RESOURCE EVALUATION

This sheet examines the influence of population on the quantity and quality of water available in the Great Egg Harbor River basin study area. Current population data for the study area and changes in population from 1930-87 are presented. Water-use data are compiled and quantities of water withdrawn and consumed from the Kirkwood-Cohansey aquifer system are estimated. Finally, a water budget is presented to evaluate major gains and losses to and from the surface- and ground-water systems.

Population

Figure 5-1 shows the estimated total population of the basin for each decennial census beginning in 1930 and from provisional estimates made for 1987; figure 5-2 shows these population values by county. Population growth rates have been similar in each of the three counties in the study area. The virtual lack of growth in the 1930's (fig. 5-1) reflects the lower national population growth rate during the Depression, whereas the increased growth rate in the late 1940's, 1950's, and through the 1960's is a result of the post-World War II "baby boom," and increased immigration both from other states and from abroad. The even steeper growth rate in the 1970's and 1980's represents a move from industrialized urban centers to more rural areas like the Great Egg Harbor River basin. (See New Jersey Department of Labor, 1984, p. iii-iv.)

The population of the study area was estimated by taking a portion of the total population of each municipality equal to the percentage of land in the study area occupied by that municipality. The population is assumed to be evenly distributed. Table 5-1 lists the total 1987 population of each municipality in the study area, the percentage of the area within the basin occupied by each municipality, and the estimated population in the part of each municipality that lies within the basin.

Water Use

Water used in the Great Egg Harbor River basin is derived almost exclusively from ground water. In the northwestern part of the basin, most ground water is pumped from aquifers below the Kirkwood-Cohansey aquifer system, whereas in the southeastern part of the basin most of the ground water used is from the Kirkwood-Cohansey aquifer system. Estimates of water withdrawn for public supply, self-supplied domestic use, irrigation, industrial use, and mining were made from reported values. In most cases, reported water-use values for 1987 were used to estimate yearly withdrawals. From these estimates, the amount of consumptive use of water in each catagory was calculated and totaled for use in a water budget for the Great Egg Harbor River basin. Consumptive water use consists of all water withdrawn from, but not returned to, the ground- or surface-water system. For example, irrigation is highly consumptive because a large percentage of the water is taken up by vegetation, whereas industrial cooling is less consumptive because a large percentage of the water withdrawn is allowed to return to the system.

Total consumptive water use is the sum of the volumes of water used for each of the water-use catagories listed above (fig. 5-3). Surface water is rarely used for any of these purposes, with the exception of mining, for which only surface water is used. The consumptive-water-use values for each category are listed in figure 5-3.

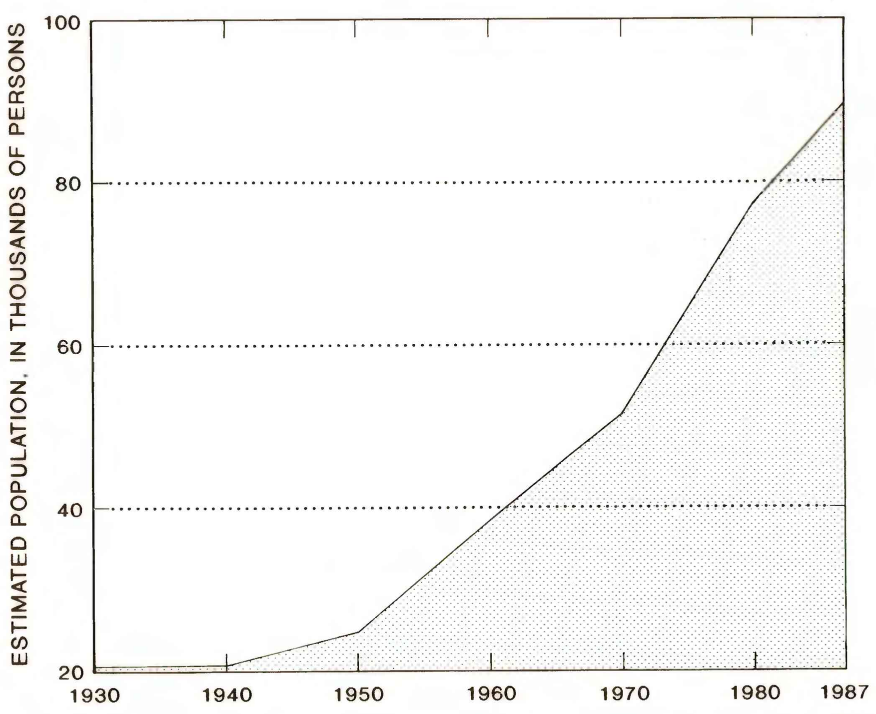


Figure 5-1.--Estimated population in the Great Egg Harbor River basin study area, 1930-87. (Data for 1987 are provisional estimates; all data from New Jersey Department of Labor, 1984, and New Jersey Department of Labor, 1988.)

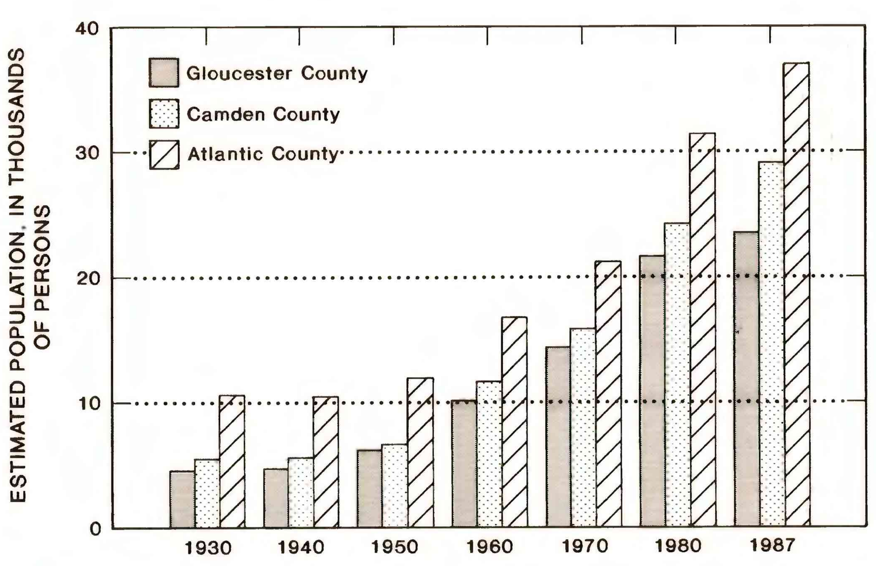
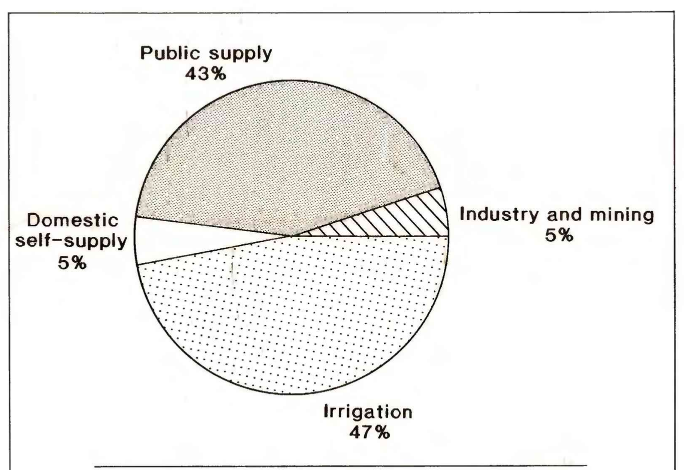


Figure 5-2.--Population in the Great Egg Harbor River basin study area, by county, 1930-87. (Data for 1987 are provisional estimates; all data from New Jersey Department of Labor, 1984, and New Jersey Department of Labor, 1988.)



Water-use category	Million gallons	Inches over the basin
Public supply	1,062.95	0.176
Domestic self-supply	129	.021
Irrigation	1,154.17	.191
Industry and mining	128.33	.021
Total consumptive use	2,470	0.409

Figure 5-3.--Summary of consumptive water use in the Great Egg Harbor River basin study area.

Table 5-1.--Estimated population of the study area based on percentage of land area in the Great Egg Harbor River basin

[Provisional data from New Jersey Department of Labor, 1988]

County Municipality	Total population, 1987	Land area within basin (percent)	Estimated population within basin, 1987
Atlantic County			
Buena Borough	3,699	43.39	1,605
Buena Vista Township	7,448	72.47	5,398
Corbin City	243	48.67	118
Egg Harbor Township	22,506	41.76	9,399
Estell Manor City	1,038	63.97	664
Folsom Borough	1,938	99.94	1,937
Galloway Township	19,861	2.45	487
Hamilton Township	12,936	96.44	12,475
Hammonton Town	12,347	22.61	2,792
Mullica Township	5,421	18.57	1,007
Weymouth Township	1,458	75.56	1,102
Camden County			
Berlin Borough	5,944	65.43	3,889
Berlin Township	5,576	35.90	2,002
Gloucester Township	51,647	11.98	6,187
Pine Hill Borough	9,069	22.45	2,036
Pine Valley Borough	25	35.47	9
Winslow Township	26,967	55.49	14,964
Gloucester County			
Franklin Township	14,070	36.14	5,085
Monroe Township	23,159	79.62	18,439
Total	225,352		89,595

Table 5-2.--Annual withdrawals for public supply from the Kirkwood-Cohansey aquifer system in the Great Egg Harbor River basin, 1975-87

[MUA, Municipal Utilities Authority; Twp, Township; all values in million gallons; ---, no reported value]

Year	Municipality: Buena Borough Supplier: Buena Borough MUA	Hamilton Twp Hamilton Twp MUA	Hammonton Town Town of Hammonton	Gloucester Twp Garden State Water Company	Winslow Twp Winslow Twp	Monroe Twp Monroe Twp MUA	Total
1975	16.55	3.02	237.50	---	134.68	244.47	636.22
1976	12.11	19.71	240.16	---	162.00	263.20	697.18
1977	14.16	32.82	262.40	---	181.20	265.69	756.27
1978	12.24	33.16	239.10	---	173.30	244.78	702.58
1979	8.74	33.68	230.30	---	180.90	293.26	746.88
1980	8.58	39.75	258.90	5.23	214.70	342.42	869.58
1981	8.89	33.19	197.90	43.94	204.01	324.30	812.23
1982	10.42	38.22	237.60	102.14	234.08	323.30	945.76
1983	12.71	37.67	243.00	79.04	277.73	360.10	1010.25
1984	11.52	40.91	213.35	---	272.28	335.67	873.73
1985	12.29	40.73	208.66	99.27	294.29	358.21	1013.45
1986	12.64	44.46	180.64	99.47	---	346.97	684.18
1987	15.65	49.38	196.96	78.33	382.40	393.55	1116.27

Public Supply

In this report, public-supply water is considered to be that used for domestic purposes only, although a small portion of public-supply water is used for industrial purposes. Table 5-2 lists reported annual public-supply withdrawals from the Kirkwood-Cohansey aquifer system within the basin from 1975 through 1987. Because some municipalities in the study area withdraw all or part of their public-supply water from aquifers below the Kirkwood-Cohansey aquifer system, this is not a comprehensive listing of all public-supply withdrawals in the study area. All public-supply water is assumed to be transported through sewers and treated at municipal sewage-treatment plants. Because most plants discharge the treated wastewater into the Delaware River west of the study area (Gloucester Township, Winslow Township, Monroe Township) or the Mullica River north of the study area (Hammonton Town), consumption is considered to be 100 percent. The remaining wastewater (from Buena Borough and Hamilton Township) is treated and discharged within the Great Egg Harbor River basin; consumption there is considered to be 18 percent (Solley and others, 1988, p. 17). Total reported public-supply withdrawals from the Kirkwood-Cohansey aquifer system in 1987 totaled 1,116.27 Mgal. On the basis of these values, consumptive water use for public supply in the study area is 1,062.95 Mgal, or 0.176 inches per year over the basin.

Domestic Self-Supply

Estimation of self-supplied domestic water use is difficult because withdrawals are not reported to any public agency. In order to estimate this value, the population of the area was multiplied by a per capita domestic-water-use value of 75 gallons per person per day (Solley and others, 1988, p. 17), and the amount of public-supply water was subtracted. Next, the percentage of self-supplied water likely to be withdrawn from the Kirkwood-Cohansey aquifer system rather than from any deeper aquifer was estimated on the basis of the percentage of domestic wells from each aquifer in the USGS GWSI data base (see section on well-numbering system); finally, that value was multiplied by 18 percent for consumptive use (Solley and others, 1988, p. 17). Total withdrawals from the Kirkwood-Cohansey aquifer system consumed for self-supplied domestic use in the basin are roughly 129 Mgal, or 0.021 inches per year over the basin.

Table 5-3.--Estimated water use for irrigation in the Great Egg Harbor River basin

[mi^2, miles squared; Mgal/yr, million gallons per year; ---, no irrigated land in township so further calculations unnecessary; data from James Gibson, New Jersey Agricultural Statistics Service, written commun., 1987; small differences in totals caused by independent rounding]

County Municipality	Irrigated land in township (acres)	Land area within basin (percent)	Estimated irrigated land in basin (acres)	Estimated irrigated land in basin (mi^2)	Estimated water use (Mgal/yr)
Atlantic County					
Buena Borough	0	---	---	---	---
Buena Vista Township	1,205.69	72.47	873.76	1.37	189.90
Corbin City	0	---	---	---	---
Egg Harbor Township	278.31	41.76	116.22	0.18	25.26
Estell Manor City	289.92	63.97	185.46	.29	40.31
Folsom Borough	15.5	99.94	15.49	.02	3.37
Galloway Township	914.92	2.45	22.42	.04	4.87
Hamilton Township	1,704.67	96.44	1,643.98	2.57	357.30
Hammonton Town	4,224.64	22.61	955.19	1.49	207.60
Mullica Township	940.66	18.57	174.68	.27	37.96
Weymouth Township	0	---	---	---	---
Camden County					
Berlin Borough	180.27	65.43	117.95	.18	25.63
Berlin Township	45	35.90	16.16	.03	3.51
Gloucester Township	4	11.98	0.48	.00	0.10
Pine Hill Borough	0	---	---	---	---
Pine Valley Borough	0	---	---	---	---
Winslow Township	688.24	55.49	381.90	.60	83.00
Gloucester County					
Franklin Township	2,909.8	36.14	1,051.60	1.64	228.55
Monroe Township	433.7	79.62	345.31	.54	75.05
Total			5,900.60	9.22	1,282.41

Irrigation

Irrigation water-use data are extremely limited. The values in table 5-3 were calculated on the basis of several assumptions: First, it was assumed that all water for irrigation in the basin is derived from the Kirkwood-Cohansey aquifer system or from surface-water sources. Available data support this assumption. Second, it was assumed that the irrigated land is evenly distributed within each municipality. The estimated 5,900 acres of irrigated land in the basin require approximately 8 inches of water per year (James Gibson, New Jersey Agricultural Statistics Service, written commun., 1987). As a result, an estimated 1,282.41 Mgal/yr (million gallons per year) is withdrawn annually for irrigation in the Great Egg Harbor River basin. According to Solley and others (1988, p. 25), in New Jersey about 90 percent of water used for irrigation is consumed. Thus, estimated water consumption for irrigation in the Great Egg Harbor River basin is 1,154.17 Mgal, or 0.191 inches per year over the basin.

Table 5-4.--Industrial water use in the Great Egg Harbor River basin, 1975-87

[all values in million gallons; ---, no reported value]

Year	Egg Harbor Township	Folsom Borough	Mullica Township	Winslow Township	Winslow Township[1]	Monroe Township	Total
1975	0.08	0.53	18.80	50.57	---	0.34	70.32
1976	.01	---	10.50	55.07	---	7.96	73.54
1977	.01	---	11.04	65.87	---	8.45	85.37
1978	.23	---	11.56	67.88	---	9.03	88.70
1979	.01	---	10.60	26.44	---	6.08	43.13
1980	.05	---	10.60	26.46	---	.81	37.92
1981	.06	---	9.10	73.46	---	.81	83.43
1982	.04	---	9.72	15.60	---	.81	26.17
1983	.05	---	8.49	37.79	---	.81	47.14
1984	.03	5.82	8.48	42.49	1.95	11.19	69.96
1985	.05	3.65	7.98	20.26	0.92	10.41	43.27
1986	1.83	---	8.50	---	---	9.43	19.76
1987	2.43	---	7.89	---	---	8.53	18.85

[1] Water used is surface water

Industry

Table 5-4 shows the annual water use by major industries using self-supplied water in the Great Egg Harbor River basin from 1975 through 1987. Self-supplied industrial water, for the purposes of this report, is considered to be the total amount of water used for industrial purposes. All the industries in table 5-4 withdraw their water from wells screened in the Kirkwood-Cohansey aquifer system, with the exception of one user in Winslow Township, which uses surface water. Total use of self-supplied industrial water for 1987 is calculated to have been 18.85 Mgal. About 7.5 percent of industrial water withdrawn in New Jersey is consumed (Solley and others, 1988, p. 33). Therefore, total consumptive use of industrial water is estimated to be 1.41 Mgal, or 0.000235 inches per year over the basin.

Mining

A small amount of surface water is used for mining in the Great Egg Harbor River basin (table 5-5). The total amount of water used for mining in 1987 is calculated to have been about 1,269.15 Mgal. Solley and others (1988, p. 37) estimate that in New Jersey 10 percent of the water used for mining is consumed; therefore, total consumptive use of mining water is estimated to be 126.92 Mgal, or 0.021 inches per year over the basin. No withdrawals for mining in the study area were recorded before 1985.

Table 5-5.--Surface-water use for mining in the Great Egg Harbor River basin, 1985-87

[all values in million gallons; ---, no reported value]

Year	Winslow Township	Monroe Township	Total
1985	1,326.18	---	1,326.18
1986	1,350.49	115.20	1,465.69
1987	1,200.15	69.00	1,269.15

Water Budget

The hydrologic cycle of the Great Egg Harbor River basin is constantly changing and dynamic. For purposes of discussion, the hydrologic cycle can be conceptualized as a hydrologic budget where inflows are balanced by equivalent outflows. The following budget analysis accounts for all water-system gains and losses. The hydrologic budget can be evaluated by using two internal budgets and corresponding balance equations, one describing gains and losses to and from the land surface, the other describing gains and losses to and from the saturated ground-water system. Many of the variables in the two budgets are difficult to evaluate. One variable that cannot be measured or estimated--recharge to the aquifer--was determined separately in both equations, and the two values were compared. The values for precipitation, base flow, direct runoff, discharge, and withdrawals by pumping were discussed in previous sections.

In order to calculate the amount of water moving through the basin, a budget volume must be defined. The budget volume for this study is defined by the extent of the Kirkwood-Cohansey aquifer system in the Great Egg Harbor River basin. It is assumed that no flow is either gained or lost across the lateral boundary into other drainage areas. Two generalized hydrogeologic sections bisect the study area to show budget area and generalized flow. Figure 5-4 shows generalized flow in the unconfined aquifer in the southwest-northeast direction. Figure 5-5 shows generalized flow in the northwest-southeast direction. Water is introduced to the land-surface system through precipitation and is lost from the land-surface system through evapotranspiration, direct runoff, and recharge to the ground-water system; these are the components of the land-surface equation. Water is introduced to the ground-water system through recharge (which was lost by the land-surface system). Water is lost from the ground-water system through base flow, withdrawals from pumping, and leakage to confined aquifers; these are the components of the ground-water-system equation.

The variables in the hydrologic budget are--

- P = precipitation
- Q_{dr} = direct runoff
- ET = evapotranspiration
- R = recharge to the aquifer
- Q_b = base flow
- L = leakage to confined aquifers
- W_p = withdrawal, consumptive use for public supply, domestic, irrigation, industry, and mining.

The equation used for the land-surface hydrologic budget is

$$P = Q_{dr} + ET + R ,$$

and the equation for the ground-water system is

$$R = Q_b + L + W_p .$$

The precipitation value in the budget is consistent with reported values for the Coastal Plain of New Jersey. The precipitation data for the study area were obtained from the records of the secondary weather station in Hammonton, Atlantic County (National Oceanic and Atmospheric Administration, 1928-88). Here the precipitation is measured less frequently than at a primary station and, as a result, precipitation data for many days are unavailable. The missing precipitation values were estimated by averaging data from several weather stations located near the basin. The estimated value for annual precipitation in the basin, 45.3 inches, is well within the range of values (43-48 inches) reported for the Coastal Plain of New Jersey.

The discharge measurements used in the budget analysis were taken from information in the text (sheet 3). Discharge data for the Great Egg Harbor River at the Folsom, N.J., gaging station provide the most complete record from which to estimate base flow and direct runoff; however these streamflow components vary throughout the basin. For this reason, discharge data from several stations were examined--Great Egg Harbor River at Folsom (01411000), Great Egg Harbor River near Blue Anchor, N.J. (01410820)(upstream) and Great Egg Harbor River near Weymouth, N.J. (01411110)(downstream). For each station, the volume of the base flow per square mile of drainage area was calculated from the values given in tables 3-1 and 3-2. (The base-flow value for Great Egg Harbor River at Folsom is found in the accompanying text.) Each of the three base-flow values was distributed over a portion of the basin equal to the precentage of the basin drained by the river at each surface-water station. For example, the value of base flow per square mile for Great Egg Harbor River near Blue Anchor was distributed over an area one-quarter of the size of the drainage area of the Great Egg Harbor River near Weymouth because the percentage of the basin drained by the Great Egg Harbor River near Blue Anchor is one-quarter of the percentage of the basin drained by the Great Egg Harbor River near Weymouth. By using this method, total flow was estimated to be 20.7 inches per year and base flow was estimated to be 17.6 inches per year over the entire basin. Because base flow was assumed to be 85 percent of total flow throughout the basin, direct runoff was calculated to be 3.1 inches per year over the entire basin.

Evapotranspiration can be calculated by using any of several methods. For this study, evapotranspiration was calculated by using the Thornthwaite method (Dunne and Leopold, 1978, p. 137-138). This method takes into account the latitude of and mean monthly temperature at the site, but does not consider precipitation, soil moisture, or vegetative cover. Several problems arise with the use of this method. First, evidence suggests that differences in soil and plant types can cause variations in evapotranspiration, even under conditions of adequate soil moisture (Warren and others, 1968, p. C24). Second, the Thornthwaite method is used to estimate a potential value rather than an actual value. Potential evapotranspiration is the amount of moisture that would transpire and evaporate if there was at no time a deficiency of water. The value of potential evapotranspiration does not account for dry periods when little moisture is available for transpiration or evaporation; therefore it is generally much higher than the actual evapotranspiration value. Rooney (1971, p. 15), in a report on the water resources of Cumberland County, N.J., used the Thornthwaite method to calculate a potential evapotranspiration value of 28.7 inches per year. Potential evapotranspiration in the Great Egg Harbor River basin was estimated to be 27.6 inches per year by using the Thornthwaite method.

Another method of calculating evapotranspiration is to examine 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 values calculated by Gill (1962, p. 33), Hardt and Hilton (1969, p. 54), Vowinkel and Foster (1981, p. 18), and Rhodehamel (1970, p. 7) with this method range from 22 to greater than 25 inches.

Reported values of evapotranspiration discussed above for the Coastal Plain of New Jersey range from 22 to 29 inches. The Thornthwaite potential evapotranspiration for the Great Egg Harbor River basin study area was calculated to be 27.6 inches. This value is high for the topography and geology of the area. Infiltration is rapid as a result of the sandy soil, and the direct-runoff component of flow is small. A value in the lower part of the reported range--for example, 22 to 24 inches--would be a better estimate of actual evapotranspiration. The reported values of evapotranspiration in the Coastal Plain of New Jersey mentioned above were averaged, and the resulting value of 24 inches was used to represent the actual evapotranspiration for the study area. This value allows for a difference between actual evapotranspiration and the potential evapotranspiration calculated by using the Thornthwaite method, and is used in the water budget in this report.

The value for leakage in the budget is actually the sum of the leakage across three separate boundaries, as shown in figure 5-5. The three leakage values were derived from the analysis of a ground-water flow model of the New Jersey Coastal Plain (Martin, 1987). Flow rates in the model cells in the Kirkwood-Cohansey aquifer system in the Great Egg Harbor River basin were totaled over each of the three boundaries. Two of the three values describe vertical flow through a confining unit to the confined aquifer below. In the upper part of the basin, this value (3.76 ft^3/s) represents flow from the Kirkwood-Cohansey aquifer system through the Alloway Clay Member to the Piney Point aquifer below; in the lower part of the basin, this value (0.75 ft^3/s) represents flow through the confining unit overlying the Atlantic City 800-foot sand. (The leakage value used for the lower part of the basin is in reality the simulated rate of flow through the confining unit overlying the Rio Grande water-bearing zone. Because the Rio Grande water-bearing zone is a minor unit in the study area, and because the rates of flow through the confining units above and below the Rio Grande water-bearing zone are similar, flow through the confining unit overlying the Rio-Grande water bearing zone was assumed to approximate flow through the confining unit overlying the Atlantic City 800-foot sand.) The third value for leakage (4.71 ft^3/s) represents horizontal flow in the downdip direction from the lower part of the Kirkwood-Cohansey aquifer system to the Atlantic City 800-foot sand.

Thus, leakage to confined aquifers in the basin totaled 9.22 ft^3/s, which, when divided by the model area, is equal to 0.3 inch per year over the Great Egg Harbor River basin.

The value for withdrawal, 0.4 inch, is discussed above in the section on water use. This value represents total consumptive withdrawals by pumping.

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

- P = 45.3
- Q_{dr} = 3.1
- ET = 24
- Q_b = 17.6
- L = 0.3
- W_p = 0.4 .

By inserting these values into the above equations:

$$P = Q_{dr} + ET + R$$
$$45.3 = 3.1 + 24 + R$$
$$R = 18.2 \text{ inches}$$

and

$$R = Q_b + L + W_p$$
$$R = 17.6 + 0.3 + 0.4$$
$$R = 18.3 \text{ inches} .$$

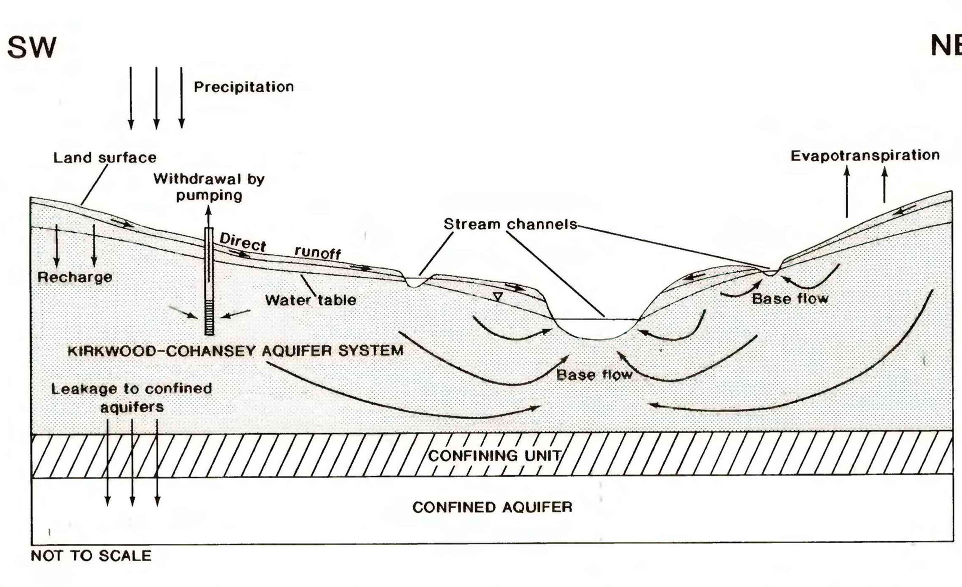


Figure 5-4.--Generalized southwest-northeast hydrogeologic section through the Great Egg Harbor River basin study area. (Area for which hydrologic budget is calculated is shaded.)

In this budget, recharge from the land surface to the surficial aquifer system is about 18 inches, a substantial component of both equations. The only component entering the hydrologic cycle is precipitation, and the two major components leaving the hydrologic cycle are evapotranspiration and discharge. Evapotranspiration in this budget is 53 percent of precipitation, whereas discharge, composed of base flow and direct runoff, is 46 percent of precipitation. Consumptive water use in this basin is a very small percentage of the total--less than 1 percent. Consumptive water use most likely will become a larger factor in the budget as the population of and industry in the basin continue to increase.

This hydrologic analysis quantifies the amount of water available from ground-water and surface-water sources in the Great Egg Harbor River basin and indicates the extent of consumptive use of this water under current (1991) conditions. The effects of development on the hydrology of the basin could be monitored by updating this analysis periodically.

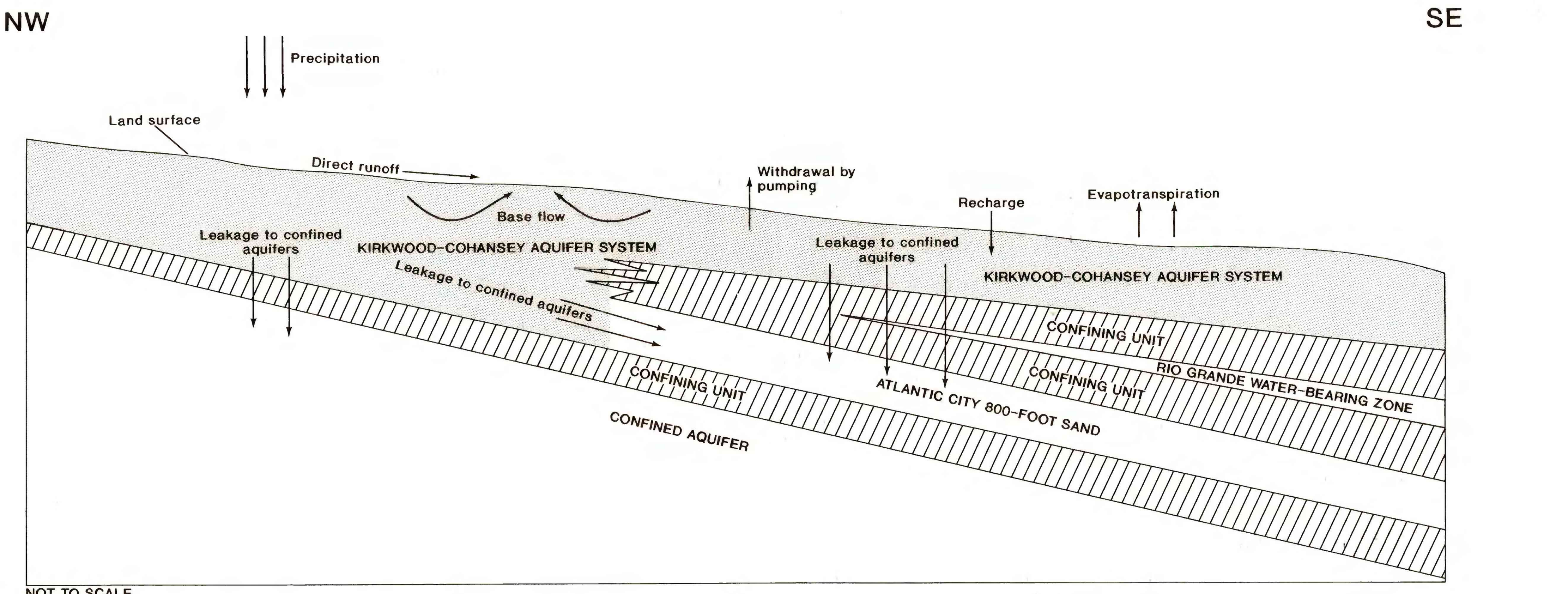


Figure 5-5.--Generalized northwest-southeast hydrogeologic section through the Great Egg Harbor River basin study area. (Area for which hydrogeologic budget is calculated is shaded.)

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By
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1992