1979), the Englishtown aquifer system (Nichols, 1977), and the Wenonah-Mount Laurel aquifer (Nemickas, 1976). Zapecza and others (1987) reported ground-water-withdrawal data on the major aquifers in the Coastal Plain.

Withdrawal data were compiled by Sargent and others (1985) for ground water, by Schopp and Bauersfeld (1986) for surface water, and by Qualls and Horn (1990) for ground water and surface water. The NJDEP compiled data on withdrawals of ground water and surface water in New Jersey during 1987 (Merend, 1989) and 1988 (Saarela, 1992).

The USGS published National water-use reports, at 5- year intervals from 1950 through 1990, that included withdrawal data on water users in New Jersey (MacKichan, 1951, 1957; MacKichan and Kammerer, 1961; Murray, 1968; Murray and Reeves, 1972, 1977; Solley and others, 1983, 1988, 1993; Solley and Pierce, 1992). In addition, data on the source, use, and disposition of water throughout the United States were compiled by Carr and others (1990) as part of the National Water Summary, a series of annual reports on the Nation's water resources.

Acknowledgments

The authors thank Helve Saarela, Michael Bleicher, and Richard Kropp of the New Jersey Department of Environmental Protection for their professional guidance in preparing this report. The authors also thank the NJDEP personnel who collected and entered monthly withdrawal data into computer files.

WITHDRAWALS OF GROUND WATER AND SURFACE WATER

In this study, withdrawals of ground water and surface water were grouped into seven categories--public supply, domestic supply, commercial, irrigation, industrial, mining, and thermoelectric power. Withdrawal data in this study represent withdrawals of freshwater. Most withdrawal data were compiled from monthly withdrawal data that were reported by water users as part of the water-allocation program in New Jersey.

In 1989, withdrawals in New Jersey totaled about 2,350 Mgal/d--about 570 Mgal/d of ground water and about 1,780 Mgal/d of surface water (table 3). In 1990, withdrawals totaled nearly 2,170 Mgal/d--about 557 Mgal/d of ground water and about 1,610 Mgal/d of surface water (table 4). Ground-water withdrawals accounted for about 25 percent of all withdrawals in the State; surface-water withdrawals accounted for about 75 percent. Hereafter, "average" represents the arithmetic mean of withdrawals reported in 1989 and 1990 (table 5).

Public Supply

Withdrawals for public supply accounted for about one-half of all withdrawals in the State. In 1989, withdrawals for public supply were nearly 1,040 Mgal/d--404 Mgal/d of ground water and 632 Mgal/d of surface water (table 3). In 1990, withdrawals for public supply totaled more than 1,020 Mgal/d--390 Mgal/d of ground water and 635 Mgal/d of surface water (table 4). Ground water accounted for about 39 percent of withdrawals for public supply, and surface water provided about 61 percent (table 5).

A public-supply system serves at least 25 people or has a minimum of 15 service connections (Solley and others, 1988, p. 10). In 1990, New Jersey had 638 public-supply systems (table 6), including 314 municipal systems, 102 investor-owned systems, 193 small community public-supply systems (homeowner associations, mobile-home parks, real-estate developers,

Table 3. Withdrawals of ground water and surface water in New Jersey by county and water-use category, 1989

[Figures may not add to totals because of independent rounding. Withdrawal data are metered values, except as noted. Values are rounded to nearest whole number, and values greater than 1,000 are rounded to three significant figures. All values in million gallons per day;**, withdrawals less than 1 million gallons per day; --, withdrawals less than reporting level of 0.005 million gallons per day]

County	Public supply		Domestic supply		Commercial		Irrigation[3]		Industrial		Mining		Thermoelectric power		Total[1]	
	Ground water[1]	Surface water	Ground water[2]	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water
Atlantic	17	2	5	--	1	--	3	2	1	--	--	--	--	--	27	4
Bergen	20	91	2	--	1	--	**	**	2	2	--	--	--	--	25	93
Burlington	34	1	6	--	1	--	3	89	6	1	--	6	--	69	50	166
Camden	62	--	2	--	**	--	**	**	**	6	1	2	--	--	66	8
Cape May	20	--	3	--	**	--	**	**	**	--	--	8	**	--	24	8
Cumberland	15	--	4	--	1	--	4	3	3	--	1	79	--	--	27	82
Essex	24	17	**	--	**	--	**	**	1	--	--	--	--	--	25	17
Gloucester	19	--	4	--	**	**	1	1	10	56	--	1	--	--	34	58
Hudson	--	--	--	--	**	--	--	--	**	--	--	--	--	--	**	--
Hunterdon	3	58	5	--	--	--	**	--	3	40	--	--	**	47	11	145
Mercer	10	32	2	--	**	**	**	**	1	3	--	--	--	604	13	639
Middlesex	37	1	2	--	**	**	**	**	8	**	**	3	--	--	48	4
Monmouth	30	30	4	--	**	--	**	**	1	--	--	--	--	--	36	30
Morris	38	57	6	--	**	--	**	**	3	1	--	1	--	--	47	59
Ocean	38	2	8	--	**	**	**	1	3	7	--	4	--	--	49	14
Passaic	6	255	2	--	--	--	**	**	**	11	--	--	--	--	8	266
Salem	3	1	2	--	--	--	**	1	4	9	--	--	1	--	10	11
Somerset	2	79	4	--	**	**	**	**	1	--	**	--	--	--	7	79
Sussex	2	1	6	--	**	--	--	**	--	--	6	--	--	--	14	1
Union	14	5	**	--	1	--	**	--	3	12	1	--	--	--	19	17
Warren	10	--	3	--	8	--	**	1	4	79	--	--	--	--	25	80
State	404	632	70	--	16	1	14	99	55	227	9	102	2	720	570	1,780

[1] Includes estimated water-use values
[2] Estimated water-use values
[3] Includes withdrawal values estimated by water user

Table 4. Withdrawals of ground water and surface water in New Jersey by county and water-use category, 1990

[Figures may not add to totals because of independent rounding. Withdrawal data are metered values, except as noted. Values are rounded to nearest whole number, and values greater than 1,000 are rounded to three significant figures. All values in million gallons per day;**, withdrawals less than 1 million gallons per day; --, withdrawals less than reporting level of 0.005 million gallons per day]

County	Public supply		Domestic supply		Commercial		Irrigation[3]		Industrial		Mining		Thermoelectric power		Total[1]	
	Ground water[1]	Surface water	Ground water[2]	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water
Atlantic	23	3	5	--	1	--	5	1	1	--	--	--	--	--	35	4
Bergen	18	94	2	--	1	--	**	--	2	2	--	--	--	--	23	96
Burlington	36	2	6	--	1	--	3	77	5	--	--	5	--	34	51	118
Camden	59	--	2	--	**	--	2	**	**	5	**	2	--	--	64	7
Cape May	20	--	4	--	**	--	1	**	**	--	--	7	**	--	25	7
Cumberland	14	--	4	--	1	--	6	1	5	--	**	24	--	--	30	25
Essex	24	17	**	--	**	--	**	**	1	--	--	--	--	--	26	17
Gloucester	20	--	4	--	**	**	1	2	11	53	--	1	--	--	36	56
Hudson	--	--	--	--	**	--	--	--	**	--	--	--	--	--	**	--
Hunterdon	3	93	5	--	--	--	**	--	2	41	--	--	**	29	11	163
Mercer	11	31	2	--	**	**	**	**	1	3	--	--	--	533	14	567
Middlesex	32	1	2	--	**	**	**	**	5	**	**	2	--	--	40	3
Monmouth	28	30	4	--	**	--	**	1	1	--	--	--	--	--	33	31
Morris	37	53	6	--	**	--	**	**	3	1	--	1	--	--	47	55
Ocean	36	1	8	--	**	**	**	1	3	6	--	6	--	--	47	14
Passaic	5	224	2	--	--	--	**	**	**	16	--	--	--	--	8	240
Salem	3	1	2	--	--	--	1	1	3	11	--	--	1	--	10	13
Somerset	1	79	4	--	--	**	**	**	1	--	**	--	--	--	6	79
Sussex	2	1	6	--	**	--	--	**	--	--	7	--	--	--	15	1
Union	10	5	**	--	1	--	**	--	3	8	**	--	--	--	15	13
Warren	8	--	3	--	6	--	**	**	5	94	--	--	--	--	22	94
State	390	635	71	--	14	1	21	85	52	241	8	48	1	596	558	1,610

[1] Includes estimated withdrawal values
[2] Estimated withdrawal values
[3] Includes withdrawal values estimated by water user

Table 5. Average withdrawals of ground water and surface water in New Jersey by county and water-use category, 1989-90

[Figures may not add to totals because of independent rounding. Values in this table may not equal the average of values in tables 3 and 4 as a result of independent rounding. Withdrawal data are metered values, except as noted. Values are rounded to nearest whole number, and values greater than 1,000 are rounded to three significant figures. All values in million gallons per day;**, withdrawals less than 1 million gallons per day; --, withdrawals less than reporting level of 0.005 million gallons per day]

County	Public supply		Domestic supply		Commercial		Irrigation[3]		Industrial		Mining		Thermoelectric power		Total[1]	
	Ground water[1]	Surface water	Ground water[2]	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water
Atlantic	20	2	5	--	1	--	4	1	1	--	--	--	--	--	31	3
Bergen	19	92	2	--	1	--	**	**	2	2	--	--	--	--	24	94
Burlington	35	1	6	--	1	--	3	83	5	**	--	5	--	51	50	140
Camden	60	--	2	--	**	--	1	**	**	5	**	2	--	--	65	7
Cape May	20	--	3	--	**	--	**	**	**	--	--	7	**	--	24	7
Cumberland	14	--	4	--	1	--	5	2	4	--	**	51	--	--	28	53
Essex	24	17	**	--	**	--	**	**	1	--	--	--	--	--	25	17
Gloucester	19	--	4	--	**	**	1	1	10	54	--	1	--	--	35	56
Hudson	--	--	--	--	**	--	--	--	**	--	--	--	--	--	**	--
Hunterdon	3	75	5	--	--	--	**	--	2	40	--	--	**	38	11	153
Mercer	10	31	2	--	**	**	**	**	1	3	--	--	--	568	13	602
Middlesex	34	1	2	--	**	**	**	**	6	**	**	2	--	--	44	3
Monmouth	29	30	4	--	**	--	**	**	1	--	--	--	--	--	34	30
Morris	37	55	6	--	**	--	**	**	3	1	--	1	--	--	47	57
Ocean	37	1	8	--	**	**	**	1	3	6	--	5	--	--	48	13
Passaic	6	239	2	--	--	--	**	**	**	13	--	--	--	--	8	252
Salem	3	1	2	--	--	--	**	1	3	10	--	--	1	--	10	12
Somerset	1	79	4	--	**	**	**	**	1	--	**	--	--	--	6	79
Sussex	2	1	6	--	**	--	--	**	--	--	6	--	--	--	14	1
Union	12	5	**	--	1	--	**	--	3	6	**	--	--	--	17	15
Warren	9	--	3	--	7	--	**	**	4	86	--	--	--	--	23	87
State	395[4]	630[4]	70[4]	--	15[4]	1[4]	16[4]	89[4]	53[4]	230[4]	8[4]	74[4]	2[4]	657[4]	561[4]	1,680[4]

[1] Includes estimated water-use values
[2] Estimated water-use values
[3] Includes withdrawal values estimated by water user
[4] Value may not equal total due to rounding

Table 6 . Public-supply systems in New Jersey by county and ownership, 1990
[From unpublished data on file at the New Jersey Department of Environmental Protection, Trenton, N.J.; --, no values reported]

County	Municipal[1]	Investor-owned[2]	Community-owned	Institution-operated[3]	Total
Atlantic	10	2	25	--	37
Bergen	16	2	1	--	19
Burlington	15	7	24	6	52
Camden	14	3	6	2	25
Cape May	13	3	13	1	30
Cumberland	4	1	13	2	20
Essex	18	1	--	1	20
Gloucester	18	3	7	--	28
Hudson	6	--	--	--	6
Hunterdon	9	9	1	2	21
Mercer	6	2	1	2	11
Middlesex	16	2	--	1	19
Monmouth	28	5	6	4	43
Morris	48	13	12	5	78
Ocean	32	9	30	1	72
Passaic	23	2	2	1	28
Salem	4	1	8	--	13
Somerset	3	1	4	--	8
Sussex	22	28	28	--	78
Union	2	1	1	--	4
Warren	7	7	11	1	26
State	314	102	193	29	638

[1] Includes municipal water departments, utilities, and authorities
[2] Includes community or condominium associations
[3] Includes residential schools, prisons, and governmental and military facilities

and apartment owners), and 29 institution-owned systems, including those supplying military, hospital, and correctional facilities (unpublished data on file at New Jersey Department of Environmental Protection, Trenton, N.J).

Although the number of people served by public-supply systems is unknown, it is estimated that about 6.8 million people, or 87 percent of the residents of New Jersey, are served by public-supply systems (fig. 6A; table 7). In urban counties, such as Bergen, Camden, Essex, Hudson, Middlesex, and Union, almost all of the population (96 percent or greater) is served by public-supply systems (figs. 1 and 6A). In contrast, in rural counties, such as Hunterdon and Sussex, fewer than one-third of the residents are served by public-supply systems.

Transfer of Surface-Water Withdrawals

Early in this century, potable water was not available in sufficient quantity near the large population centers in northern New Jersey; consequently, water-supply reservoirs and water-distribution systems were constructed to deliver surface water from rural areas to urban areas (fig. 4)(Capen, 1937). Withdrawals in Hunterdon, Morris, Passaic, and Somerset Counties are exported to water users in Essex, Hudson, and Union Counties. In Bergen County, the Hackensack Water Company imports and exports surface water for public supply. Withdrawals in Hunterdon, Morris, Passaic, and Somerset Counties are higher than would be expected if withdrawals were evaluated on the basis of population; withdrawals in Essex, Hudson, and Union Counties are lower than would be expected as a result of transfers of water (figs. 1 and 6; table 7).

Withdrawals of surface water for public supply in one county can be distributed widely among several counties through interconnected water systems. The North Jersey District Water Supply Commission administers the Wanaque Reservoir system (Passaic County) (figs. 4 and 7), the largest water-supply reservoir in the State. Water from the Wanaque system is distributed to communities throughout northeastern New Jersey. The Hackensack Water Company (Bergen County) withdraws water in the county for delivery to adjacent counties and receives water from the Wanaque Reservoir system in Passaic County. Water from water-supply reservoirs in Morris County is distributed to water utilities in Essex (City of Newark) and Hudson Counties (Jersey City) (fig. 7).

In central New Jersey, as much as 100 Mgal/d may be diverted from the Delaware River in Hunterdon County through the Delaware and Raritan Canal (Saarela, 1992, p. 9) (figs. 4 and 7). The New Jersey Water Supply Authority administers withdrawals from the Delaware and Raritan Canal, the Spruce Run-Round Valley reservoir system in Hunterdon County, and the Raritan River in Somerset County. The Elizabethtown Water Company withdraws water from the canal and the Raritan River in Somerset County for delivery to other counties (Edward Mullen, Elizabethtown Water Company, oral commun., 1992).

Withdrawals by County

Withdrawals for public supply in Passaic County averaged 245 Mgal/d, or 24 percent of all publicly supplied water in New Jersey (table 5). Withdrawals for public supply averaged 111 Mgal/d in Bergen County, 92 Mgal/d in Morris County, 80 Mgal/d in Somerset County, and 78 Mgal/d in Hunterdon County (figs. 8B, M, Q,I; table 5).

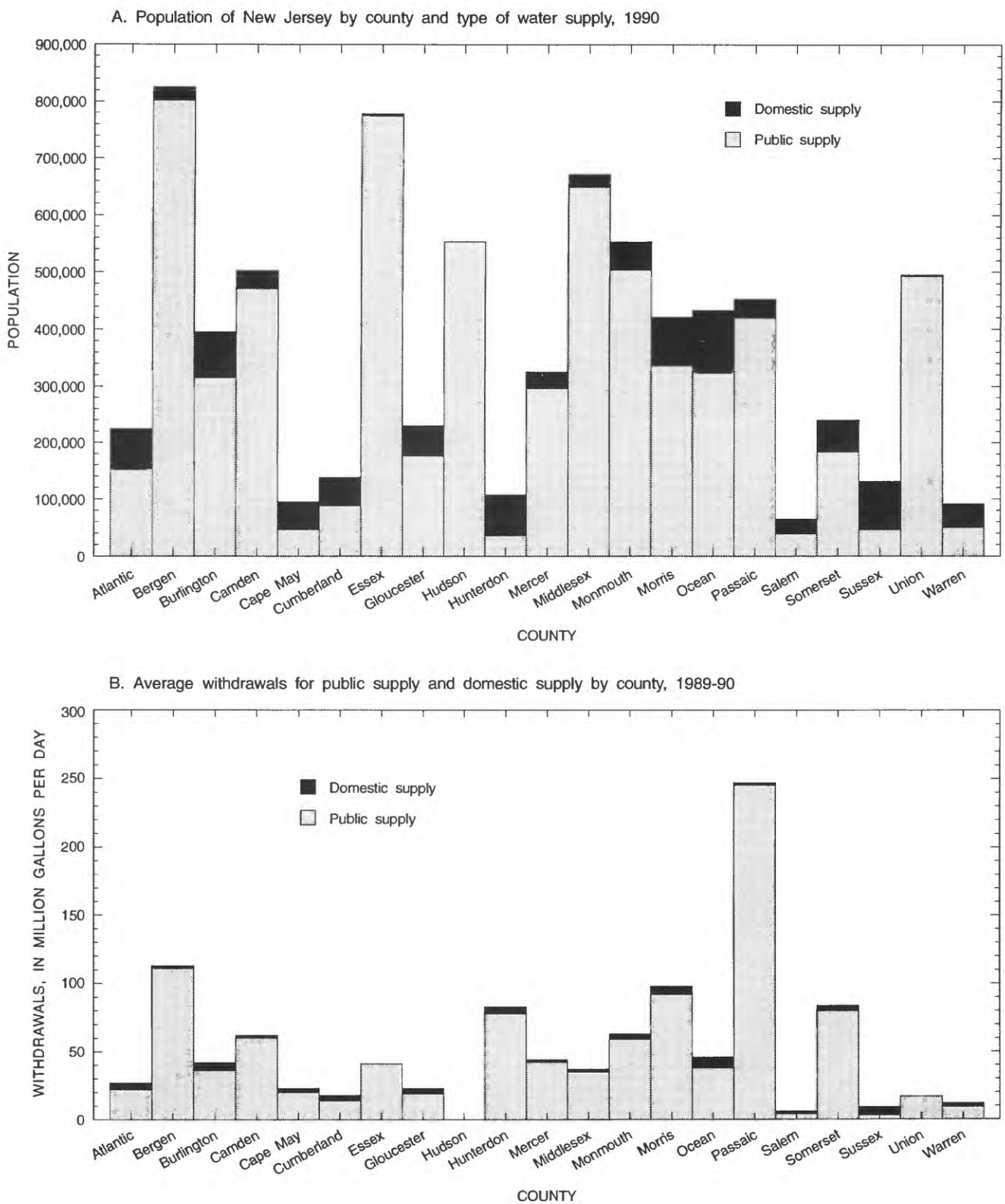

Figure 6. (A) Population of New Jersey by county and type of water supply, 1990; and (B) Average withdrawals for public supply and domestic supply by county, 1989-90.

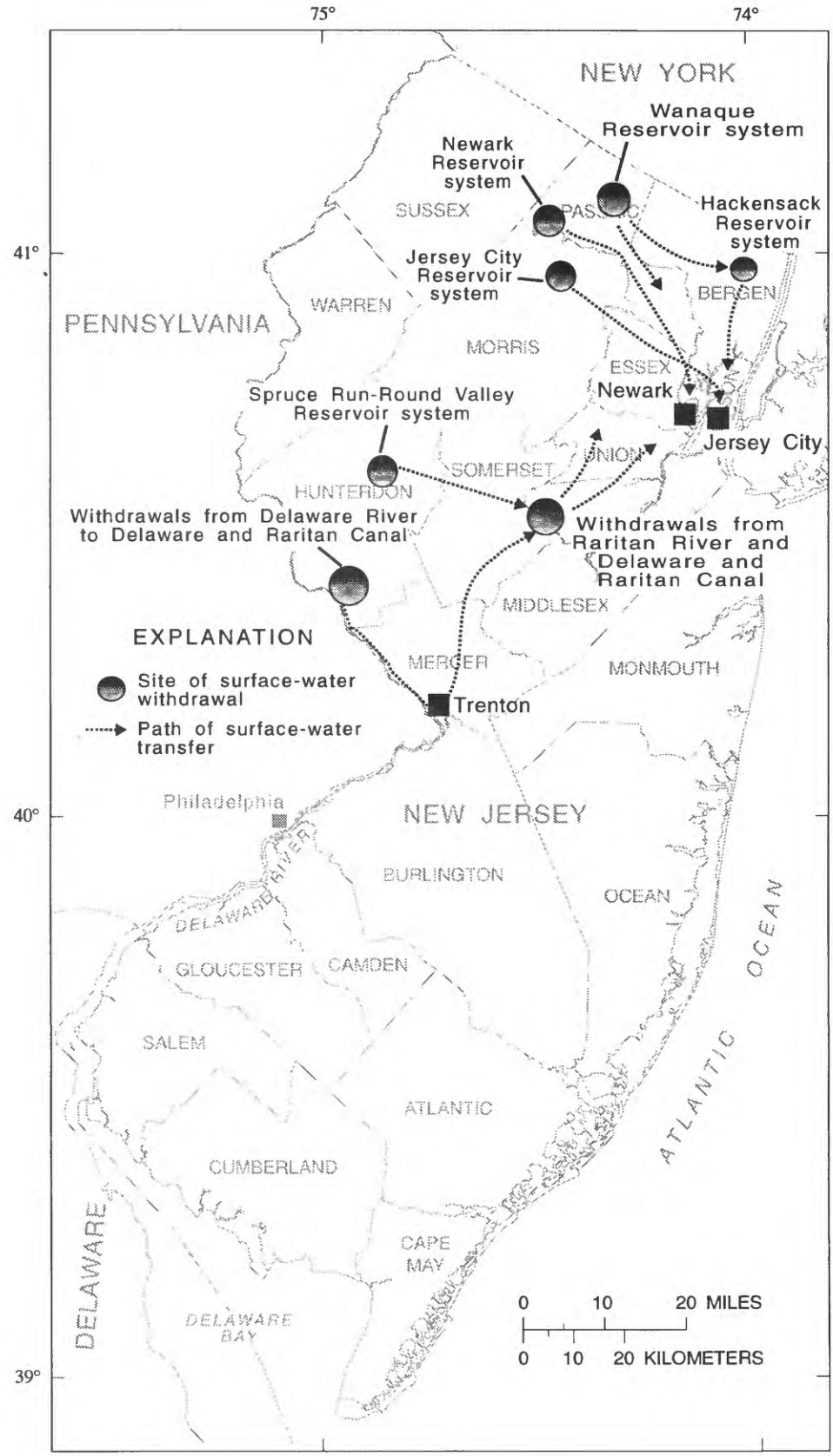

Figure 7. Transfers of surface water among public-supply systems in New Jersey.

Table 7. Population of New Jersey by county and type of water supply, 1990

[Figures may not add to totals because of independent rounding; --, value less than 1. Population data from 1990 U.S. Census on file at the New Jersey Department of Labor, Trenton, N.J. Population data rounded to nearest thousand]

County	Total population	Domestic supply		Public supply	
		Population served[1]	Percent of total population	Population served[1]	Percent of total population
Atlantic	224,000	71,000	32	153,000	68
Bergen	825,000	23,000	3	802,000	97
Burlington	395,000	80,000	20	315,000	80
Camden	502,000	31,000	6	471,000	94
Cape May	95,000	48,000	51	47,000	49
Cumberland	138,000	50,000	36	88,000	64
Essex	778,000	4,000	1	774,000	99
Gloucester	230,000	54,000	23	176,000	77
Hudson	553,000	--	--	553,000	100
Hunterdon	108,000	72,000	67	36,000	33
Mercer	326,000	29,000	9	297,000	91
Middlesex	672,000	22,000	3	649,000	97
Monmouth	553,000	50,000	9	503,000	91
Morris	421,000	85,000	20	336,000	80
Ocean	433,000	107,000	25	326,000	75
Passaic	453,000	33,000	7	420,000	93
Salem	65,000	26,000	40	39,000	60
Somerset	240,000	56,000	23	184,000	77
Sussex	131,000	85,000	65	46,000	35
Union	494,000	1,000	--	493,000	100
Warren	92,000	42,000	46	50,000	54
State	7,730,000	972,000	13	6,760,000	87

[1] Estimated data

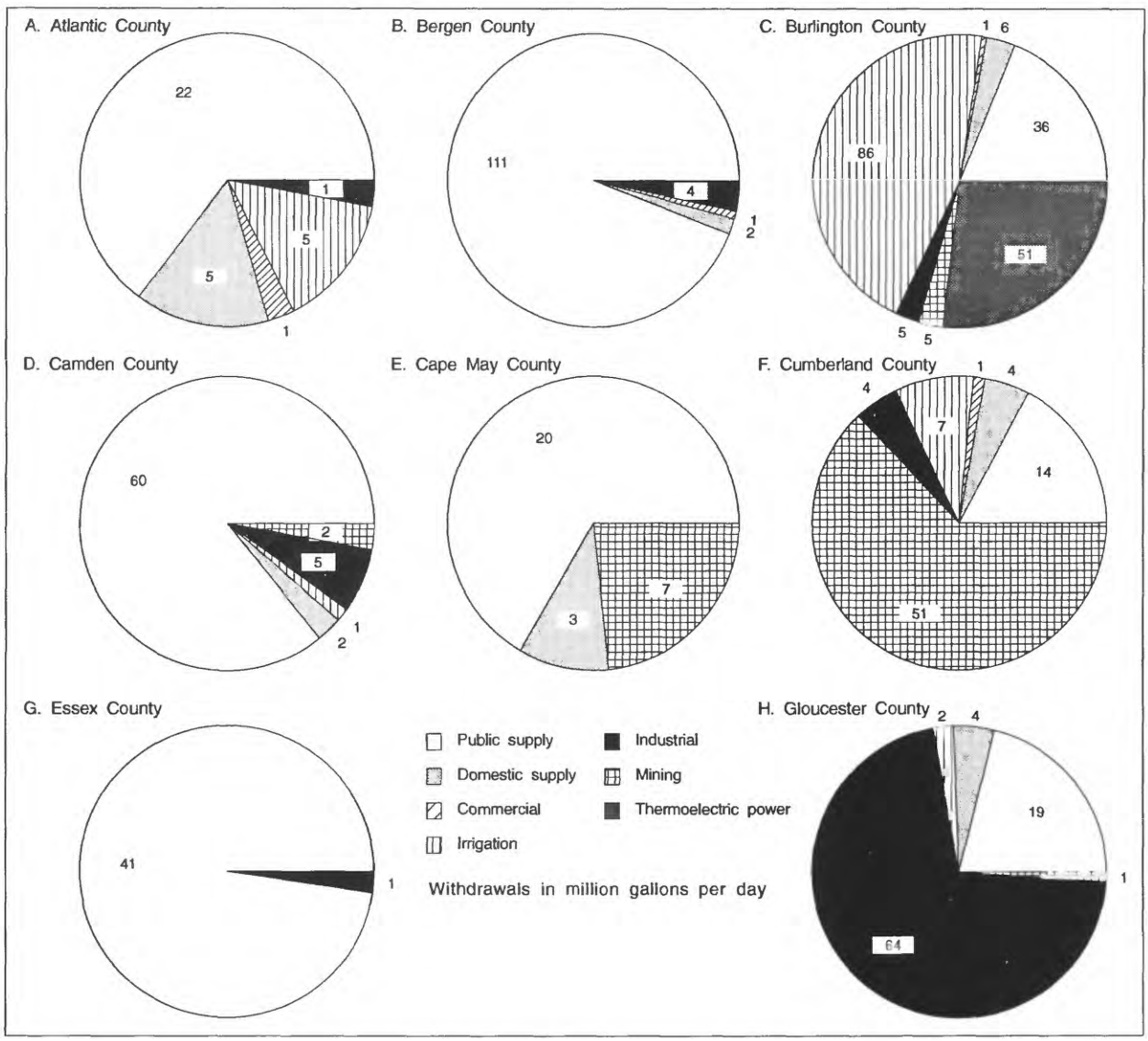

Figure 8. Average withdrawals of ground water and surface water in New Jersey by water-use category, 1989-90: (A) Atlantic County, (B) Bergen County, (C) Burlington County, (D) Camden County, (E) Cape May County, (F) Cumberland County, (G) Essex County, and (H) Gloucester County.

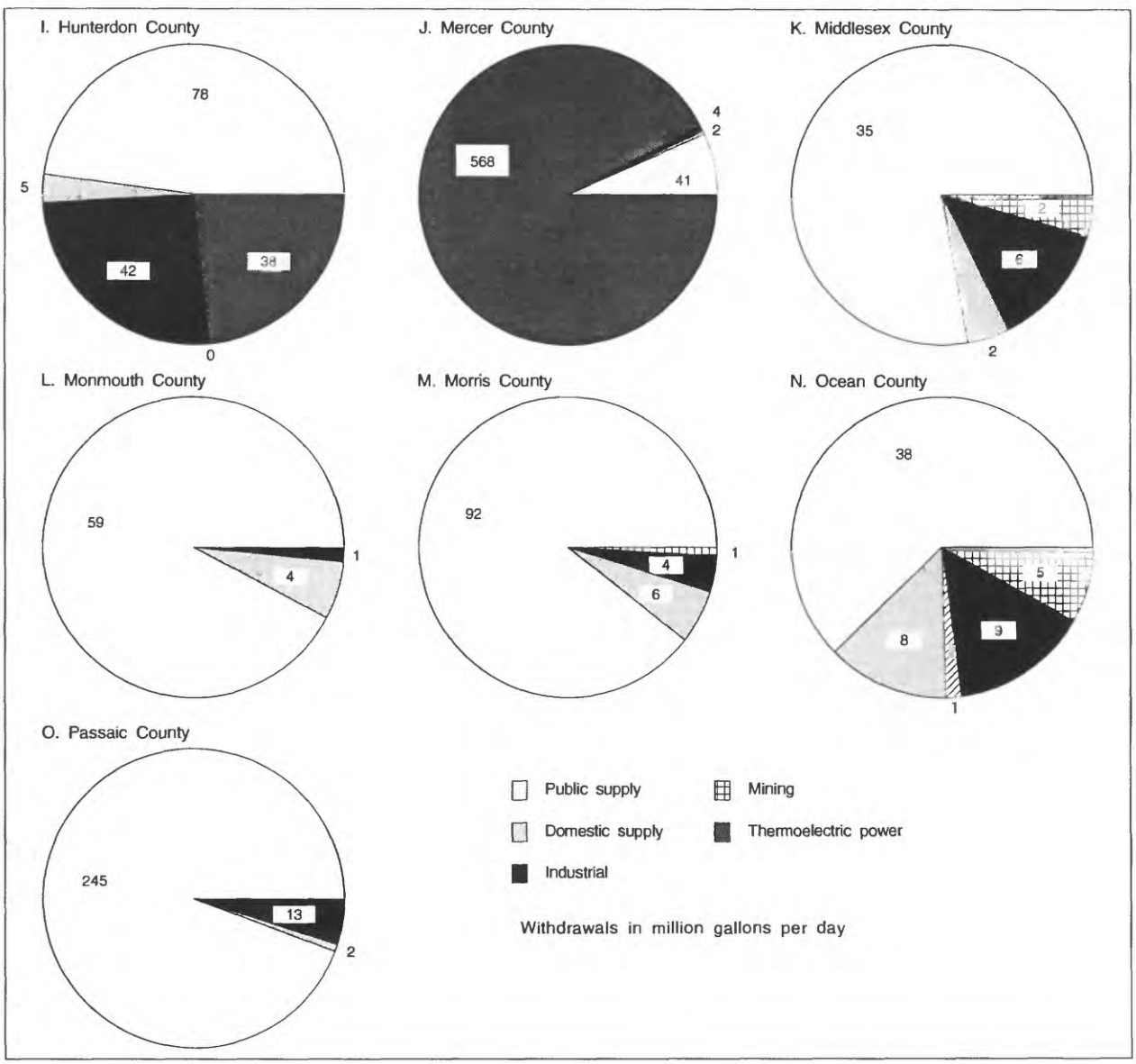

Figure 8. Average withdrawals of ground water and surface water in New Jersey by water-use category, 1989-90: (I) Hunterdon County, (J) Mercer County, (K) Middlesex County, Monmouth County, (M) Morris County, (N) Ocean County, and (O) Passaic County--Continued.

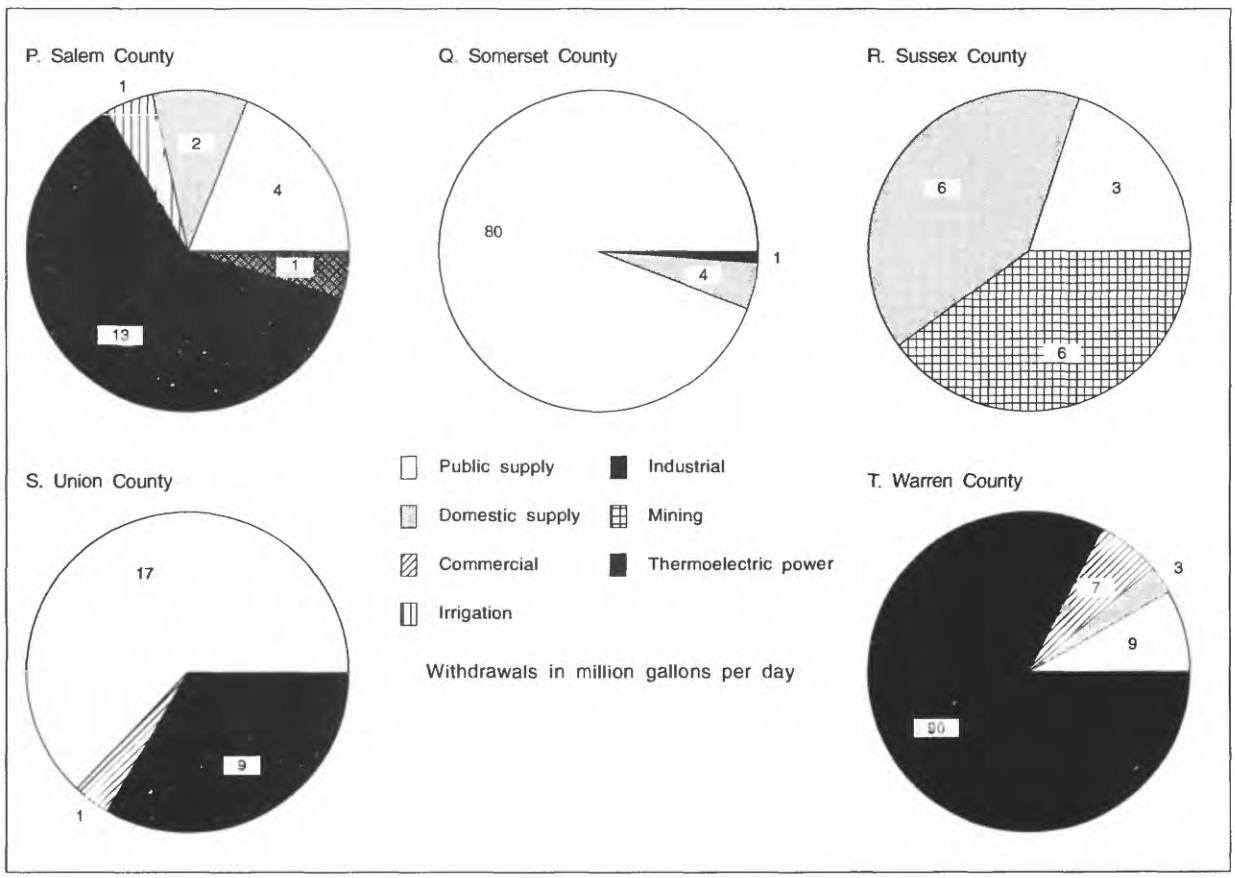

Figure 8. Average withdrawals of ground water and surface water in New Jersey by water-use category, 1989-90: (P) Salem County, (Q) Somerset County, (R) Sussex County, (S) Union County, and (T) Warren County--Continued.

In the Coastal Plain, ground water is the primary source of water. Withdrawals in Camden County accounted for 15 percent (average 60 Mgal/d) of all public-supply withdrawals of ground water in New Jersey (fig. 8D; table 5). Withdrawals of ground water for public supply averaged 37 Mgal/d, 35 Mgal/d, and 34 Mgal/d in Ocean, Burlington, and Middlesex Counties, respectively (table 5).

In northeastern and central New Jersey (fig. 1), surface water is the primary source of water, although public-supply withdrawals of ground water in Morris County averaged 37 Mgal/d (table 5). Withdrawals from water-supply reservoirs in Passaic County (figs. 1, 4, and 7) averaged 239 Mgal/d (table 5). Withdrawals of surface water for public supply averaged 92 Mgal/d in Bergen County, 79 Mgal/d in Somerset County, and 75 Mgal/d in Hunterdon County (table 5).

Withdrawals by Hydrologic Cataloging Unit

Withdrawals for public supply in the Hackensack-Passaic HUC averaged 462 Mgal/d (fig. 9; tables 8 and 9). Withdrawals for public supply averaged 135 Mgal/d in the Raritan HUC, 122 Mgal/d in the Middle Delaware- Musconetcong HUC, 101 Mgal/d in the Lower Delaware HUC, and 85 Mgal/d in the Sandy Hook-Staten Island HUC (fig. 9; tables 8 and 9). Because estimated withdrawals are not included in the compilation of withdrawal data by HUC, total (State) withdrawals reported by HUC (tables 8 and 9) may differ from the total (State) withdrawals reported by county (tables 3, 4, and 5).

Ground water was the only source of water used for public supply in the Lower Delaware HUC and averaged 101 Mgal/d (fig. 9; tables 8 and 9). Average ground-water withdrawals by water utilities in the Hackensack-Passaic, Raritan, and Mullica-Toms HUC's were 76 Mgal/d, 53 Mgal/d, and 44 Mgal/d, respectively (tables 8 and 9).

Withdrawals for public supply from the public-supply reservoirs in the Hackensack-Passaic HUC averaged 386 Mgal/d (tables 8 and 9). Withdrawals of surface water in the Middle Delaware-Musconetcong HUC averaged 108 Mgal/d. The withdrawals were solely from the Delaware River and included withdrawals for the City of Trenton (fig. 1) and water transfers to the Delaware and Raritan Canal (figs. 4 and 7). Average withdrawals of surface water for public supply were 82 Mgal/d in the Raritan HUC and 52 Mgal/d in the Sandy Hook-Staten Island HUC (tables 8 and 9).

Withdrawals by Aquifer and Physiographic Province

Withdrawals of ground water for public supply in the Coastal Plain averaged 268 Mgal/d (table 10). Withdrawals from the Potomac-Raritan-Magothy aquifer system, the primary source of ground water for public supply in New Jersey, averaged 176 Mgal/d (table 10). Average withdrawals from the upper, middle, and lower Potomac-Raritan-Magothy aquifers were 67 Mgal/d, 58 Mgal/d, and 47 Mgal/d, respectively (fig. 10A; table 10). Withdrawals for public supply averaged 54 Mgal/d from the Kirkwood-Cohansey aquifer system and 20 Mgal/d from the Atlantic City 800-foot sand (fig. 10A; table 10). The largest withdrawals of ground water in New Jersey were in Camden County (figs. 10B and 11B; table 5), where most of the water was for public-supply users (fig. 8D; table 5). Because estimated withdrawals are not included in the compilation of withdrawal data by aquifer, total (State) withdrawals reported by aquifer (tables 10 and 11) may differ from the total (State) withdrawals reported by county (tables 3, 4, and 5).

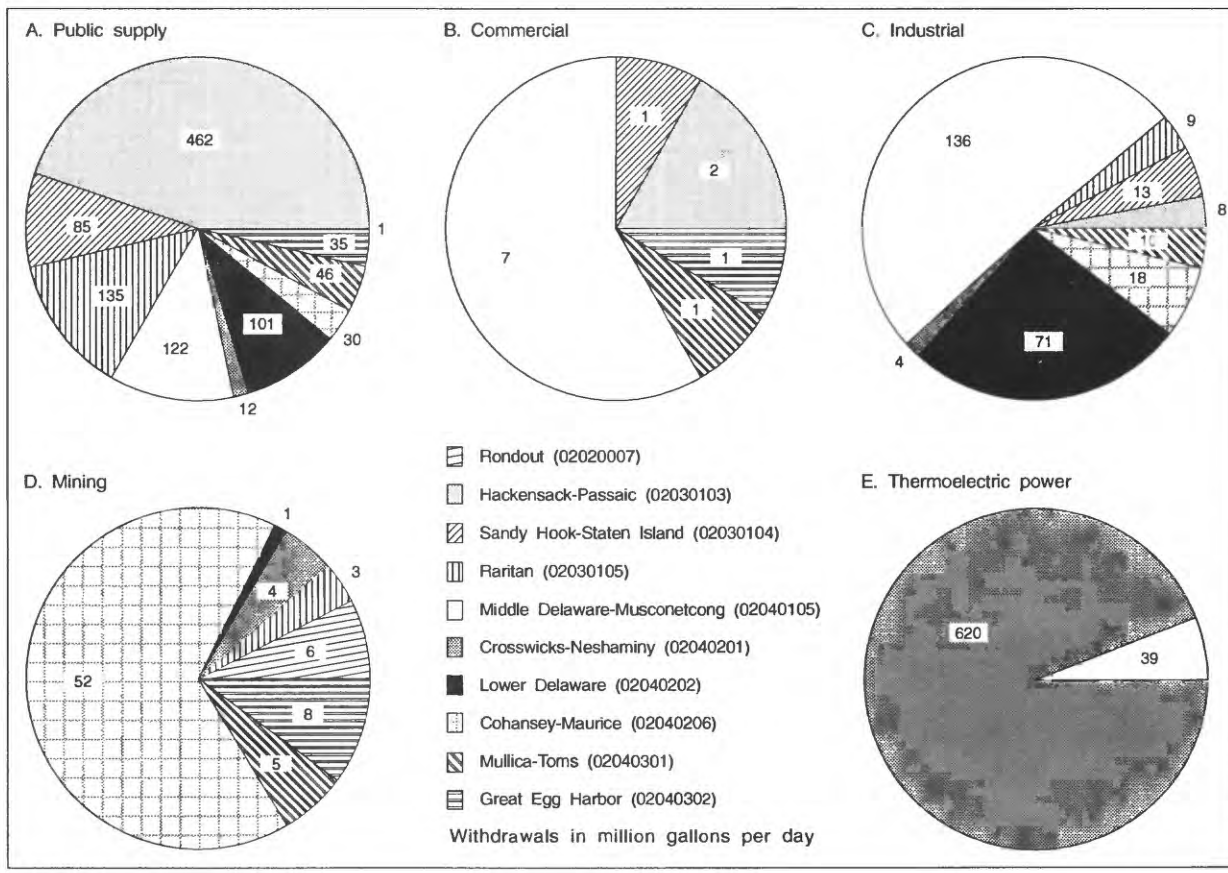

Figure 9. Average withdrawals of ground water and surface water in New Jersey by hydrologic cataloging unit, 1989-90, for: (A) public supply, (B) commerical use, (C) industrial use, (D) mining use, and (E) thermoelectric-power use.

Table 8. Withdrawals of ground water and surface water in New Jersey by hydrologic cataloging unit and water-use category, 1989

[Figures may not add to totals because of independent rounding. Withdrawal data for domestic-supply, irrigation, and small public-supply users are not included. Withdrawal data are metered values and are rounded to nearest whole number. Values greater than 1,000 are rounded to three significant figures. All values in million gallons per day;**, withdrawals less than 1 million gallons per day; --, withdrawals less than reporting level of 0.005 million gallons per day]

Hydrologic cataloging unit and code	Public supply		Commercial		Industrial		Mining		Thermoelectric power		Total	
	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water
Rondout (02020007)	1	**	**	--	--	--	6	--	--	--	7	**
Hackensack-Passaic (02030103)	78	402	2	--	7	2	--	**	--		87	404
Sandy Hook-Staten Island (02030104)	35	52	1	--	4	12	1	--	--	--	41	64
Raritan (02030105)	56	82	**	--	9	1	**	3	**	--	65	86
Middle Delaware-Musconetcong (02040105)	15	91	8	**	5	122	--	--	--	47	28	260
Crosswicks-Neshaminy (02040201)	10	1	**	--	5	--	--	5	--	673	15	679
Lower Delaware (02040202)	102	--	**	**	11	62	**	1	--	--	114	63
Cohansey-Maurice (02040206)	29	1	**	--	8	9	1	79	1	--	39	89
Mullica-Toms (02040301)	46	2	1	**	4	7	--	4	--	--	51	13
Great Egg Harbor (02040302)	29	2	1	--	1	--	**	9	**	--	32	11
State	401	633	14	1	54	215	9	101	2	720	480	1,670

Table 9. Withdrawals of ground water and surface water in New Jersey by hydrologic cataloging unit and water-use category, 1990

[Figures may not add to totals because of independent rounding. Withdrawal data for domestic-supply, irrigation, and small public-supply users are not included. Withdrawal data are metered values and are rounded to nearest whole number; values greater than 1,000 are rounded to three significant figures. All values in million gallons per day;**, withdrawals less than 1 million gallons per day; --, withdrawals less than reporting level of 0.005 million gallons per day]

Hydrologic cataloging unit and code	Public supply		Commercial		Industrial		Mining		Thermoelectric power		Total	
	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water	Ground water	Surface water
Rondout (02020007)	1	**	**	--	--	--	7	--	--	--	8	**
Hackensack-Passaic (02030103)	75	369	2	--	6	2	--	**		--	83	371
Sandy Hook-Staten Island (02030104)	31	52	1	--	2	8	**	--	--	--	34	60
Raritan (02030105)	51	82	**	**	8	1	**	3	--	--	59	86
Middle Delaware-Musconetcong (02040105)	13	125	6	**	5	139	--	--	**	30	24	294
Crosswicks-Neshaminy (02040201)	11	2	--	--	4	--	--	4	--	567	15	573
Lower Delaware (02040202)	101	--	**	--	12	58	--	2	--	--	113	60
Cohansey-Maurice (02040206)	29	1	**	--	9	11	**	24	1	--	39	36
Mullica-Toms (02040301)	43	1	1	**	4	6	--	6	--	--	48	13
Great Egg Harbor (02040302)	36	3	1	--	**	--	**	8	--	--	37	11
State	391	635	11	1	50	225	8	47	1	597	461	1,500

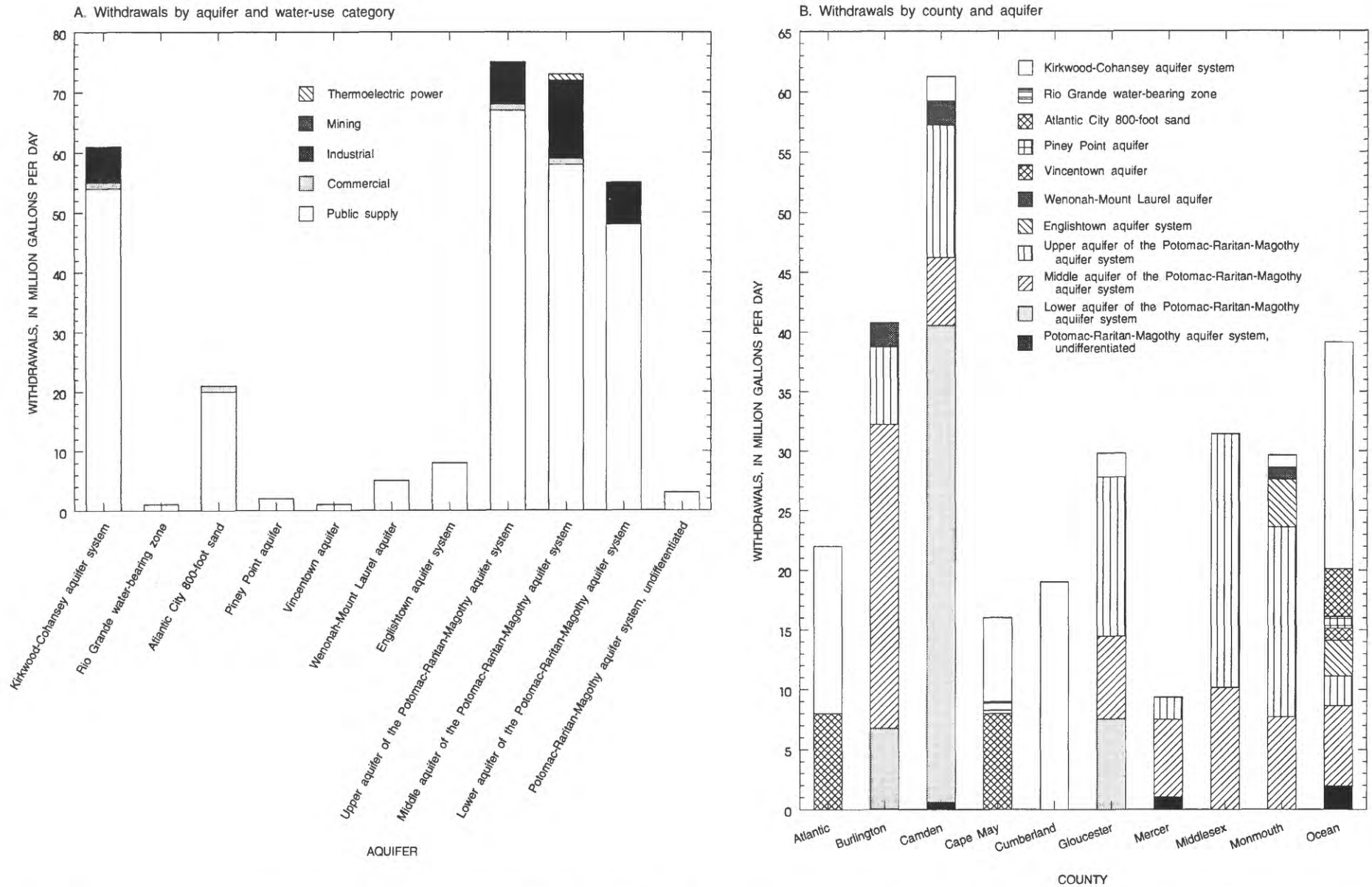

Figure 10. Average withdrawals of ground water in the Coastal Plain of New Jersey, 1989-90, by: (A) aquifer and water-use category, and (B) county and aquifer.

The glacial-deposit aquifers lie in all three physiographic provinces north of the Fall Line (fig. 2) and were the chief source of ground water for public supply in northern New Jersey (fig. 11A; table 10). Withdrawals for public supply from the glacial-deposit aquifers in Morris County averaged 34 Mgal/d and were the largest public-supply withdrawals of ground water north of the Fall Line (fig. 11B; table 11). Withdrawals from aquifers of the Brunswick Group in the Piedmont Province averaged 42 Mgal/d. Ground-water withdrawals for public supply (excluding withdrawals from glacial-deposit aquifers) in the Highlands and Valley and Ridge Provinces averaged about 8 Mgal/d, including about 5 Mgal/d from the aquifers of the Kittatinny Supergroup and about 2 Mgal/d from the Precambrian crystalline-rock aquifers (fig. 11A; table 10).

Domestic Supply

Withdrawals of ground water for domestic supply, water from private wells for household use, were estimated to be 70 Mgal/d in 1989 and 71 Mgal/d in 1990 (tables 3 and 4). Although State well permits have been issued since 1947 (Principi, 1991, p. 2-3), withdrawals by users with low-capacity pumps (less than 70 gal/min) are not reported to the NJDEP (Saarela, 1992). The estimated population distribution of domestic-supply users in New Jersey in 1990 is shown in table 7.

About 13 percent of the population of New Jersey maintains their own water-supply systems (fig. 6A; table 7). Most residents of Hunterdon (67 percent) and Sussex (65 percent) Counties and about one-half of the population of Cape May (51 percent) and Warren (46 percent) Counties are supplied by domestic wells. Domestic-supply users in Salem, Cumberland, and Atlantic Counties include about 40 percent, 36 percent, and 32 percent, respectively, of all county residents (fig. 6A; table 7).

In Ocean County, private wells are used for domestic supply by about 25 percent of the residents (fig. 6A, table 7); however, the average withdrawals (8 Mgal/d) in the County accounted for 11 percent of all withdrawals for domestic supply in the State (figs. 6B and 8N; table 5). Average domestic- supply withdrawals were 6 Mgal/d each in Morris, Sussex, and Burlington Counties, and 5 Mgal/d each in Hunterdon and Atlantic Counties (figs. 6B and 8 M,R, C, I,A; table 5).

Commercial

Withdrawals for commercial use are chiefly ground water. In 1989, withdrawals for commercial use totaled 17 Mgal/d, including 1 Mgal/d of surface water. In 1990, withdrawals for commercial use totaled 15 Mgal/d, including 1 Mgal/d of surface water (tables 3 and 4).

About 75 percent of the 214,000 establishments (see glossary for definition) in New Jersey in 1989 were classified as commercial (Horner, 1992, p. 249). Service industries (32 percent), retail trade (23 percent), wholesale trade (8 percent), finance/real estate/insurance (8 percent), and transportation establishments (4 percent) make up the commercial water users in the State. Most of these commercial users are located in urban areas and served by water utilities. Typically, self-supplied commercial users are schools, colleges, parks, and toll-road service areas distant from water utilities. Large commercial water users, such as hospitals, hotels, and research centers, purchase supplemental water from public-supply systems.

Table 10. Withdrawals of ground water in New Jersey by physiographic province, aquifer, and water-use category, 1989 and 1990

[Figures may not add to totals because of independent rounding. Withdrawal data for domestic-supply, irrigation, and small public-supply users are not included. Withdrawal data are metered values and are rounded to nearest whole number. All values in million gallons per day;**, withdrawals less than 1 million gallons per day; --, withdrawals less than reporting level of 0.005 million gallons per day]

Physiographic province	Public supply		Commercial		Industrial		Mining		Thermoelectric power		Total	
Aquifer	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Coastal Plain Aquifers												
Coastal Plain												
Kirkwood-Cohansey aquifer system	51	58	1	1	5	7	**	**	**	**	58	66
Rio Grande water-bearing zone	1	1	**	--	--	--	--	--	--	--	1	1
Atlantic City 800-foot sand	21	19	1	1	--	--	--	--	**	**	22	20
Piney Point aquifer	2	2	--	**	--	--	--	--	--	--	2	2
Vincentown aquifer	1	1	--	--	--	--	--	--	--	--	1	1
Wenonah-Mount Laurel aquifer	5	5	**	**	**	**	--	--	**	**	5	5
Englishtown aquifer system	9	7	**	**	--	--	--	--	--	--	9	7
Potomac-Raritan-Magothy aquifer system												
Upper aquifer	66	68	1	**	9	6	--	--	--	--	76	74
Middle aquifer	59	57	1	1	14	12	--	--	1	1	75	71
Lower aquifer	49	46	--	--	8	7	--	--	--	--	57	53
Undifferentiated	4	3	--	--	--	**	**	--	--	--	4	3
Coastal Plain total	268	267	4	4	36	32	**	**	2	1	310	304

Table 10. Withdrawals of ground water in New Jersey by physiographic province, aquifer, and water-use category, 1989 and 1990 --Continued

Physiographic province / Aquifer	Public supply		Commercial		Industrial		Mining		Thermoelectric power		Total	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Non-Coastal Plain Aquifers												
Piedmont, Highlands, and Valley and Ridge Provinces												
Glacial-deposit aquifers	60	60	8	6	3	2	--	--	--	--	71	68
Piedmont Province												
Aquifers of the Brunswick Group	47	38	3	3	10	9	1	**	**	**	61	50
Lockatong Formation	--	--	--	--	**	**	--	--	--	--	**	**
Stockton Formation	1	1	**	**	**	**	--	--	--	--	1	1
Province total[1]	48	39	3	3	10	9	1	**	**	**	62	51
Highlands and Valley and Ridge Provinces												
Aquifers of the Kittatinny Supergroup	6	5	**	**	5	5	--	--	--	--	11	10
Franklin Limestone	**	**	--	--	--	--	6	7	--	--	6	7
Precambrian crystalline-rock aquifers	3	2	--	--	**	1	--	--	--	--	3	3
Highlands and Valley and Ridge Provinces total[1]	9	7	**	**	5	6	6	7	--	--	20	20
State	385	373	15	14	54	49	7	8	2	1	463	443

[1] Total does not include withdrawals from glacial-deposit aquifers

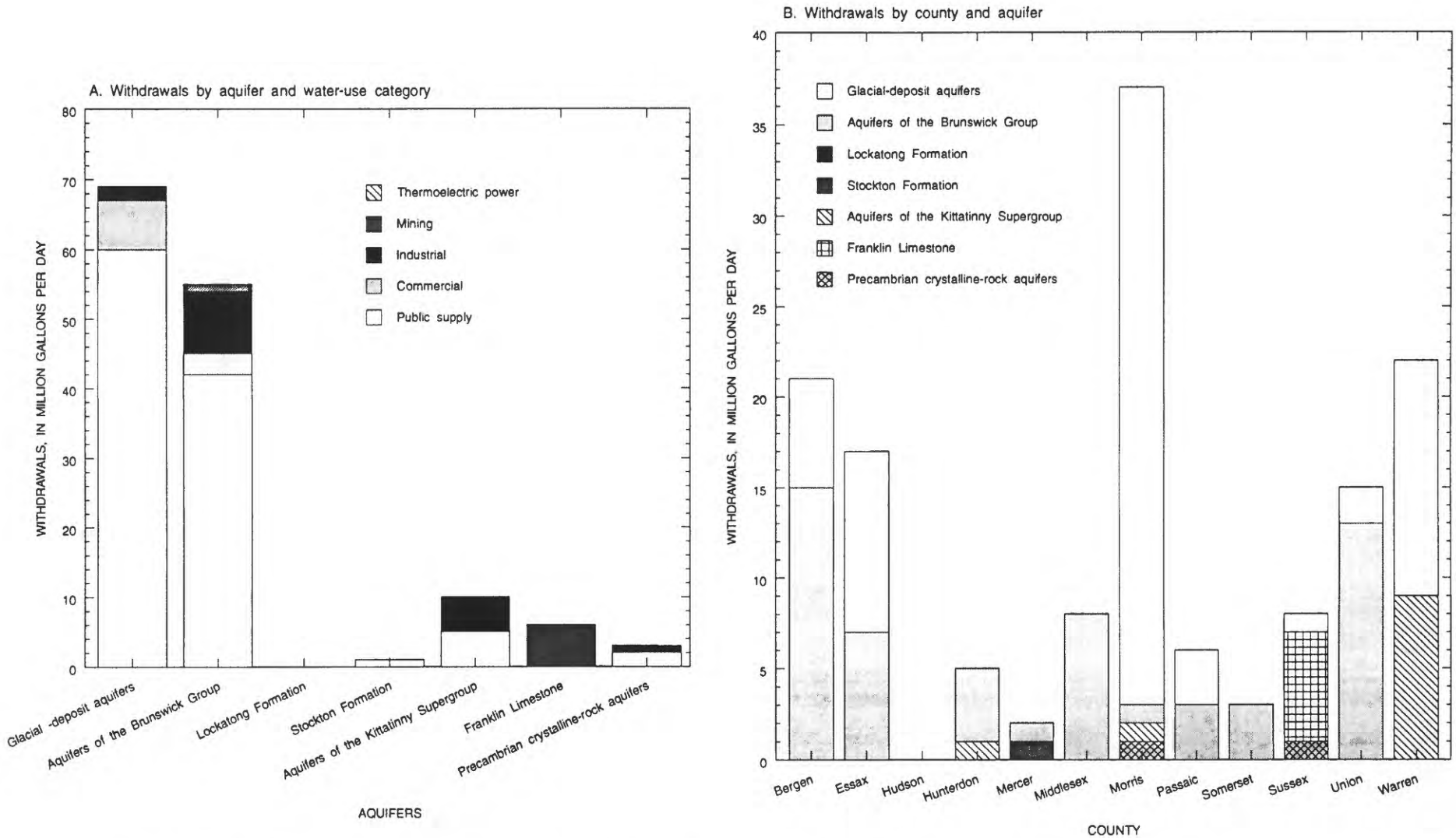

Figure 11. Average withdrawals of ground water in the Piedmont, Highlands, and Valley and Ridge Physiographic Provinces in New Jersey, 1989-90, by: (A) aquifer and water-use category, and (B) county and aquifer.

Withdrawals by County

Withdrawals for commercial use in Warren County averaged 7 Mgal/d (fig. 8T), accounting for nearly one-half of all withdrawals for commercial use in New Jersey (table 5). Withdrawals by commercial users in Atlantic, Bergen, Burlington, Cumberland, and Union Counties averaged 1 Mgal/d each in 1989 and 1990 (tables 3 and 4). Withdrawals for commercial use consisted almost entirely of ground water; most withdrawals were in Warren County where the Pequest (State-operated) fish hatcheries are located. Surface-water withdrawals for commercial use averaged 1 Mgal/d each in 1989 and 1990 (tables 3 and 4).

Withdrawals by Hydrologic Cataloging Unit

The largest withdrawals by commercial users (average 7 Mgal/d) in the State were in the Middle Delaware-Musconetcong HUC (fig. 9; tables 8 and 9). Withdrawals by commercial facilities averaged 2 Mgal/d in the Hackensack- Passaic HUC and 1 Mgal/d each in the Sandy Hook-Staten Island, Mullica-Toms, and Great Egg Harbor HUC's (fig. 9; tables 8 and 9).

Withdrawals by Aquifer and Physiographic Province

Average withdrawals from the glacial-deposit aquifers for commercial use were 7 Mgal/d (fig. 11A; table 10) and were chiefly in Warren County (table 5). Withdrawals for commercial use in the Coastal Plain averaged 4 Mgal/d (fig. 10A; table 10). Withdrawals for commercial use from aquifers of the Brunswick Group averaged 3 Mgal/d (fig. 11A; table 10).

Irrigation

New Jersey, the Garden State, supports a viable agricultural trade as a result of the State's productive soils, proximity to major markets, and abundant water resources. In 1990, about 8,000 farms occupied 19 percent (900,000 acres or 1,406 mi^2) of the land area of the State (U.S. Bureau of the Census, 1991a, p. 262). Peaches, tomatoes, hay, and soybeans were among the primary agricultural products (U.S. Bureau of the Census, 1991b, p. 664, 669). Almost all of the irrigated crop and orchard cultivation in New Jersey is in counties located in the Coastal Plain.

In 1989, withdrawals for irrigation use totaled 113 Mgal/d--14 Mgal/d of ground water and 99 Mgal/d of surface water (table 3). In 1990, withdrawals for irrigation use were 106 Mgal/d--21 Mgal/d of ground water and 85 Mgal/d of surface water (table 4).

The amount of water attributed to irrigation use in New Jersey can be misleading because the non-consumptive use of water in cranberry production accounted for about 7 of every 10 gal of water used for irrigation (unpublished data on file at New Jersey Department of Environmental Protection, Trenton, N.J.). In 1989, New Jersey ranked third in the United States in cranberry production (U.S. Bureau of the Census, 1991b). Cranberry bogs cover about 3,000 acres in the State (Clawges and Titus, 1993), and the bogs are flooded twice a year for harvesting and frost protection (Titus and others, 1990, p. 2, 17). Withdrawals for cranberry production in the State were estimated to be 76 Mgal/d in 1986 (unpublished data on file at New Jersey Department of Environmental Protection, Trenton, N.J.). Average withdrawals for irrigation (1989-90) in Burlington County, primarily for cranberry production, were 86 Mgal/d, accounting for 78 percent of all withdrawals by irrigators (fig. 8C; table 5). If water demand for cranberry

Table 11. Average withdrawals of ground water in New Jersey by physiographic province, aquifer, and county, 1989-90

[Figures may not add to totals because of independent rounding. Withdrawal data for domestic-supply, irrigation, and small public-supply users are not included. Withdrawal data are metered values and are rounded to nearest whole number. All values in million gallons per day; **, withdrawals less than 1 million gallon per day; --, withdrawals less than 0.005 million gallons per day; ##, aquifer not present]

Physiographic province / Aquifer	County										
	Atlantic	Burlington	Camden	Cape May	Cumberland	Gloucester	Mercer	Middlesex	Monmouth	Ocean	Salem
					Coastal Plain aquifers						
Coastal Plain											
Kirkwood-Cohansey aquifer system	14	**	2	7	19	2	##	##	1	19	**
Rio Grande water-bearing zone	--	##	##	1	##	##	##	##	##	**	##
Atlantic City 800-foot sand	8	##	##	8	##	##	##	##	##	4	##
Piney Point aquifer	**	**	--	--	--	--	##	##	##	1	--
Vincentown aquifer	##	--	--	##	##	--	##	##	**	1	--
Wenonah-Mt. Laurel aquifer	--	2	2	--	--	--	##	##	1	--	**
Englishtown aquifer system	--	**	**	##	--	--	##	##	4	3	--
Upper Potomac-Raritan-Magothy aquifer	--	7	11	--	--	13	2	21	16	2	3
Middle Potomac-Raritan-Magothy aquifer	##	25	6	##	##	7	6	10	8	7	3
Lower Potomac-Raritan-Magothy aquifer	##	7	40	##	##	8	##	##	##	##	1
Undifferentiated	--	**	1	--	--	--	1	--	--	2	**
Total for Potomac-Raritan-Magothy aquifer system	--	39	57	--	--	28	9	31	24	11	7
Coastal Plain total	23	41	61	16	19	29	9	31	30	40	8

Table 11. Average withdrawals of ground water in New Jersey by physiographic province, aquifer, and county,1989-90--Continued

Physiographic province / Aquifer	County											
	Bergen	Essex	Hudson	Hunterdon	Mercer	Middlesex	Morris	Passaic	Somerset	Sussex	Union	Warren
	Non-Coastal Plain aquifers											
Piedmont, Highlands, and Valley and Ridge Provinces												
Glacial-deposit aquifers	6	10	##	**	##	##	34	3	--	1	2	13
Piedmont Province												
Aquifers of the Brunswick Group	15	7	**	4	1	8	1	3	3	##	13	##
Lockatong Formation	--	--	--	**	--	**	##	##	--	##	--	##
Stockton Formation	--	##	--	--	1	##	##	##	**	##	##	##
Piedmont Province total	15[1]	17	**	4[1]	2	8	1[1]	3[1]	3	##	15	##
Highlands and Valley and Ridge Provinces												
Aquifers of the Kittatinny Supergroup	##	##	##	1	##	##	1	##	##	**	##	9
Franklin Limestone	##	##	##	##	##	##	##	##	##	6	##	##
Precambrian crystalline-rock aquifers	--	##	##	**	##	##	1	**	--	1	##	**
Highlands and Valley and Ridge Provinces total	--	##	##	1[1]	##	##	2[1]	**[1]	--	7	##	22
Non-Coastal Plain total	21	17	**	5	2	8	37	6	3	8	15	22

[1] Province total does not include withdrawals from glacial-deposit aquifers

production is assumed to be about the same every year, agricultural withdrawals for non-cranberry irrigation are estimated to have been about 37 Mgal/d in 1989 and about 30 Mgal/d in 1990.

Withdrawals of Ground Water

About 75 percent of the withdrawals of ground water for irrigation use were from aquifers in the Coastal Plain (unpublished data on file at New Jersey Department of Environmental Protection, Trenton, N.J.). Withdrawals of ground water for agricultural activities in Cumberland, Atlantic, and Burlington Counties averaged 5 Mgal/d, 4 Mgal/d, and 3 Mgal/d, respectively (table 5).

Withdrawals of Surface Water

Withdrawals of surface water for irrigation in Burlington County averaged 83 Mgal/d. Surface-water withdrawals averaged 2 Mgal/d in Cumberland County and 1 Mgal/d each in Atlantic, Gloucester, Ocean, and Salem Counties (table 5).

Industrial

In 1989, withdrawals for industrial use were 282 Mgal/d--55 Mgal/d of ground water and 227 Mgal/d of surface water (table 3). In 1990, withdrawals for industrial use were 293 Mgal/d--52 Mgal/d of ground water and 241 Mgal/d of surface water (table 4).

Industrial users include chemical, petroleum, and paper-manufacturing facilities that require large volumes of water for cooling or production processes. The U.S. Bureau of the Census (1991a, p. 273) reported that 90 percent of the 14,400 industrial facilities in New Jersey in 1987 had fewer than 100 employees. Most of these small industrial operations are located in urban areas and are served by water utilities. Many self-supplied industrial facilities in New Jersey receive supplemental water from local water utilities.

Withdrawals by County

Withdrawals for industrial use were largest in Warren, Gloucester, and Hunterdon Counties, where withdrawals averaged 90 Mgal/d, 64 Mgal/d, and 42 Mgal/d, respectively (figs. 8T, H,I; table 5). Paper-products manufacturing and chemical production in Warren and Hunterdon Counties accounted for nearly all of the withdrawals for industrial use in these counties. Chemical and oil-refinery facilities accounted for the large withdrawals for industrial use reported in Gloucester County.

Industries in counties in the Coastal Plain withdrew the largest volume of ground water for industrial operations (figs. 10A and 11A; table 10). Withdrawals of ground water for industrial use in Gloucester, Middlesex, and Burlington Counties averaged 10 Mgal/d, 6 Mgal/d, and 5 Mgal/d, respectively (table 5). In other parts of the State, the average withdrawals of ground water for industrial use were 4 Mgal/d in Cumberland and Warren Counties, 3 Mgal/d each in Morris, Ocean, Salem, and Union Counties, and 2 Mgal/d each in Hunterdon and Bergen Counties (table 5).

Withdrawals of surface water in Warren County averaged 86 Mgal/d and accounted for 37 percent of all surface-water withdrawals for industrial use in New Jersey. Withdrawals of surface water averaged 54 Mgal/d in Gloucester County, 40 Mgal/d in Hunterdon County, 13 Mgal/d in Passaic County, 10 Mgal/d in Salem County, 6 Mgal/d each in Ocean and Union Counties, and 5 Mgal/d in Camden County (table 5).

Withdrawals by Hydrologic Cataloging Unit

During 1989-90, withdrawals for industrial facilities in the Middle Delaware-Musconetcong HUC averaged 136 Mgal/d, or about one-half of all withdrawals for industrial use in the State (fig. 9; tables 8 and 9). Withdrawals in the Lower Delaware, Cohansey-Maurice, and Sandy Hook-Staten Island HUC's averaged 71 Mgal/d, 18 Mgal/d, and 13 Mgal/d, respectively (fig. 9; tables 8 and 9).

Ground-water withdrawals averaged 11 Mgal/d in the Lower Delaware HUC, 8 Mgal/d each in the Cohansey-Maurice and Raritan HUC's, 6 Mgal/d in the Hackensack-Passaic HUC, 5 Mgal/d in the Middle Delaware-Musconetcong HUC, and 4 Mgal/d in the Crosswicks-Neshaminy HUC (tables 8 and 9).

Average surface-water withdrawals in the Middle Delaware-Musconetcong HUC, 130 Mgal/d, accounted for the largest volume of water used by New Jersey industries. Withdrawals of surface water averaged 60 Mgal/d in the Lower Delaware HUC, 10 Mgal/d each in the Cohansey-Maurice and Sandy Hook-Staten Island HUC's, and 6 Mgal/d in the Mullica-Toms HUC (tables 8 and 9).

Withdrawals by Aquifer and Physiographic Province

Withdrawals of ground water by industrial users in the Coastal Plain, Piedmont, and Highlands and Valley and Ridge Physiographic Provinces averaged 34 Mgal/d, 9 Mgal/d, and 5 Mgal/d, respectively (figs. 10A and 11A; table 10). Withdrawals from the Potomac-Raritan-Magothy aquifer system (average 28 Mgal/d) represent more than one-half of all ground-water withdrawals for industrial use in New Jersey. Average withdrawals were 13 Mgal/d from the middle aquifer and 7 Mgal/d each from the upper and lower aquifers. Withdrawals for industrial use from the Kirkwood-Cohansey aquifer system averaged 6 Mgal/d (fig. 10A; table 10).

In the Piedmont Province, ground water for industrial use (average 9 Mgal/d) was withdrawn chiefly from aquifers of the Brunswick Group. In the Highlands and Valley and Ridge Provinces, the largest withdrawals of ground water for industrial use (average 5 Mgal/d) were from the aquifers of Kittatinny Supergroup (fig. 11A; table 10).

Mining

The geologic resources of New Jersey support a diversity of mining activities for the 158 mining facilities in the State (Horner, 1992, p. 249). Crushed stone, consisting of basalt and granite, is extracted throughout the Piedmont, Highlands, and Valley and Ridge Provinces. Shale is quarried in the Piedmont Province. The Coastal Plain yields sand and gravel for housing and road construction, industrial sand for glass-making, fire clay for furnaces and ceramics, and greensand for fertilizer (Harrison, 1988).

In 1989, withdrawals for mining operations were 111 Mgal/d--9 Mgal/d of ground water and 102 Mgal/d of surface water (table 3). In 1990, withdrawals for mining use were 56 Mgal/d--8 Mgal/d of ground water and 48 Mgal/d of surface water (table 4). Although ground-water withdrawals for mining were constant from 1989 to 1990, surface-water withdrawals decreased by 54 Mgal/d. The decrease in withdrawals can be traced to the reduced production of one mining facility in Cumberland County.

Withdrawals by County

The largest withdrawals for mining activities were in Cumberland County (80 Mgal/d in 1989 and 24 Mgal/d in 1990) (tables 3 and 4). Average withdrawals in Cape May and Sussex Counties were 7 Mgal/d and 6 Mgal/d, respectively (fig. 8E, R; table 5). Withdrawals in Burlington and Ocean Counties averaged 5 Mgal/d each (figs. 8C, N; table 5). Eleven of the 21 counties in New Jersey reported withdrawals for mining use (tables 3 and 4).

Withdrawals by Hydrologic Cataloging Unit

The largest withdrawals of water by mining facilities were in the Cohansey-Maurice HUC and averaged 52 Mgal/d (fig. 9; tables 8 and 9). Withdrawals averaged 8 Mgal/d in the Great Egg Harbor HUC, 6 Mgal/d in the Rondout HUC, and 5 Mgal/d in the Mullica-Toms HUC (fig. 9; tables 8 and 9).

Withdrawals of ground water for mining use in the Rondout HUC averaged 6 Mgal/d, the largest withdrawals in the State (tables 8 and 9). Surface-water withdrawals in the Cohansey-Maurice HUC decreased from 79 Mgal/d in 1989 to 24 Mgal/d in 1990 (tables 8 and 9) because of reduced mining production. Withdrawals of surface water for mining use averaged 8 Mgal/d in the Great Egg Harbor HUC, 5 Mgal/d in the Mullica-Toms HUC, and 4 Mgal/d in the Crosswicks-Neshaminy HUC (tables 8 and 9).

Withdrawals by Aquifer and Physiographic Province

Withdrawals in Sussex County (fig. 8R) from the Franklin Limestone, chiefly for mining use, averaged 6 Mgal/d, the largest ground-water withdrawals for mining in the State (figs. 11A and B; tables 10 and 11). Withdrawals from the Kirkwood-Cohansey aquifer system and aquifers of the Brunswick Group averaged less than 1 Mgal/d each (figs. 10A and 11A; table 10).

Thermoelectric Power

Water provided the power for industrial development in New Jersey. Early mills used paddle wheels to harness the waterpower of streams and canals. In the 20th century, electric power replaced waterpower; however, power generation still depends largely on water. Most thermoelectric-power plants in the State withdraw surface water for cooling purposes and steam generation. Ground water is used for steam generation, potable water, and other non-cooling purposes.

In 1989, thermoelectric- and hydroelectric-power facilities in New Jersey generated 41.1 gigawatt-hours of electricity from nuclear (56 percent), coal (20 percent), petroleum (13 percent), gas (11 percent), and hydroelectric (0.06 percent) sources of energy (U.S. Bureau of

the Census, 1991a, p. 284). Electric power was produced at 30 power plants in New Jersey, including three nuclear power plants (Morgan and others, 1992, p. 163-164). About 30 percent of all water withdrawn in New Jersey during 1989 and 1990 was used to generate thermoelectric power (table 5).

In 1989, withdrawals for thermoelectric-power use totaled 722 Mgal/d--2 Mgal/d of ground water and 720 Mgal/d of surface water (table 3). In 1990, withdrawals for thermoelectric-power use were 597 Mgal/d--1 Mgal/d of ground water and 596 Mgal/d of surface water (table 4).

Withdrawals by County

The Delaware River is the chief source of freshwater for thermoelectric-power facilities in New Jersey. Electric utilities operate fossil-fuel generating stations along the Delaware River in Mercer, Burlington, and Hunterdon Counties, where surface-water withdrawals averaged 568 Mgal/d, 51 Mgal/d, and 38 Mgal/d, respectively (figs. 8J, C, I; table 5). Withdrawals of ground water for thermoelectric-power use in Salem County averaged 1 Mgal/d for the combined pumpage of three electric generating stations. Withdrawals of ground water in Cape May and Hunterdon Counties were less than 1 Mgal/d each (table 5).

Withdrawals by Hydrologic Cataloging Unit

Withdrawals of water for thermoelectric-power use averaged 620 Mgal/d in the Crosswicks-Neshaminy HUC and 39 Mgal/d in the Middle Delaware-Musconetcong HUC (fig. 9; tables 8 and 9). Ground-water withdrawals for thermoelectric-power use were largest in the Cohansey-Maurice HUC, averaging 1 Mgal/d. Withdrawals of ground water in the Great Egg Harbor HUC averaged less than 1 Mgal/d. Surface-water withdrawals in the Crosswicks-Neshaminy HUC accounted for more than 90 percent (average 620 Mgal/d) of the withdrawals for thermoelectric-power generation in the State (tables 8 and 9). Withdrawals of surface water in the Middle Delaware-Musconetcong HUC averaged 39 Mgal/d (tables 8 and 9).

Withdrawals by Aquifer and Physiographic Province

Withdrawals of ground water by nuclear-power facilities located in the Coastal Plain accounted for most of the withdrawals of ground water for thermoelectric-power use. The Middle aquifer of the Potomac-Raritan-Magothy aquifer system provided 1 Mgal/d for generation of thermoelectric power, and the Atlantic City 800-foot sand, Kirkwood-Cohansey aquifer system, and Wenonah-Mount Laurel aquifer provided less than 1 Mgal/d each (fig. 10A; table 10). Average withdrawals for thermoelectric-power use were less than 1 Mgal/d from the aquifers of the Brunswick Group (fig. 11A; table 10).

SUMMARY

Data on withdrawals of ground water and surface water in New Jersey in 1989 and 1990 were compiled from metered and estimated withdrawal data. Monthly withdrawals data were provided to the New Jersey Department of Environmental Protection (NJDEP) by water users with pumping equipment capable of producing 100,000 gal/d (gallons per day) or greater.

Withdrawals by domestic-supply users and small community public-supply systems were estimated by using a per capita coefficient of 75 gal/d. Irrigation withdrawals for agricultural/horticultural purposes were estimated by the water user and reported to the NJDEP.

In 1989, withdrawals in New Jersey totaled about 2,350 Mgal/d (million gallons per day)--about 570 Mgal/d of ground water and about 1,780 Mgal/d of surface water. In 1990, withdrawals totaled nearly 2,170 Mgal/d--about 557 Mgal/d of ground water and about 1,610 Mgal/d of surface water.

In 1989, withdrawals for public supply totaled nearly 1,040 Mgal/d--404 Mgal/d of ground water and 632 Mgal/d of surface water. In 1990, withdrawals for public supply were more than 1,020 Mgal/d--390 Mgal/d of ground water and 635 Mgal/d of surface water. The largest public-supply withdrawals, chiefly surface water, were in Passaic County and averaged 245 Mgal/d. The largest ground-water withdrawals for public supply were in Camden County and averaged 60 Mgal/d. Among the hydrologic cataloging units (HUC's) in New Jersey, the largest withdrawals for public supply were in the Hackensack-Passaic HUC and averaged 462 Mgal/d. Public-supply withdrawals from the Potomac-Raritan-Magothy aquifer system, the most heavily pumped aquifer in New Jersey, averaged 176 Mgal/d.

Withdrawals of ground water for domestic supply in New Jersey averaged about 70 Mgal/d. About 972,000 residents, or 13 percent of the population of New Jersey, supply their own water. The largest withdrawals for domestic supply were in Ocean County and averaged 8 Mgal/d. Withdrawals for domestic supply in Burlington, Morris, and Sussex Counties were estimated to be 6 Mgal/d each.

Withdrawals for commercial use, primarily ground water, totaled 17 Mgal/d in 1989 and 15 Mgal/d in 1990. Annual withdrawals of surface water for commercial use averaged about 1 Mgal/d each in 1989 and 1990. State-operated fish hatcheries in Warren County were the largest commercial water users in New Jersey. Withdrawals from the glacial-deposit aquifer in Warren County averaged 7 Mgal/d and were the largest ground-water withdrawals for commercial use in the State. The largest withdrawals for commercial use were reported in the Middle Delaware-Musconetcong HUC.

Withdrawals for irrigation use in 1989 were 113 Mgal/d--14 Mgal/d of ground water and 99 Mgal/d of surface water. Withdrawals for irrigation in 1990 were 106 Mgal/d--21 Mgal/d of ground water and 85 Mgal/d of surface water. Withdrawals in Burlington County, primarily for cranberry production, averaged 86 Mgal/d and accounted for 79 percent of withdrawals for irrigation use in the State. The largest ground-water withdrawals for irrigation use were reported in Cumberland County and averaged 5 Mgal/d.

Withdrawals for industrial use in New Jersey in 1989 totaled 282 Mgal/d--55 Mgal/d of ground water and 227 Mgal/d of surface water. In 1990, withdrawals for industrial use totaled 293 Mgal/d--52 Mgal/d of ground water and 241 Mgal/d of surface water. Average withdrawals in Warren, Gloucester, and Hunterdon Counties were 90 Mgal/d, 64 Mgal/d, and 42 Mgal/d, respectively. The largest withdrawals for industrial use in New Jersey were in the Middle Delaware-Musconetcong HUC and averaged 135 Mgal/d. Withdrawals for industrial use from the Potomac-Raritan-Magothy aquifer system, the largest withdrawals of ground water for this use, averaged 28 Mgal/d.

Withdrawals for mining use in New Jersey in 1989 totaled about 111 Mgal/d--9 Mgal/d of ground water and 102 Mgal/d of surface water. In 1990, withdrawals were 56 Mgal/d--8 Mgal/d of ground water and 48 Mgal/d of surface water. During 1989-90, withdrawals of surface water for mining use in Cumberland County decreased from 79 Mgal/d to 24 Mgal/d. This decrease is attributed to reduced production of a single user. The largest withdrawals for mining use were reported in the Cohansey-Maurice HUC. The largest ground-water withdrawals for mining use were from the Franklin Limestone and averaged 6 Mgal/d.

Withdrawals for thermoelectric-power use in New Jersey totaled 722 Mgal/d in 1989 and 598 Mgal/d in 1990. Ground-water withdrawals averaged less than 2 Mgal/d. Surface-water withdrawals for thermoelectric-power use in Mercer County averaged 568 Mgal/d, the largest withdrawals among the counties in the State. The average withdrawals for thermoelectric-power use in the Crosswicks-Neshaminy HUC were 620 Mgal/d, the largest withdrawals among the HUC's in the State.

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GLOSSARY

Aquifer: A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Commercial use: Ground water or surface water withdrawn by commercial facilities. Hotels, non-residential schools, retail stores, and shopping centers are examples of commercial users. Publicly operated fish hatcheries also are included in this category.

Domestic-supply use: Ground water obtained from residential wells and used for general household purposes, home landscaping, and recreation.

Establishment: An economic unit, generally within a single location, where business activities are conducted or where services or industrial activities are performed.

Freshwater: Water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; water containing more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.

Ground water: Subsurface water as distinct from surface water; specifically, that part of subsurface water that is in the zone of saturation (an area in which voids are filled with water).

Hydrologic cataloging unit: A geographic area representing all or part of a surface drainage basin or a distinct hydrologic feature. An eight-digit code and hydrologic unit name, assigned by the U.S. Geological Survey, provides a standardized base for locating, storing, retrieving, and exchanging hydrologic data.

Industrial use: Ground water or surface water withdrawn by industrial facilities. Examples of industrial establishments are facilities that manufacture chemical, steel, or paper products and facilities that refine petroleum.

Irrigation use: Ground water or surface water artificially applied to farm, orchard, and horticultural crops, and for landscaping (golf courses).

Mining use: Ground water or surface water withdrawn by mining facilities. Water is used in mineral extraction and quarrying, well operations (dewatering), and milling (crushing, screening, washing, and flotation).

Per capita water use: The average amount of water used per person per day. In New Jersey, the per capita water use was estimated to be 75 gallons per day (Solley and others, 1988, p. 17).

Public supply: Ground water or surface water withdrawn by public and private water-supply systems and delivered to domestic, commercial, industrial, and other users.

Saline water: Water that contains 1,000 mg/L or greater of dissolved solids.

Surface water: An open body of water such as a river, stream, lake, or pond.

GLOSSARY--Continued

Thermoelectric-power use: Ground water or surface water withdrawn in the process of generating electricity with fossil fuel (coal, oil, or natural gas), geothermal energy, or nuclear energy. Withdrawals of saline water are not included in this study.

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