Charles, E.G., Storck, D.A., and Clawges, R.M., 2001, Hydrology of the unconfined aquifer system, Maurice River area: Maurice and Cohansey River Basins, New Jersey, 1994-95.

RESOURCE EVALUATION

This sheet describes land use, contaminated sites, population changes, water use, and water budgets in the Maurice River study area. Population data (1990) and changes in population during 1930-90 are presented. Water-use data are compiled, quantities of water withdrawn and consumed from the unconfined aquifers and from surface water are presented, and separate water budgets are calculated for three areas for the period 1985-94. The three budget areas are (1) the entire Maurice River study area, which includes the Maurice and Cohansey River Basins and tidal areas and of minor tributaries to the Delaware Bay; (2) the Maurice River Basin; and (3) the Cohansey River Basin (sheet 1, fig. 1-2).

Land Use

Approximately 35 percent of the land in the study area is forested, 32 percent is used for agriculture, 16 percent is wetland, 12 percent is urban land, 3 percent is water, and 2 percent is barren land (fig. 5-1). Land-use areas are based on interpretations of 1:250,000-scale aerial photos taken in the early 1970's, and were classified according to the system developed by Mitchell and others (1977). Land use in the study area has not changed substantially since the early 1970's. Most of the forested land is in the southeastern half of the study area and most of the agricultural land is in the northern half, near urban markets.

Contaminated Sites

NJDEP's comprehensive contaminated site list (New Jersey Department of Environmental Protection, 1994b), includes 166 known contaminated sites that, on the basis of street address, are located within the study area (tables 5-1 and 5-2). Contaminated sites are more common in urban areas than in all other land-use areas.

Population

The census data that are gathered at the beginning of each decade (decennial census) were used to describe population trends in the Maurice River study area. The estimated total population at each decennial census beginning in 1930 is shown in figure 5-2. Population for each decennial census year was estimated by multiplying the reported population of each municipality by the percentage of land in the municipality that is in the study area. The population was assumed to be evenly distributed throughout the municipality, although this may cause the population in urban areas to be underestimated and the population in rural areas to be overestimated. Table 5-3 lists the 1990 population and land area of each municipality in the Maurice River study area and the total estimated population of the study area, which was about 186,000 in 1990, or about 2.4 percent of the total population of New Jersey (New Jersey Department of Labor, 1991b). From 1930 to 1990, the population of the Maurice River study area increased 123 percent. Growth was most rapid from 1940 to 1970, when the population increased 54 percent.

Water Use

Estimates of water use in the Maurice River study area are presented below. Reported water-use values for 1994 were used as the mean annual values for the entire budget period (1985-94) because the water-use data for earlier years are much less complete, especially for agricultural use, which is a large part of water use in the study area. Applying the 1994 water-use data to the entire water-budget period is believed to provide an adequate assessment of actual water use during 1985-94. Estimated annual withdrawals of water for public and self-supplied domestic use, irrigation, industrial use, and commercial use are discussed below. From these estimates, the consumptive use of water (that part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment (Solley and others, 1993, p. vi)) in each category was calculated and totaled for use in the water budgets. All water withdrawals from the undifferentiated hydrogeologic unit, the Kirkwood-Cohansey aquifer system, and surface-water bodies were considered in the water budget (table 5-4). Water is withdrawn from confined aquifers in the study area also (table 5-5), but, as shown in table 5-5, accounts for less than 5 percent of total withdrawals from all sources.

Public Supply

Although most of the Maurice River study area is rural (agricultural or forested), many municipalities provide at least part of their population with public-supply water. Most of the public-supply water is withdrawn from the unconfined aquifer. Although public-supply systems commonly provide water for domestic, commercial, and industrial users, only the total is reported by municipalities. Because the principal purpose of summarizing water use in this report is to calculate consumptive use for the water budget, all public-supply water is considered to be used for domestic purposes, and all these users are assumed to be served by public sewer systems, except those in Elmer Borough. These assumptions do not introduce significant error, because it is assumed that the study area is similar to the rest of New Jersey, in which about 75 percent of public-supply water is allotted for domestic supply (Solley and others, 1990, p. 371), and consumptive-use percentages for water used for domestic, commercial, and industrial purposes are low. Most withdrawals were from the Kirkwood-Cohansey aquifer system (table 5-4). Withdrawals from the Piney Point aquifer, the Wenonah-Mount Laurel aquifer, and the Potomac-Raritan-Magothy aquifer system are shown in table 5-5; during 1994, these withdrawals accounted for about 2.9 percent of all water withdrawals in the study area. During 1994, public-supply withdrawals from the unconfined aquifer totaled 6,370 Mgal in the study area (Site-Specific Water Use Data System (SSWUDS)--unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.).

Where public-supply water is withdrawn and the treated wastewater is released to the ground-water or surface-water system in the same basin, consumptive use for purposes of the water budget is considered to be 18 percent (Solley and others, 1993, p. 29). Where treated domestic wastewater is not returned to the ground-water or surface-water system in the basin, consumptive use for purposes of the water budget is considered to be 100 percent. Public-supply withdrawals from the unconfined aquifer in Washington Township, Gloucester County, totaled 260 Mgal during 1994, and are considered to be 100-percent consumptive because all the treated wastewater is discharged to the Delaware River. The remaining wastewater from public-supply withdrawals from the unconfined aquifer in the study area is discharged within the basin. The ratio of consumptive use to total use is 21 percent, which brings total consumptive use of public-supply water during 1994 to 1,360 Mgal (fig. 5-3).

Domestic Self-Supply

Estimation of self-supplied domestic water use is difficult because withdrawals are not reported to any public agency. The amount of self-supplied domestic water withdrawn in the Maurice River study area was approximated by estimating the percentage of the population in each municipality that is not served by public-water supplies. This percentage was multiplied by a per capita domestic-water-use value of 100 gal/d (J.P. Nawyn, U.S. Geological Survey, oral commun., 1996); the result was multiplied by the consumptive-use rate of 18 percent for domestic water used in New Jersey (Solley and others, 1993, p. 29). All residents who use self-supplied water for domestic purposes were assumed to treat their wastewater with on-site septic systems. All self-supplied water withdrawn for domestic purposes was assumed to come from the unconfined aquifer on the basis of information from the NJDEP's GWSI data base. Total withdrawals from the unconfined aquifer in the Maurice River study area for self-supplied domestic use during 1994 are estimated to be about 2,452 Mgal, of which about 441 Mgal was consumptive use (fig. 5-3).

Commercial

Table 5-4 shows annual use of self-supplied water reported by commercial facilities during 1988-94. Commercial water use includes water used by motels, hotels, restaurants, office buildings, and other commercial facilities (Solley and others, 1993, p. 30). Some commercial use of water from public-supply systems is accounted for as part of public supply; therefore, to avoid double counting, only self-supplied commercial water use is tabulated for the commercial water-use category. In the Maurice River study area, all self-supplied water for commercial purposes is withdrawn from the unconfined aquifer, and all treated commercial water is discharged within the respective basins. According to Solley and others (1993, p. 29), about 4 percent of the water withdrawn for commercial purposes in New Jersey is consumed. During 1994, 888 Mgal of unconfined ground water was withdrawn for commercial use (SSWUDS--unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.). Thus, annual consumptive use is about 36 Mgal (fig. 5-3).

Irrigation

Almost half of the land in the Maurice River study area is used for agriculture, and much of that land is irrigated. Agricultural irrigation withdrawals are regulated by the State under a special agricultural/horticultural certification program, and withdrawals typically are estimated on the basis of pump capacity and duration of pumping (J.P. Nawyn, written commun., 1993). About 90 percent of the water used for irrigation in New Jersey is consumed (Solley and others, 1993, p. 37). Almost all irrigation water in the Maurice River study area is withdrawn from the unconfined aquifer over about 4 months during the growing season. Withdrawals for irrigation in the study area during 1988-94 (SSWUDS--unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.) are listed in table 5-4. Estimated total irrigation withdrawals during 1994 are 4,659 Mgal of unconfined ground water and 166 Mgal of surface water. Thus, consumptive use is about 4,342 Mgal (fig. 5-3).

Industry

Annual use of self-supplied water reported by industries during 1988-94 is shown in table 5-4. Most of the self-supplied water used for industrial purposes is unconfined ground water; the confined Potomac-Raritan-Magothy aquifer system provides some industrial supply in the northern part of the study area (table 5-5). Industrial use of water from public-supply systems is accounted for as part of public supply; therefore, to avoid double counting, only self-supplied industrial water use is tabulated in the industrial water-use category. All industrial water that is treated is discharged within the respective basin in which it is withdrawn. According to Solley and others (1993, p. 45), about 8 percent of the water withdrawn for industrial uses is consumed. During 1994, 1,563 Mgal of unconfined ground water was withdrawn for industrial use (SSWUDS--unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.). Thus, annual water use is about 125 Mgal (fig. 5-3).

Mining

Annual water use for mining reported by sand and gravel companies during 1988-94 is listed in table 5-4. Most of the water used for mining in the study area is used in the mines near tributaries to the Delaware Bay. According to Solley and others (1993, p. 48), about 8 percent of the water withdrawn for mining purposes in New Jersey is consumed. In 1994, 24,404 Mgal of unconfined ground water was withdrawn for mining use (SSWUDS--unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.). Thus, annual consumptive use is about 1,952 Mgal (fig. 5-3).

Total Water Use

Water for domestic use (both public- and self-supplied), irrigation, industry, commercial, and mining purposes accounts for all significant water use in the Maurice River study area. Surface water is only a minor source (less than 4 percent) of the total water used for agricultural irrigation. Estimates of consumptive use of unconfined ground water and surface water in the Maurice and Cohansey River Basins for each water-use category are shown in figure 5-3. Irrigation is the largest consumptive use and accounts for 53 percent of total consumption of unconfined ground water and surface water. Public supply is the second largest consumptive use in the Maurice River study area, and accounts for 16 percent of total consumption. In the Maurice (fig. 5-5) and Cohansey (fig. 5-4) River Basins, irrigation is the largest consumptive use and accounts for 57 percent and 76 percent of total consumption of water, respectively. Public supply is the second largest consumptive use at 25 and 14 percent of withdrawals of unconfined ground water in the Maurice and Cohansey River Basins, respectively.

Water Budgets

The following water budgets provide estimated values for the components of the hydrologic cycle in the Maurice River study area for 1985-94. Although the flow and storage of water in different parts of the hydrologic system can change yearly, seasonally, and daily (as a result of a storm), it is assumed that for the long-term average water budget used here no significant long-term change occurs in the flow and storage of water. The water budget for the entire study area, which includes the Maurice River Basin, the Cohansey River Basin, and the tidal areas and subbasins of minor tributaries to the Delaware Bay, is described first. Separate water budgets are presented for the Maurice River Basin and Cohansey River Basin. No budget was calculated for the tidal areas or the subbasins of the minor tributaries to the Delaware Bay (sheet 1, fig. 1-2) because no streamflow data are available for these areas.

Water-Budget Equations

The hydrologic cycle in the study area can be represented by a long-term water budget in which inflows are balanced by equivalent outflows, and therefore, there is no long-term net change in storage. The following budget analyses account for all water-system gains and losses in the budget area. The water budget can be evaluated by using two interrelated, corresponding balance equations: one that describes gains and losses to and from the land surface and one that describes gains and losses to and from the unconfined ground-water system. Many of the variables in the two interrelated budgets are difficult to evaluate. Recharge, a variable that cannot be measured or estimated directly apart from other hydrologic data, was determined separately in both equations, and the two values were compared. The values of precipitation, direct runoff, base flow, evapotranspiration, and withdrawals by pumping were discussed in previous sections.

In order to calculate the amount of water moving through the budget area, a budget volume must be defined. The budget volume is the "package" of geologic material into and out of which the movement of water is calculated. For the purposes of this analysis, the budget volume is defined by the extent of the unconfined aquifer in the study area (sheet 1, fig. 1-2). The entire thickness of the Kirkwood-Cohansey aquifer system in the study area is assumed to be one large, hydraulically connected unconfined aquifer system; it is assumed that neither surface- nor ground-water flow is gained or lost across the lateral boundaries of the study area. Figures 5-6 and 5-7 are generalized hydrogeologic sections through the study area that illustrate the budget volume and flow within the system. Water is introduced to the land surface through precipitation and artificial recharge from water that is pumped from confined aquifers, used, treated, and released into the unconfined ground-water system. Water is lost from the land surface through direct runoff, evapotranspiration, withdrawals from surface-water bodies, and natural recharge to the ground-water system. These terms represent the components of the land-surface equation. Water is introduced to the ground-water system through natural recharge and artificial recharge from septic systems that treat domestic wastewater that initially was pumped from confined aquifers. Water is lost from the ground-water system through withdrawals by pumping, leakage to confined aquifers, and ground-water discharge to surface-water bodies. These terms represent the components of the ground-water-system equation. The equation used for the land surface is

$$P + R_{as} = Q_{dr} + ET + W_s + R_n$$

and the equation for the ground-water system is

$$R_n + R_{ag} = W_g + L + Q_g$$

The variables used in the water budget are

P = precipitation,
Q_{dr} = direct runoff,
Q_b = base flow,
ET = evapotranspiration,
L = leakage and flow to confined aquifers,
W_s = consumptive use from surface-water withdrawals,
W_g = consumptive use from unconfined-ground-water withdrawals,
R_{as} = artificial recharge to the surface-water system,
R_{ag} = artificial recharge to the ground-water system,
R_n = natural recharge to the aquifer ($P + R_{as} - Q_{dr} - ET - W_s$), and
Q_g = ground-water discharge ($Q_b - R_{as} + W_s$).

Values of Water-Budget Variables

The precipitation value (P) used in the water budget is consistent with reported values for the Coastal Plain of New Jersey. A single precipitation value was used for all budget areas and was based on the average of the values recorded at the Glassboro and Millville weather stations during the 10 years of record, 1985-94. This average value, 42.9 in., was used in the water-budget equation.

To obtain the discharge values that were used in the water-budget analysis, total-runoff values were separated into base flow (Q_b) and direct-runoff (Q_{dr}) components. For the Maurice River Basin, the discharge values used were the predicted discharges at the Maurice River near Millville, N.J. (01411800), low-flow, partial-record station and the measurements made during 1977-85 at the Menantico Creek near Millville, N.J. (01412000), continuous-record streamflow-gaging station. Discharge values for the ungaged part of the Maurice River Basin downstream from these two stations were estimated by applying the long-term area-weighted discharge values from the Maurice River near Millville, N.J. (01411800), gaging station. For the Cohansey River Basin, discharge measurements made during 1977-88 at the Cohansey River at Seeley, N.J. (01412800), continuous-record streamflow-gaging station were used. Discharge values for the part of the Cohansey River Basin downstream from this station were assumed to be equal to the long-term area-weighted discharge value upstream from the station. Discharge values for the tidal areas and tributaries to the Delaware Bay were assumed to be equivalent to the long-term area-weighted discharge of the Maurice River near Millville, N.J. (01411800), low-flow, partial-record station. The values of the discharge components used in the water budget for the entire Maurice River study area are 15.9 in. for base flow (Q_b) and 3.1 in. for direct runoff (Q_{dr}).

Evapotranspiration can be calculated by using any of several methods. For this study, potential evapotranspiration was calculated by using the Thornthwaite method (Thornthwaite and Mather, 1957). This method takes into account the latitude of and mean monthly temperature at the site, but does not consider precipitation, soil moisture, or adequate soil moisture (Warren and others, 1968, p. C24). Second, the Thornthwaite method is used to estimate a potential rate rather than an actual rate. Potential evapotranspiration is water that would be transpired and evaporated if there was no limit to the availability of water. The rate of potential evapotranspiration can be calculated for dry periods, when little moisture is available for transpiration or evaporation; therefore, it generally is much higher than the actual evapotranspiration rate. Potential evapotranspiration in the Maurice River study area was estimated to be 28.9 in/yr (see sheet 3).

Alternatively, evapotranspiration can be calculated by examining the precipitation-runoff relation. This method takes into account the geology and topography of the area and requires a long period of record to make adjustments for changes in storage in the soil. Reported evapotranspiration rates in and near the Maurice River study area calculated by Hardt and Hilton (1969, p. 54), Vowinkel and Foster (1981, p. 18), and Parker and others (1964, p. 111) by using this method range from 18.5 to 27.5 in/yr.

To estimate actual evapotranspiration in the Maurice River study area, monthly potential evapotranspiration rates were compared with the monthly precipitation rates at the Glassboro and Millville weather stations. For those months during which the precipitation rate was greater than the potential-evapotranspiration rate, the potential-evapotranspiration rate was used as the actual rate. For those months during which the precipitation rate was less than the potential-evapotranspiration rate, the precipitation rate was used as the actual rate of evapotranspiration. These monthly "actual" evapotranspiration rates were totaled for the year and used in the water-budget analysis of the Maurice River study area. The actual evapotranspiration (ET) is estimated to be 24.6 in/yr.

For the Maurice River study area, the rate of leakage and flow to confined aquifers (L) in the water budget is the sum of vertical leakage through the underlying confining unit to the confined aquifer (the Piney Point aquifer) plus horizontal flow into the downdip confined aquifer (the Atlantic City 800-foot sand) along the southeastern margin of the study area (sheet 1, fig. 1-6). Leakage into the Piney Point aquifer and flow into the Atlantic City 800-foot sand are depicted in the generalized hydrogeologic section shown in figure 5-7. Leakage rates and flow rates were estimated by using the New Jersey Regional Aquifer-System Analysis ground-water flow model (Martin, 1998), and withdrawal data through 1988. The estimated rate of leakage plus flow to confined aquifers (L) from the Kirkwood-Cohansey aquifer system over the entire study area is 0.053 in/yr (A.D. Gordon, U.S. Geological Survey, written commun., 1996).

The values for consumptive water use (W_s and W_g) in the Maurice River study area are discussed in the section on water use. These values total 0.014 in. for consumptive water use from surface-water withdrawals (W_s) and 0.79 in. for consumptive use from unconfined-ground-water withdrawals (W_g).

The values for artificial recharge (R_{as} and R_{ag}) were estimated from water-use data. Artificial recharge to the surface-water system (R_{as}) was estimated by considering withdrawals from confined aquifers, consumptive-water-use rates, and whether discharge points for wastewater-treatment plants were located inside or outside the study area. Artificial recharge to the surface-water system (R_{as}), derived from municipal wastewater treatment and industry and mining operations, totaled 0.66 in. over the entire Maurice River study area.

Artificial recharge to the unconfined ground-water system (R_{ag}) was estimated from approximations of self-supplied domestic withdrawals from confined aquifers and from information on consumptive-water-use rates. Artificial recharge to the unconfined ground-water system (R_{ag}) occurs in the Elmer Borough area (sheet 1, fig. 1-3), where water for public supply is withdrawn from the confined Wenonah-Mount Laurel aquifer, treated by domestic septic systems, and then discharged to the unconfined ground-water system. A minor amount of artificial recharge occurs in small shore communities along the Delaware Bay where water is pumped from the confined Piney Point aquifer through domestic wells, treated in septic systems, and released into the unconfined ground-water system. Because no usage data for this artificial recharge are available, and because this recharge occurs at the edge of the unconfined aquifer, it is not included in the value of artificial recharge to ground water. The total artificial recharge to the unconfined ground-water system (R_{ag}) is 0.0054 in. over the entire Maurice River study area.

Ground-water discharge (Q_g) is estimated from variables already discussed. The base-flow-separation technique does not differentiate among the relatively constant rates of ground-water discharge (Q_g), wastewater-treatment-plant discharge (R_{as}), and surface-water withdrawals (W_s)—that is,

$$Q_b = Q_g + R_{as} - W_s ;$$

however, ground-water discharge (Q_g) can be computed from the equation.

$$Q_g = Q_b - R_{as} + W_s .$$

The ground-water discharge (Q_g) for the Maurice River study area is 15.3 in.

Water Budget for the Maurice River Study Area

The values discussed above and previously in the text can be used to determine a water budget for the entire study area. These values are as follows (in inches):

P = 42.9,
Q_{dr} = 3.1,
Q_b = 15.9,
ET = 24.6,
L = 0.053,
W_s = 0.014,
W_g = 0.79,
R_{as} = 0.66,
R_{ag} = 0.0054, and
Q_g = 15.3 .

By inserting these values into the land-surface and ground-water-system budget equations,

$$P + R_{as} = Q_{dr} + ET + W_s + R_n$$
$$42.9 + 0.66 = 3.1 + 24.6 + 0.014 + R_n$$
$$R_n = 15.8 \text{ in., and}$$
$$R_{ag} + R_n = L + W_g + Q_g$$
$$0.0054 + R_n = 0.053 + 0.79 + 15.3$$
$$R_n = 16.1 \text{ in.}$$

Recharge from the land surface to the unconfined aquifer in the Maurice River study area is the average value computed by using the two water-budget equations--16.0 in/yr, or 37 percent of annual precipitation. Consumptive use of all sources of water amounts to 5.0 percent of natural recharge to the unconfined aquifer. The close agreement of the recharge values (R_n) calculated by using the land-surface and ground-water-system equations for the entire Maurice River study area corroborates the values of the variables used in those two equations. Most of the natural recharge is removed from the ground-water system by ground-water discharge (Q_g) to streams. Increases in leakage and flow to confined aquifers or in water withdrawals would reduce the amount of ground water available for ground-water discharge, thereby decreasing streamflow.

The ultimate source of water in the hydrologic cycle is precipitation, and the two major discharge components of the hydrologic cycle are evapotranspiration and stream discharge. Evapotranspiration in this budget is 56 percent of the sum of precipitation and artificial recharge; discharge, composed of direct runoff and ground-water discharge, is 42 percent of the sum of precipitation and artificial recharge.

Water Budget for the Maurice River Basin

In a manner similar to that used to calculate the water budget for the entire study area, a separate water budget for the Maurice River Basin was calculated by using the following values (in inches):

P = 42.9,
Q_{dr} = 3.0,
Q_b = 16.4,
ET = 24.6,
L = 0.054,
W_s = 0.0086,
W_g = 0.66,
R_{as} = 0.82,
R_{ag} = 0.0084, and
Q_g = 15.6,

and the following land-surface and ground-water-system budget equations:

$$P + R_{as} = Q_{dr} + ET + W_s + R_n$$
$$42.9 + 0.82 = 3.0 + 24.6 + 0.0086 + R_n$$
$$R_n = 16.0 \text{ in., and}$$
$$R_{ag} + R_n = L + W_g + Q_g$$
$$0.0084 + R_n = 0.054 + 0.66 + 15.6$$
$$R_n = 16.3 \text{ in.}$$

In this water budget, recharge from the land surface to the unconfined aquifer in the Maurice River Basin is about 16.2 in/yr, which is 38 percent of annual precipitation. Consumptive use of all sources of water amounts to 4.1 percent of natural recharge to the unconfined aquifer. The close agreement of the recharge values (R_n) calculated by using the land-surface and ground-water system equations for the Maurice River Basin corroborates the values of the variables used in those two equations. Evapotranspiration in this budget is 56 percent of the sum of precipitation and artificial recharge; discharge, composed of direct runoff and ground-water discharge, is 43 percent of the sum of precipitation and artificial recharge.

Water Budget for the Cohansey River Basin

A separate water budget for the Cohansey River Basin was calculated by using the following values (in inches):

P = 42.9,
Q_{dr} = 3.6,
Q_b = 13.5,
ET = 24.6,
L = 0.067,
W_s = 0.049,
W_g = 0.92,
R_{as} = 0.49,
R_{ag} = 0, and
Q_g = 13.1,

and the following land-surface and ground-water-system budget equations:

$$P + R_{as} = Q_{dr} + ET + W_s + R_n$$
$$42.9 + 0.49 = 3.6 + 24.6 + 0.049 + R_n$$
$$R_n = 15.1 \text{ in., and}$$
$$R_{ag} + R_n = L + W_g + Q_g$$
$$0 + R_n = 0.067 + 0.92 + 13.1$$
$$R_n = 14.1 \text{ in.}$$

Recharge from the land surface to the unconfined aquifer in the Cohansey River Basin determined by using this water budget is 14.6 in/yr, which is 34 percent of annual precipitation. Consumptive use of all sources of water amounts to 6.6 percent of natural recharge to the unconfined aquifer. The difference between recharge (R_n) calculated with the land-surface and ground-water system equations for the Cohansey River Basin is about 7 percent and indicates some inaccuracy in the estimates for the variables used in those two equations. Evapotranspiration in this budget is 57 percent of the sum of precipitation and artificial recharge; discharge, composed of direct runoff and ground-water discharge, is 38 percent of the sum of precipitation and artificial recharge.

Comparison of Water Budgets

These three water budgets estimate the flow of water into and out of the unconfined-ground-water and surface-water systems in the Maurice River study area, the Maurice River Basin, and the Cohansey River Basin and indicate the consumptive use of this water under 1985-94 conditions. This type of water-budget analysis can be updated periodically as new data become available to assess changes in the hydrologic system.

Recharge values calculated for the Cohansey River Basin are less than those calculated for the Maurice River Basin. The most obvious difference between values in the two water budgets is in the ground-water discharge (Q_g). The ground-water-discharge value for the Cohansey River Basin is 2.5 in. less than that for the Maurice River Basin. This smaller value could be the result of the location of the streamflow-gaging station (Cohansey River at Seeley, N.J. (1412800)) in relation to ground-water flow paths through the unconfined aquifer system. It is possible that a substantial quantity of ground water flows underneath and past this streamflow-gaging station and is ultimately captured as ground-water discharge downstream on the Cohansey River, thus providing unrepresentatively low values of ground-water discharge. Additional study would be needed to determine whether differences in the water budgets of the Maurice and Cohansey River Basins result from the difference in values of ground-water discharge or in those of other variables.

Land use	Area (square miles)	Percent of total area
Urban land	73.45	12.2
Agricultural/grassland	190.06	31.6
Forest	213.13	35.4
Water	19.05	3.2
Wetland	90.92	15.1
Barren land	14.45	2.4
Total	600.06	100.0

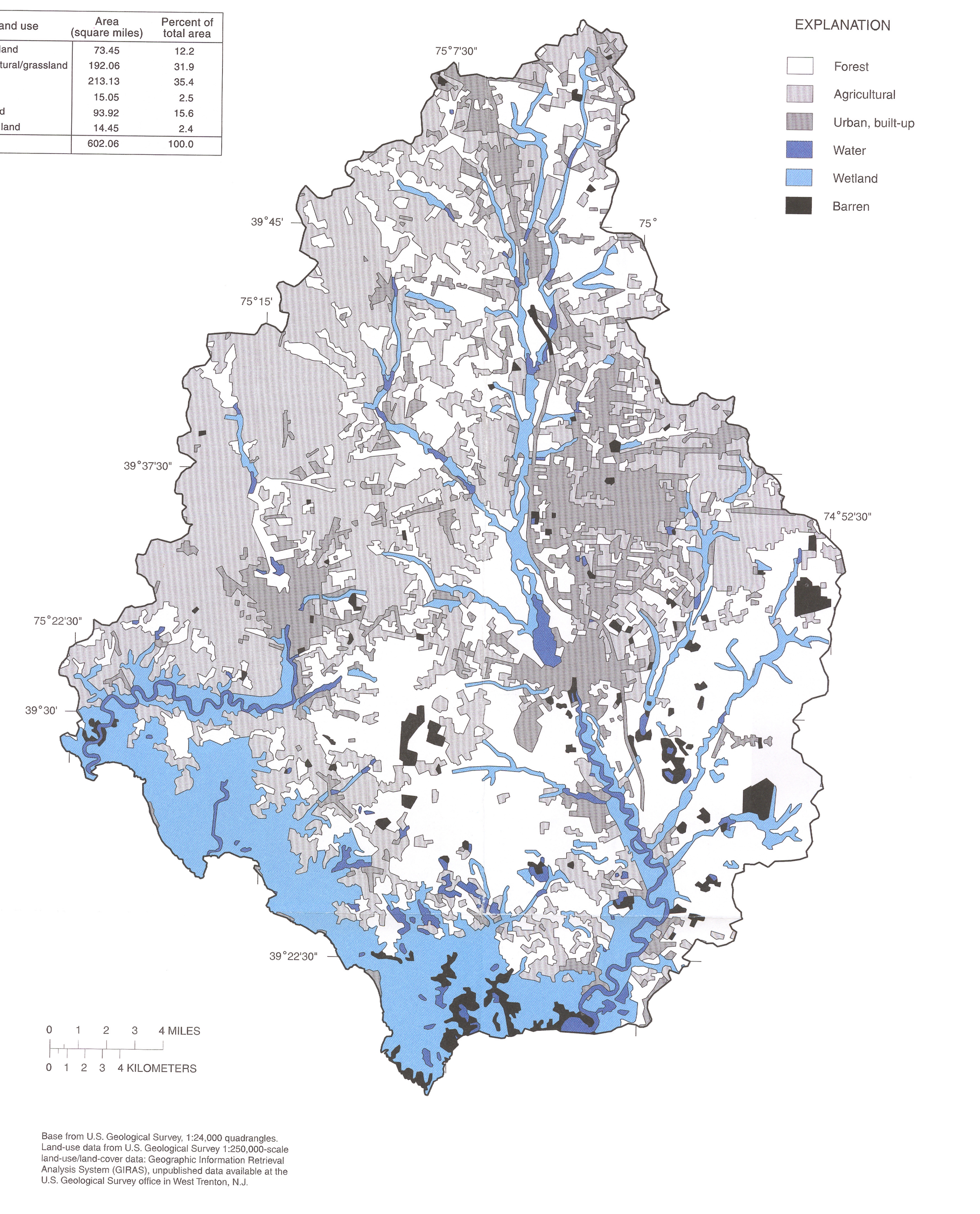


Figure 5-1. Land use in the Maurice River study area, New Jersey, in the early 1970's.

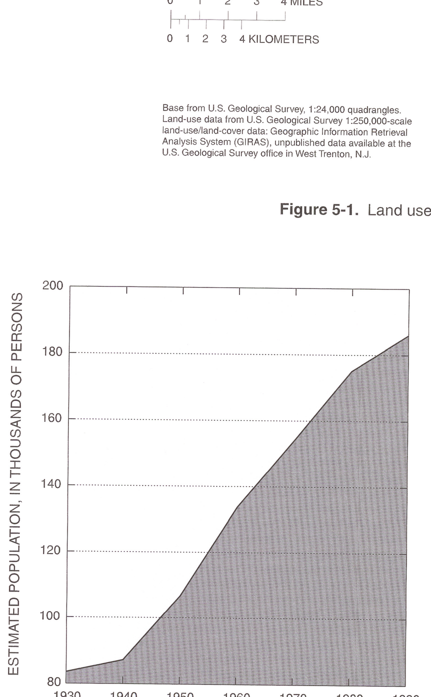
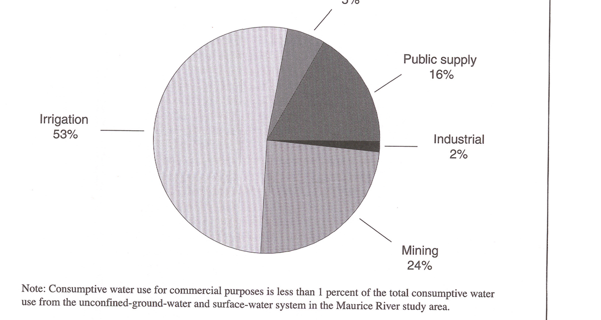


Figure 5-2. Estimated population in the Maurice River study area, New Jersey, 1930-90. (Data from New Jersey Department of Labor, 1991a, 1991b)

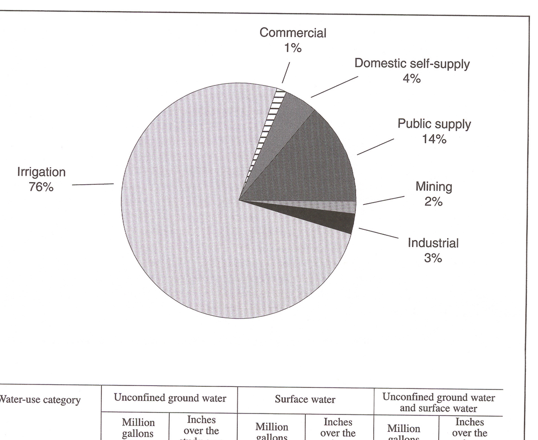


Note: Consumptive water use for commercial purposes is less than 1 percent of the total consumptive water use from the unconfined-ground-water and surface-water system in the Maurice River study area.

Water-use category	Unconfined ground water		Surface water		Unconfined ground water and surface water	
	Million gallons	Inches over the study area	Million gallons	Inches over the study area	Million gallons	Inches over the study area
Public supply[1]	1,360	0.13	0	0	1,360	0.13
Domestic self-supply	441	.042	0	0	441	.042
Commercial[1]	36	.003	0	0	36	.003
Irrigation[1]	4,193	.40	149	.014	4,342	.41
Industrial[1]	125	.012	0	0	125	.012
Mining	1,952	.19	0	0	1,952	.19
Total consumptive use[2]	8,107	.77	149	.014	8,256	.79

[1]Water-use data for public supply, industry, commercial, irrigation, and mining are from Site-Specific Water Use Data System (SSWUDS): unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.
[2]Small differences in totals may be caused by independent rounding.

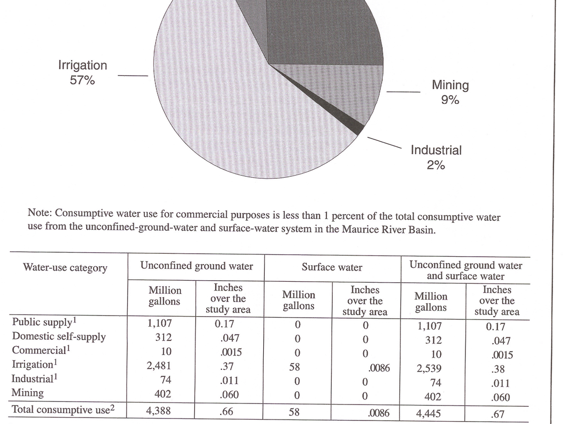
Figure 5-3. Summary of estimated annual consumptive water use from unconfined ground water and surface water in the Maurice River study area, New Jersey, by water-use category, 1994.



Water-use category	Unconfined ground water		Surface water		Unconfined ground water and surface water	
	Million gallons	Inches over the study area	Million gallons	Inches over the study area	Million gallons	Inches over the study area
Public supply[1]	252	0.14	0	0	252	0.14
Domestic self-supply	82	.044	0	0	82	.044
Commercial[1]	25	.014	0	0	25	.014
Irrigation[1]	1,277	.69	92	.049	1,369	.74
Industrial[1]	51	.027	0	0	51	.027
Mining	31	.017	0	0	31	.017
Total consumptive use[2]	1,719	.92	92	.049	1,810	.97

[1]Water-use data for public supply, industry, commercial, irrigation, and mining are from Site-Specific Water Use Data System (SSWUDS): unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.
[2]Small differences in totals may be caused by independent rounding.

Figure 5-4. Summary of estimated annual consumptive water use from unconfined ground water and surface water in the Cohansey River Basin, New Jersey, by water-use category, 1994.



Note: Consumptive water use for commercial purposes is less than 1 percent of the total consumptive water use from the unconfined-ground-water and surface-water system in the Maurice River Basin.

Water-use category	Unconfined ground water		Surface water		Unconfined ground water and surface water	
	Million gallons	Inches over the study area	Million gallons	Inches over the study area	Million gallons	Inches over the study area
Public supply[1]	1,107	0.17	0	0	1,107	0.17
Domestic self-supply	312	.047	0	0	312	.047
Commercial[1]	10	.0015	0	0	10	.0015
Irrigation[1]	2,481	.37	58	.0086	2,539	.38
Industrial[1]	74	.011	0	0	74	.011
Mining	402	.060	0	0	402	.060
Total consumptive use[2]	4,388	.66	58	.0086	4,445	.67

[1]Water-use data for public supply, industry, commercial, irrigation, and mining are from Site-Specific Water Use Data System (SSWUDS): unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.
[2]Small differences in totals may be caused by independent rounding.

Figure 5-5. Summary of estimated annual consumptive water use from unconfined ground water and surface water in the Maurice River Basin, New Jersey, by water-use category, 1994.

Table 5-1. Known contaminated sites in the Maurice River study area, New Jersey[1]

Site name[2]	Street address
Atlantic County	
Buena Borough	
Cirgo Service Station Buena Borough[3]	Rte. 40
Garden State Cleaners	Summer Ave.
La Cresca D'Oro Bakery	643 Wheat Rd. S.
Pedroni Fuel Company	385 Wheat Rd. E.
Sandy Products Incorporated	160 Railroad Blvd.
South Jersey Clothing Company	Atlantic and Central Ave.
Buena Vista Township	
Buena Vista Township sanitary landfill	Union Rd.
Buena Vista Township sanitary landfill	Rte. 54
Railroad Glass Company Incorporated	Rte. 557 (Tuckahoe Rd.)
Wheaton Glass Company Incorporated	Harding Hwy. and Oak Rd.
Wawa Food Market	[illegible] Central Ave.
Cumberland County	
Bridgeton City	
Seven Up Bottling Company	3 Glass St.
A.J. Peterson Incorporated	173 Water St.
Agway Incorporated	Manheim Ave.
Bridgeton City landfill	Aitken Dr.
Bridgeton Coal Gas (SSI)	Vine and Water Sts.
Cooper Industries Incorporated	East Ave. S. and Pamphylia Ave.
Cumberland County Utilities Authority	333 Water St.
Don Oil Company Incorporated	Water St. and University and Belmont Aves.
Hess Service Station Bridgeton City	Carlls Corner
Manhattan Electric Cable Corporation	330 E. Commerce St.
Maul Food Packer Incorporated	Penn and Bank Sts.
Owens Illinois Incorporated	N. Laurel St.
Smith and Richards Lumber Company Incorporated	110 Laurel St. S.
Texaco Service Station Bridgeton City	860 Pearl St. N.
Tylee Pipe	Roundtops Ave.
Commercial Township	
Mauricetown Division	Noble St.
Deerfield Township	
Deerfield Township ground-water contamination	Kenyon Ave.
Deerfield Township sanitary landfill	Vineland Ave.
Lakeside Brothers Motor Express Incorporated	N. Delsea Dr.
Major Petroleum Industries	Bridgeton Vineland Pike
Sherman Avenue and Beaver Dam Road	Sherman Ave. and Beaver Dam Rd.
Downe Township	
Downe Township Sanitary Landfill 2	Ackley Mill Rd.
U.S. Silica Company Transformer Station	Rte. 553
Fairfield Township	
605A Fairton Millville Road	605A Fairton-Millville Rd.
Cole Brothers	Fairton-Gouldtown Rd.
Fairfield Chemical	Clarks Pond Rd.
Fairfield Township landfill	Lummis Mill Rd.
Optopics Laboratory Corporation	Main St.
Greenwich Township	
Woods County Store	Ye Greate St. and Bacons Neck Rd.
Hopewell Township	
Hopewell Township sanitary landfill	Trench Rd.
Maurice River Township	
Maurice River Township sanitary landfill 2	Rte. 47 (Delsea Dr.)
Maurice River Township sanitary landfill	Weatherby Rd.
N.J. Dept. of Transportation[3]	Rte. 49
Millville City	
2335 Main St. Wawa	2335 Main St.
Airwork Corporation	Bogden Blvd.
American National Can Company	2nd St. S.
Associated Packaging Incorporated	1601 Eden Rd.
Conrail Service Station Millville City	High and Spruce Sts.
Conrail Facility Millville	Ladow Ave.
East Main Street and Wade Boulevard	Main St. E. and Wade Blvd.
Hess Service Station Millville City	2nd and McNeal Sts.
Kerr Glass Manufacturing Corporation	328 to 330 S. 2nd St.
Leeds and Northrup Company	Birch and Sassafras Sts.
Maul Technology Company	311 15th St. S.
Millville City Solid Waste Disposal Area	Cedarville Rd.
Millville City Water Department Aquaer Well 3	Bogden Blvd. and Wade Blvd.
Millville Coal Gas (SSI)	1211 N. 2nd St.
Millville Manufacturer Farm	Brand St. and Wade Blvd.
Nuccofer Corporation	Davis Ave.
Ponds By George	2311 Rte. 47 (Delsea Dr.)
Sico Company	2110 Rte. 47 (Delsea Dr.)
South 2nd Street and Route 47	S. 2nd St. and Rte. 47 (Delsea Dr.)
Ultra Tire Equipment Company	Birch and Sassafras Sts.
Wica Company	10th and G Sts.
Wheaton Industries Incorporated	[illegible]
Upper Deerfield Township	
Clement Pappas Company	W. Parsonage Rd.
N.J. Dept. of Transportation	Rte. 77
Seabrook Farms Incorporated sanitary landfill	Finley Rd. and Central Railroad
Upper Deerfield Township Municipal Building	Rte. 77
Upper Deerfield Township sanitary landfill	Northfield Station Rd.
Vineland Construction	Burlington Rd.
Vineland City	
1445 Utopia Lane	1445 Utopia Ln.
Agway Petroleum Vineland	521 Paul St.
Allenwood Brothers Garage	West Rd. N. and Grove Rd.
Andrews Glass Company	1740 West Blvd. N.
Anchor Glass Company	410 Fourth St.
Carelton R and T Company Incorporated	805 Sheridan Ave.
Cirgo and Amoco Service Station	S. Lincoln and E. Landis Ave.
Coastal Service Station Vineland City	Main Rd. and Chestnut Ave.
E.P. Henry Corporation	4200 S. West Blvd.
[illegible]	[illegible]
Essex Service Station Vineland City	[illegible]
Frontier Laboratories	[illegible]
Garrison Rd. ground-water contamination	Garrison Rd.
Gulf Service Station Vineland City	[illegible]
High Concrete Structures Incorporated of N.J.	[illegible]
Kimble Glass Company Incorporated	[illegible]
Lab Glass Incorporated	[illegible]
Miranda National Bank	[illegible]
Moria Company Incorporated	[illegible]
Newcomb Medical Center	[illegible]
N.J. Dept. of Transportation	[illegible]
North Vineland Carwash	[illegible]
[illegible]	[illegible]
Pillsbury Green Giant	[illegible]
Ralphs Auto Salvage	[illegible]
Rudco Products Incorporated	[illegible]
Samuel Coraluzzo Company Incorporated	[illegible]
Service Station Vineland City (former)	[illegible]
Shell Service Station Vineland City	[illegible]
Sico Company Direct 2	[illegible]
Southern State Fabricators of N.J.	[illegible]
Texaco Service Station Millville City	[illegible]
United Parcel Service	[illegible]
U.S.A. Auto Brokers Incorporated	[illegible]
Vineland Chemical Company Incorporated	[illegible]
Vineland City Landfill 1	[illegible]
Vineland City Water and Sewer Authority Well 3	[illegible]
Vineland Landfill	[illegible]
Weymouth Road Terminal	Weymouth Rd.
Gloucester County	
Clayton Borough	
Echo Products Incorporated	[illegible]
Harmony Auto Repair Shop	[illegible]
Oil Recovery Company Incorporated	[illegible]
Franklin Township	
[illegible]	[illegible]
Glassboro Borough	
[illegible]	[illegible]
Monroe Township	
[illegible]	[illegible]
Newfield Borough	
[illegible]	[illegible]
Washington Township	
[illegible]	[illegible]
Salem County	
Elmer Borough	
Fred Hartz and Son	26 Rte. 40 (Harding Way)
N.J. Dept. of Transportation	Rte. 40
Whites Welding and Body Shop Incorporated	5 Mill St.
Pittsgrove Township	
Pittsgrove Township sanitary landfill	Burden Hill Rd. S.
Upper Pittsgrove Township sanitary landfill	Bert Groff Rd.
Upper Pittsgrove Township	
Route 77 and Whig Lane Hardingville Road	Rte. 77 and Whig Lane Hardingville Rd.

[1]New Jersey Department of Environmental Protection, 1994b.
[2]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.
[3]It is not clear whether this site is located in the study area on the basis of the street address.

Table 5-2. Sites with unknown source(s) of contamination in the Maurice River study area, New Jersey[1]

Site name[2]	Street address
Atlantic County	
Buena Borough	
Janet Street ground-water contamination	Brewster and Weir Rds.
Cumberland County	
Bridgeton City	
Bridgeton City Water Department wellfield contamination	Various locations
Deerfield Township	
Danna Estates ground-water contamination	Morton Ave.
Millville City	
U.S. Postal Service	502 High St. N.
Vineland City	
Pillsbury Green Giant	270 N. Mill Rd.
Vineland City Water and Sewer Authority Well 10	Delsea Dr. and Arbor Ave.
Salem County	
Pittsgrove Township	
Schalick Property	Morton Ave.

[1]New Jersey Department of Environmental Protection, 1994b, Known contaminated sites in New Jersey: Trenton, New Jersey, New Jersey Department of Environmental Protection, July 1994, 477 p.
[2]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.

Table 5-3. Estimated population of the Maurice River study area, New Jersey
[Population data from New Jersey Department of Labor, 1991b]

Municipality	Total population	Land area within study area (percent)	Estimated population within study area, 1990
Atlantic County			
Buena Borough	4,441	57	2,531
Buena Vista Township	7,655	23	1,761
Cumberland County			
Bridgeton City	18,942	100	18,942
Commercial Township	5,026	100	5,026
Deerfield Township	2,933	100	2,933
Downe Township	1,702	100	1,702
Fairfield Township	5,699	100	5,699
Greenwich Township	911	55	501
Hopewell Township	4,215	100	4,215
Lawrence Township	2,433	100	2,433
Maurice River Township	6,648	57	3,789
Millville City	25,992	100	25,992
Shiloh Borough	408	92	375
Stow Creek Township	1,437	10	144
Upper Deerfield Township	6,927	100	6,927
Vineland City	54,780	100	54,780
Gloucester County			
Clayton Borough	6,155	100	6,155
Elk Township	3,806	66	2,512
Franklin Township	14,482	64	9,268
Glassboro Borough	15,614	46	7,182
Monroe Township	26,703	20	5,341
Newfield Borough	1,592	100	1,592
Washington Township	41,960	10	4,196
Salem County			
Alloway Township	2,795	22	615
Elmer Borough	1,571	100	1,571
Pittsgrove Township	8,121	100	8,121
Upper Pittsgrove Township	3,140	61	1,915
Total	276,088		186,218

Table 5-4. Reported annual water withdrawals from the unconfined-aquifer and surface-water systems in the Maurice River study area, New Jersey, by water-use category, 1988-94
[Site-Specific Water Use Data System (SSWUDS): unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.; all values in million gallons; all values rounded to the nearest million gallon; small differences in totals may be caused by independent rounding; --, withdrawals either not reported or less than 500,000 gallons per year]

Year	Unconfined ground water: Public supply	Industrial	Commercial	Irrigation	Mining	Total	Surface water: Irrigation
Total study area							
1988	6,138	--	--	4,508	--	10,646	313
1989	4,555	--	--	2,110	--	6,665	217
1990	4,554	--	--	2,578	--	7,132	190
1991	5,821	32	2	4,529	--	10,384	493
1992	5,797	284	38	3,802	--	9,921	299
1993	6,356	1,433	898	3,177	19,479	31,343	382
1994	6,370	1,563	888	4,659	24,404	37,884	166
Maurice River Basin							
1988	5,014	--	--	2,871	--	7,885	204
1989	3,349	--	--	1,614	--	4,963	82
1990	3,415	--	--	1,754	--	5,169	114
1991	4,697	10	2	2,827	--	7,536	106
1992	4,474	259	30	2,521	--	7,284	86
1993	5,009	948	281	2,044	4,530	12,812	118
1994	4,968	927	254	2,757	5,029	13,935	64
Cohansey River Basin							
1988	1,124	--	--	1,178	--	2,302	93
1989	1,206	--	--	183	--	1,389	130
1990	1,139	--	--	456	--	1,595	65
1991	1,124	22	--	1,297	--	2,443	385
1992	1,323	25	8	1,110	--	2,466	210
1993	1,343	485	617	779	--	3,224	262
1994	1,402	636	634	1,419	384	4,475	102
Tidal areas and minor tributaries							
1988	--	--	--	459	--	459	16
1989	--	--	--	313	--	313	5
1990	--	--	--	368	--	368	11
1991	--	--	--	405	--	405	2
1992	--	--	--	171	--	171	3
1993	4	--	--	354	14,949	15,307	2
1994	--	--	--	483	18,991	19,474	--

Table 5-5. Reported annual water withdrawals from confined aquifers in the Maurice River study area, New Jersey, by water-use category, 1988-94
[Site-Specific Water Use Data System (SSWUDS): unpublished data available at the U.S. Geological Survey office in West Trenton, N.J.; all values in million gallons; all values rounded to the nearest million gallon; small differences in totals may be caused by independent rounding; --, withdrawals either not reported or less than 500,000 gallons per year]

Year	Piney Point aquifer: Public supply	Wenonah-Mount Laurel aquifer: Public supply	Potomac-Raritan-Magothy aquifer system: Public supply	Potomac-Raritan-Magothy aquifer system: Industrial	Use of water from confined aquifers, in percent of total water use from all sources
1988	--	73	200	--	2.5
1989	--	60	192	--	3.7
1990	--	62	201	--	3.6
1991	--	81	[illegible]	--	[illegible]
1992	40	149	[illegible]	--	[illegible]
1993	37	302	[illegible]	[illegible]	[illegible]
1994	35	328	[illegible]	[illegible]	2.9

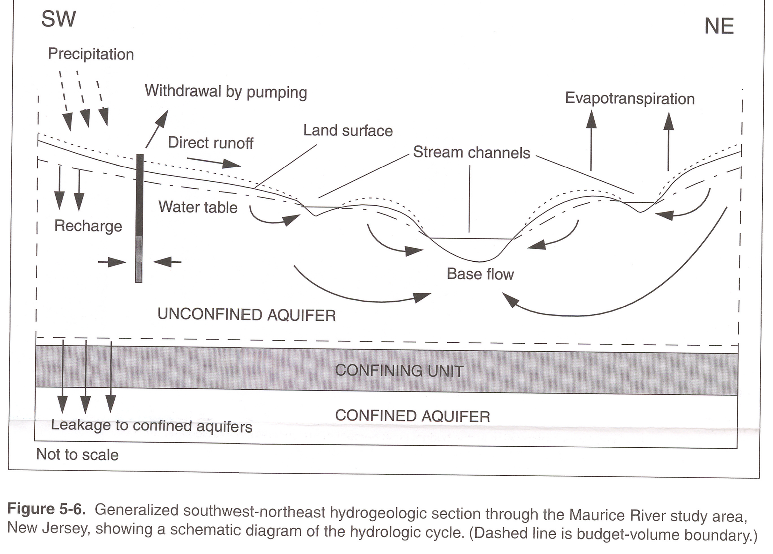


Figure 5-6. Generalized southwest-northeast hydrogeologic section through the Maurice River study area, New Jersey, showing a schematic diagram of the hydrologic cycle. (Dashed line is budget-volume boundary.)

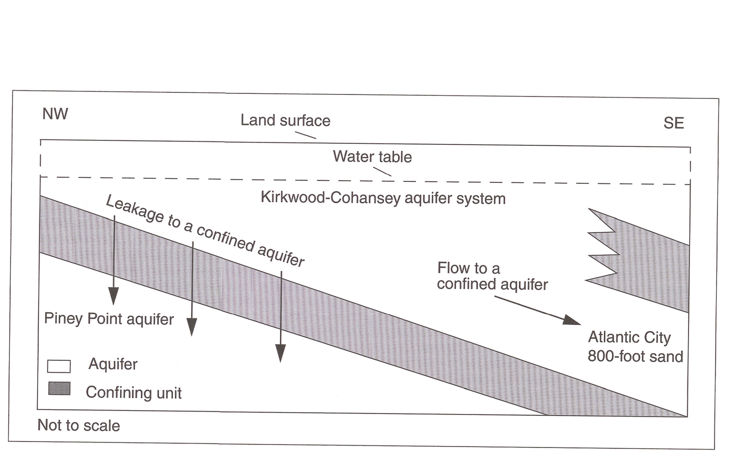


Figure 5-7. Generalized northwest-southeast hydrogeologic section through the Maurice River study area showing a schematic diagram of leakage and flow to confined aquifers. (Dashed line is budget-volume boundary.)

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