STATISTICAL CHARACTERISTICS OF STREAM DISCHARGE IN TRIBUTARIES OF SELECTED ESTUARIES IN NEW JERSEY

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4141

Prepared in cooperation with the

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

STATISTICAL CHARACTERISTICS OF STREAM DISCHARGE IN TRIBUTARIES OF SELECTED ESTUARIES IN SOUTHERN NEW JERSEY

By R. Edward Hickman

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4141

Prepared in cooperation with the

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

West Trenton, New Jersey

1995

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information
write to:

District Chief
U.S. Geological Survey
Mountain View Office Park
810 Bear Tavern Road
Suite 206
West Trenton, NJ 08628

Copies of this report can be
purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

Multiply	By	To obtain
inch	25.4	millimeter
square mile	2.590	square kilometer
cubic foot per second	0.02832	cubic meter per second

STATISTICAL CHARACTERISTICS OF STREAM DISCHARGE IN TRIBUTARIES OF SELECTED ESTUARIES IN SOUTHERN NEW JERSEY

By
R. Edward Hickman

ABSTRACT

This report presents the results of a study, done in cooperation with the New Jersey Department of Environmental Protection, to analyze the characteristics of stream discharge for tributaries of the estuaries of the Metedeconk, Toms, Great Egg Harbor, Tuckahoe, and Maurice Rivers. The following statistics were calculated for selected streamflow-gaging stations: (1) mean annual and mean monthly discharge, and (2) lowest annual 7-day mean discharge for selected recurrence intervals. Values of lowest annual 7-day mean discharge were calculated for the entire year and for the 3-, 4-, 5-, and 6-month periods of greatest tributary discharge. The monthly variation in discharge was examined. Values of discharge at different stations were converted to runoff and compared; runoff is expressed as discharge per unit area of drainage for a given period. Tests for trend were conducted on values of monthly discharge and lowest annual discharges at continuous-record stations. Statistics were determined from discharge records of the U.S. Geological Survey.

The monthly variation in discharge is similar for most streams in the study area; discharge is greatest during March and April and least during August, September, and October. The 3-, 4-, 5-, and 6-month periods of greatest discharge are February through April, January through April, January through May, and December through May, respectively.

Mean annual runoff is greater in the tributaries of the Metedeconk and Toms River estuaries than in the tributaries of the other estuaries. Runoff in tributaries of these two basins ranges from 24 to 29 inches per year; the corresponding range for tributaries of the other estuaries is 16 to 23 inches per year.

Trend analysis showed that values of lowest annual discharges at continuous-record stations on tributaries of all five estuaries decreased during water years 1970-89. For four stations, values of 183-day lowest annual discharge during the complete year decreased; for three stations, values of lowest annual 7- or 30-day mean discharge during the 3-, 4-, 5-, and 6-month periods of greatest discharge decreased. There were no trends in monthly discharge for water years 1970-89. For other periods tested, there were no trends either in lowest annual discharges or monthly discharges.

Discharge statistics at the heads of tide were calculated from the period-of-record characteristics at continuous-record stations and characteristics determined for partial-record stations. Results show that discharge at the heads of tide of the estuaries is directly related to the drainage area. Drainage areas and discharge are greatest for the Great Egg Harbor and Maurice Rivers, whose mean annual discharges are 340 and 310 cubic feet per second, respectively. Mean annual discharges of the Toms and Metedeconk Rivers are 220 and 140 cubic feet per second, respectively.

Drainage area and discharge of the Tuckahoe River are the smallest of the estuaries studied; mean annual discharge is 43.9 cubic feet per second.

INTRODUCTION

The water quality and ecology of any estuary are affected by its salinity which, in turn, is affected by the amount of freshwater entering the estuary. Reductions in freshwater discharge to the estuary could increase the salinity in the estuary and cause undesirable changes in estuarine water quality and ecology. As a result, a study of an estuary's water quality and ecology has to include an understanding of how the freshwater inflow varies over time.

Officials of the State of New Jersey are concerned about having enough water to meet the anticipated demand in southern New Jersey. Much of the water supply in this area is from ground-water withdrawals from deep aquifers, and rates of withdrawal from these aquifers are limited by the State to reduce the potential of saltwater intrusion. A description of the saltwater-intrusion problem in one of the counties in southern New Jersey is given in Gill (1962).

To meet the anticipated demand, the State is considering initiating new surface-water **diversions**[1] at sites on streams in the southern part of the state, and increasing an existing diversion from one of these streams. New diversions are being considered near the heads of tide of the Toms, Great Egg Harbor, Tuckahoe, and Maurice Rivers. Brick Township is planning to increase the rate of withdrawal from its existing diversion near the head of tide of the Metedeconk River. Officials also are assessing the potential impacts of varying the rate of diversion so that the maximum withdrawal occurs during the months of greatest streamflow. Each of the selected streams has an estuary as its most downstream reach.

This report presents the results of a statistical analysis of stream discharge in tributaries of the estuaries of the Metedeconk, Toms, Great Egg Harbor, Tuckahoe, and Maurice Rivers. These statistics describe the long-term variation of discharge over time at sites at which discharge has been measured. In addition, statistics were calculated for the heads of tide of the estuaries. The results can be used to help assess the impacts of freshwater diversions at the heads of tide and upstream, including effects on estuarine water quality and ecology.

The following statistics were determined for selected **streamflow-gaging stations** from records of the U.S. Geological Survey (USGS): (1) mean annual and mean monthly discharge, and (2) lowest 7-day mean discharge for selected **recurrence intervals**. Values of lowest 7-day mean discharge were determined for the complete year and for the 3-, 4-, 5-, and 6-month periods of greatest tributary discharge. The monthly variation of discharge was examined. A station-to-station comparison of discharge as **runoff** was made. An analysis for **trends** was done on (1) monthly discharge, (2) lowest annual discharge for complete years, and (3) lowest annual discharge during the 3-, 4-, 5-, and 6-month periods of greatest tributary discharge.

---

[1]Terms in bold are defined in the glossary.

Discharge statistics at the heads of tide of the estuaries were determined from the statistics at the streamflow-gaging stations. Statistics for the Metedeconk River estuary were determined at the location of the existing diversion.

DESCRIPTION OF STUDY AREA

The study area is in two parts. The northern part consists of the Metedeconk and Toms Rivers and their estuaries. The southern part consists of the Great Egg Harbor, Tuckahoe, and Maurice Rivers and their estuaries.

Estuaries of the Metedeconk and Toms Rivers

The estuaries of the Metedeconk and Toms Rivers are embayments in the Barnegat Bay estuary (fig. 1). For the purposes of this study, the Metedeconk and the Toms River estuaries are considered to extend from the mouths of the embayments to the heads of tide. The mouth of the Metedeconk River estuary designated in this report is different from that of Velnich (1984).

The North and South Branches of the Metedeconk River, which join just upstream from the head of tide, are the largest tributaries to the Metedeconk River estuary (fig. 1). The **drainage area** of the Metedeconk River at the head of tide is 88 percent of the drainage area of the estuary (table 1).

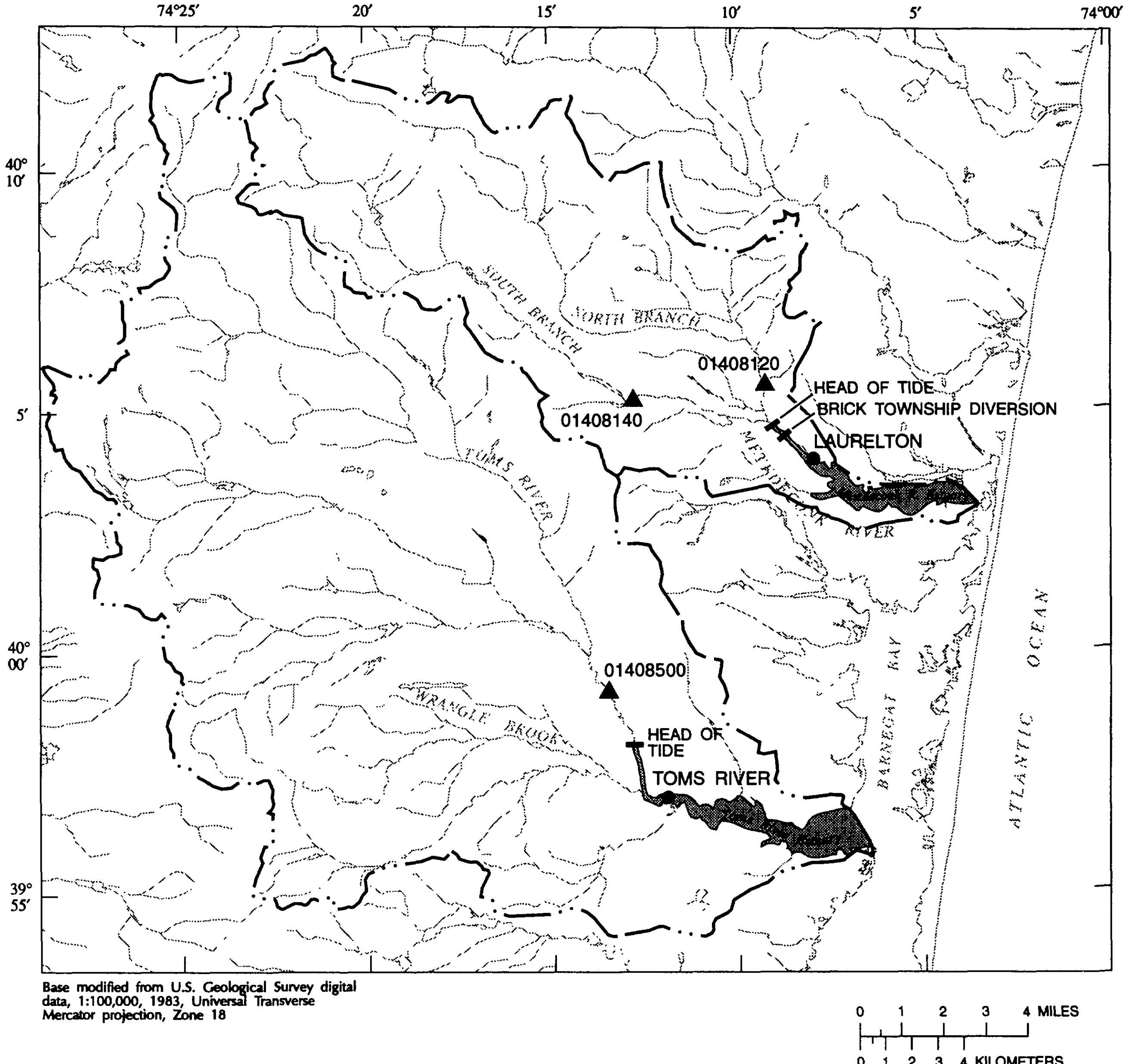
Records from two streamflow-gaging stations in the Metedeconk basin (fig. 1, table 2) were analyzed during this study. The combined drainage area of the two stations is 88 percent of the drainage area at the head of tide and 77 percent of that of the estuary (table 1). The point at which Brick Township is permitted to withdraw as much as 9.3 cubic feet per second is downstream from the head of tide. The drainage area at the diversion is only slightly different from that at the head of tide (table 1).

The largest tributary to the Toms River estuary is the Toms River (fig. 1). At the head of tide, the drainage area of the Toms River is 66 percent of the drainage area of the estuary (table 3). Discharge records were analyzed at one station just upstream from the head of tide (table 2). The drainage area of the basin associated with this station is 97 percent of the drainage area at the head of tide and 64 percent of the **drainage basin** of the estuary (table 3).

Estuaries of the Great Egg Harbor, Tuckahoe, and Maurice Rivers

The estuaries of the Great Egg Harbor, Tuckahoe, and Maurice Rivers are located near the southernmost part of the State (fig. 2). The estuaries of the Great Egg Harbor and Tuckahoe Rivers are tributary to Great Egg Harbor Bay, which discharges to the Atlantic Ocean.

The Great Egg Harbor River estuary extends from Great Egg Harbor Bay upstream to the head of tide at the outlet of Lake Lenape at Mays Landing. The drainage area at the head of tide is 59 percent of that to the mouth of the estuary (table 4).



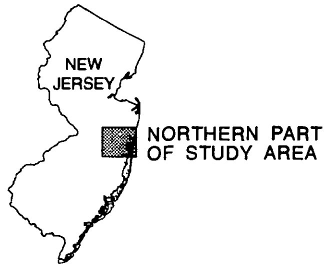


Figure 1.--Drainage basins of the estuaries of the Metedeconk and Toms Rivers.

Table 1.--Drainage areas of selected sites within the drainage basin of the Metedeconk River estuary

[Station names are given in table 2; drainage area is from Velnich (1984); NA, not applicable]

Site	Drainage area (square miles)	Percentage of total drainage area	
		To head of of tide	To mouth of estuary
Stations 01408120 and 01408140	60.9	88	77
Metedeconk River at head of tide[1/]	[3/]69.5	100	88
Metedeconk River at point of diversion by Brick Township	[3/]70.0	NA	88
Mouth of estuary[2/]	[3/]79.3	NA	100

[1/]Location of head of tide is from New Jersey State tidelands maps.

[2/]Designation of mouth of estuary is different from that in Velnich (1984). Mouth of estuary is same as mouth of river.

[3/]Determined from 1:24,000-scale topographic maps by use of a planimeter.

Table 2.--Selected streamflow-gaging stations in the drainage basins of the estuaries of the Metedeconk and Toms Rivers

[Station number is U.S. Geological Survey station number; station name is U.S. Geological Survey station name; Cont., continuous record]

Basin	Station number	Station name	Drainage area (square miles)	Type of record	Period of record (water years)
Metedeconk River estuary	01408120	North Branch Metedeconk River near Lakewood, N.J.	34.9	Cont.	1973-89
	01408140	South Branch Metedeconk River at Lakewood, N.J.	26.0	Cont.	1973-76
Toms River estuary	01408500	Toms River near Toms River, N.J.	123	Cont.	1929-89

Table 3.--Drainage areas of selected sites within the drainage basin of the Toms River estuary

[Station name is given in table 2; drainage area is from Velnich (1984); NA, not applicable]

Site	Drainage area (square miles)	Percentage of total drainage area	
		To head of tide	To mouth of estuary
Station 01408500	123	97	64
Toms River at head of tide[1]	[2]127	100	66
Mouth of estuary	192	NA	100

[1]Location of head of tide is from New Jersey State tidelands maps.

[2]Determined from 1:24,000-scale topographic maps by use of a planimeter.

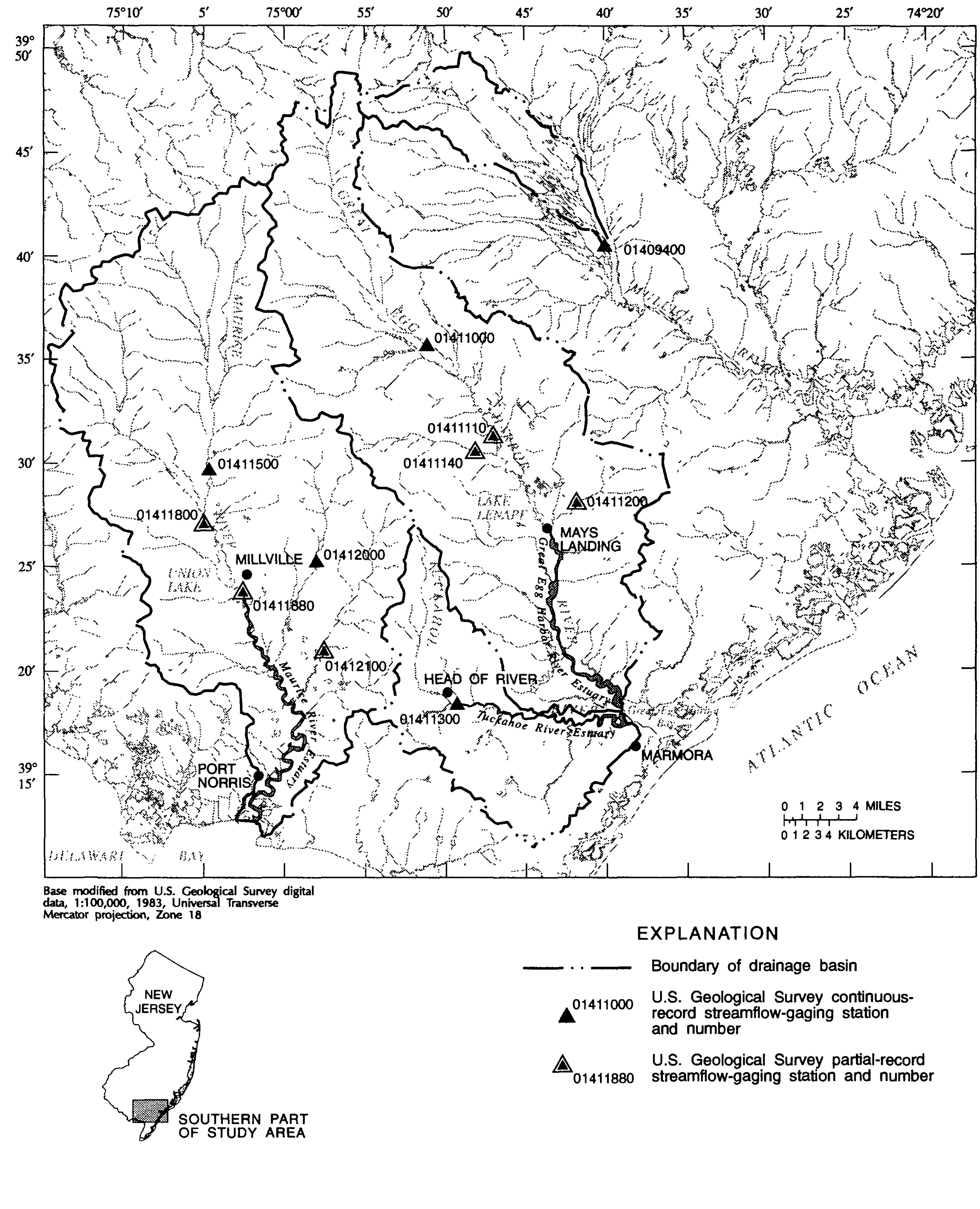


Figure 2.--Drainage basins of the estuaries of the Great Egg Harbor, Tuckahoe, and Maurice Rivers and part of the drainage basin of the Mullica River.

Table 4.--Drainage areas of selected sites within the drainage basin of Great Egg Harbor River estuary

[Station name is given in table 5; drainage area is from Velnich (1984); NA, not applicable]

Site	Drainage area (square miles)	Percentage of total drainage area: To head of tide	Percentage of total drainage area: To mouth of estuary
Stations 01411110 and 01411140 [1/]	174	85	50
Head of tide of at outlet at Lake Lenape at Mays Landing	205	100	59
Mouth of estuary	347	NA	100

[1/] Stations farthest downstream.

The records of four stations in this basin were analyzed (fig. 2, table 5). Combined, the drainage areas of the two stations farthest downstream comprise 85 percent and 50 percent, respectively, of the drainage areas at the head of tide and the mouth.

The Tuckahoe River estuary extends from Great Egg Harbor Bay upstream to the head of tide at Head of River (fig. 2). The drainage area at the head of tide is 30 percent of that to the mouth of the estuary (table 6). Discharge records were analyzed for the station at the head of tide (table 5).

The Maurice River estuary extends from Delaware Bay upstream to the head of tide at the outlet of Union Lake at Millville (fig. 2). The Maurice River is the largest tributary to the estuary; its drainage area at head of tide is 56 percent of the estuary drainage basin (table 7). Discharge records of five streamflow-gaging stations were analyzed (fig. 2, table 8); one of the stations is just downstream from the head of tide at the Sharp Street Bridge in Millville.

METHODS OF DATA ANALYSIS

Different methods were used to calculate discharge statistics at **continuous-record stations**, **partial-record stations,** and the heads of tide. The methods differed because the types and amounts of discharge data were different for each type of site.

Analysis of Discharge at Streamflow-Gaging Stations

The continuous-record and partial-record stations mentioned in this report are those that were deemed to provide the best information on water discharge at the heads of tide of the five estuaries. Generally, they are the stations farthest downstream on major tributaries near the heads of the estuaries. Standard USGS methods to measure streamflow are given in Rantz and others (1982) and Carter and Davidian (1968).

Continuous-record station 01408120, South Branch Metedeconk River at Lakewood, was analyzed as a partial-record station because only 4 years of continuous record had been collected at the time of analysis. A record of this length is not representative of long-term conditions.

Continuous-Record Stations

Records of daily mean discharge through the 1989 **water year** were used to calculate (1) mean annual and mean monthly discharges, (2) lowest annual 7-, 30-, 90-, and 183-day mean discharge for selected recurrence intervals, (3) trends in monthly discharge, (4) trends in lowest 7-, 30-, 90-, and 183-day mean discharges that occur during a complete year, and (5) trends in lowest 7-, 30-, and 90-day mean discharges that occur during the 3-, 4-, 5-, and 6-month partial year periods during which, on average, the discharge is greatest. These 3- to 6-month periods were selected from an examination of the data for the period of record.

Table 5.--Selected streamflow-gaging stations in the drainage basins of the Mullica River and the estuaries of the Great Egg Harbor and Tuckahoe Rivers

[Station number is U.S. Geological Survey station number; station name is U.S. Geological Survey station name; Cont., continuous record; Part., partial record]

Basin	Station number	Station name	Drainage area (square miles)	Type of record	Period of record (water years)
Mullica River	01409400	Mullica River near Batsto, N.J.	[1]46.7	Cont.	1958-89
Great Egg Harbor River estuary	01411000	Great Egg Harbor River at Folsom, N.J.	57.1	Cont.	1927-89
	01411110	Great Egg Harbor River at Weymouth, N.J.	154	Part.	1977-87
	01411140	Deep Run at Weymouth, N.J.	20.0	Part.	1976-86
	01411200	Babcock Creek at Mays Landing, N.J.	20.0	Part.	1959-63
Tuckahoe River estuary	01411300	Tuckahoe River at Head of River, N.J.	30.8	Cont.	1971-89

[1] Diversions from Sleeper River enter river upstream of station; the drainage area of the Sleeper River is not included in this value.

Table 6.--Drainage areas of selected sites within the drainage basin of Tuckahoe River estuary

[Station name is given in table 5; drainage area is from Velnich (1984); NA, not applicable]

Site	Drainage area (square miles)	Percentage of total drainage area: To head of tide	Percentage of total drainage area: To mouth of estuary
Station 01411300 at head of tide at Head of River	30.8	100	30
Mouth of estuary	102	NA	100

Table 7.--Drainage areas of selected sites within the drainage basin of the Maurice River estuary

[Station names are given in table 8; drainage area is from Velnich (1982); NA, not applicable]

Site	Drainage area (square miles)	Percentage of total drainage area	
		To head of tide	To mouth of estuary
Station 01411800[1/]	191	88	50
Maurice River at head of tide at outlet of Union Lake	216	100	56
Station 01411880 just below head of tide	216	100	56
Mouth of estuary	382	NA	100

[1/] Station farthest downstream on Maurice River upstream of head of tide.

Table 8.--Selected streamflow-gaging stations in the drainage basin of the Maurice River estuary

[Station number is U.S. Geological Survey station number; station name is U.S. Geological Survey station name; Cont., continuous record; Part., partial record]

Station number	Station name	Drainage area (square miles)	Type of record	Period of record (water years)
01411500	Maurice River at Norma, N.J.	112	Cont.	1933-89
01411800	Maurice River near Millville, N.J.	191	Part.	1966-71
01411880	Maurice River at Sharp St. at Millville, New Jersey; below outlet of Union Lake	216	Part.	1973-89
01412000	Menantico Creek near Millville, N.J.	22.3	Cont.	1932-57, 1978-84
01412100	Manumuskin River near Manumuskin, N.J.	32.1	Part.	1964-71

For each given duration (7, 30, 90, and 183 days) and recurrence interval, the value of lowest annual discharge is the mean discharge over the duration which, on average during a large number of years, will not be exceeded more often than the indicated recurrence interval. Recurrence intervals of 2, 5, 10, 20, and 50 years were selected. Values for the entire year were calculated for **climatic years** rather than for water years. Values calculated for water years are greater than actual values for durations of 90 and 183 days because the lowest discharges usually occur at the beginning and end of a water year.

Relations between lowest annual discharge and recurrence interval were developed for each station and duration and for the entire year and each partial-year period. The base-10 logarithms of each year's lowest annual discharge were plotted against recurrence interval, and a log-Pearson III curve was fit to the data. The recurrence interval for each value of lowest annual discharge was calculated by means of the following equation:

$$RI = (n+1)/m, \qquad (1)$$

where RI is recurrence interval, in years;
n is number of values of lowest annual discharge; and
m is rank of value, from smallest to largest.

Values of lowest annual discharge were calculated for recurrence intervals up to twice the length of the period of record of the data. These techniques are discussed in Riggs (1968, 1972) and in Dempster (1984). An example of a log-Pearson III curve and the data from which it was calculated are shown in figure 3.

Trends in monthly discharge and in lowest annual discharge were identified by means of the Seasonal Kendall test (Hirsch and others, 1982; Hirsch and Slack, 1984). Tests were done on monthly discharge throughout the year and on monthly discharge and lowest annual discharge during the winter-spring periods of greatest discharge; periods tested were the periods of record and water years 1970-89 and 1980-89. Trend tests on lowest annual discharges during complete years were done on climatic years that approximated the same periods; results for the climatic-year periods were assumed to be representative of the water-year periods. Trends are reported only if the level of significance of the trend is 0.05 or less. For periods of more than 10 years, the level of significance of the trend was adjusted for serial correlation in the data. A **trend slope** and the 95-percent **confidence interval** for the trend slope are reported for each significant trend. The confidence interval was calculated according to the methods of Hollander and Wolfe (1973, p. 207-8). Monthly discharge data were analyzed for trends by considering each month as a season. Data for station 01412000, Menantico Creek near Millville, were not analyzed for trends because of the large amount of missing data.

Partial-Record Stations

For each partial-record station, (1) mean annual and monthly discharge and (2) lowest annual 7-day mean discharge for selected recurrence intervals were calculated. Relations between discharge at the partial-record station and discharge at an "index" continuous-record station were used to calculate

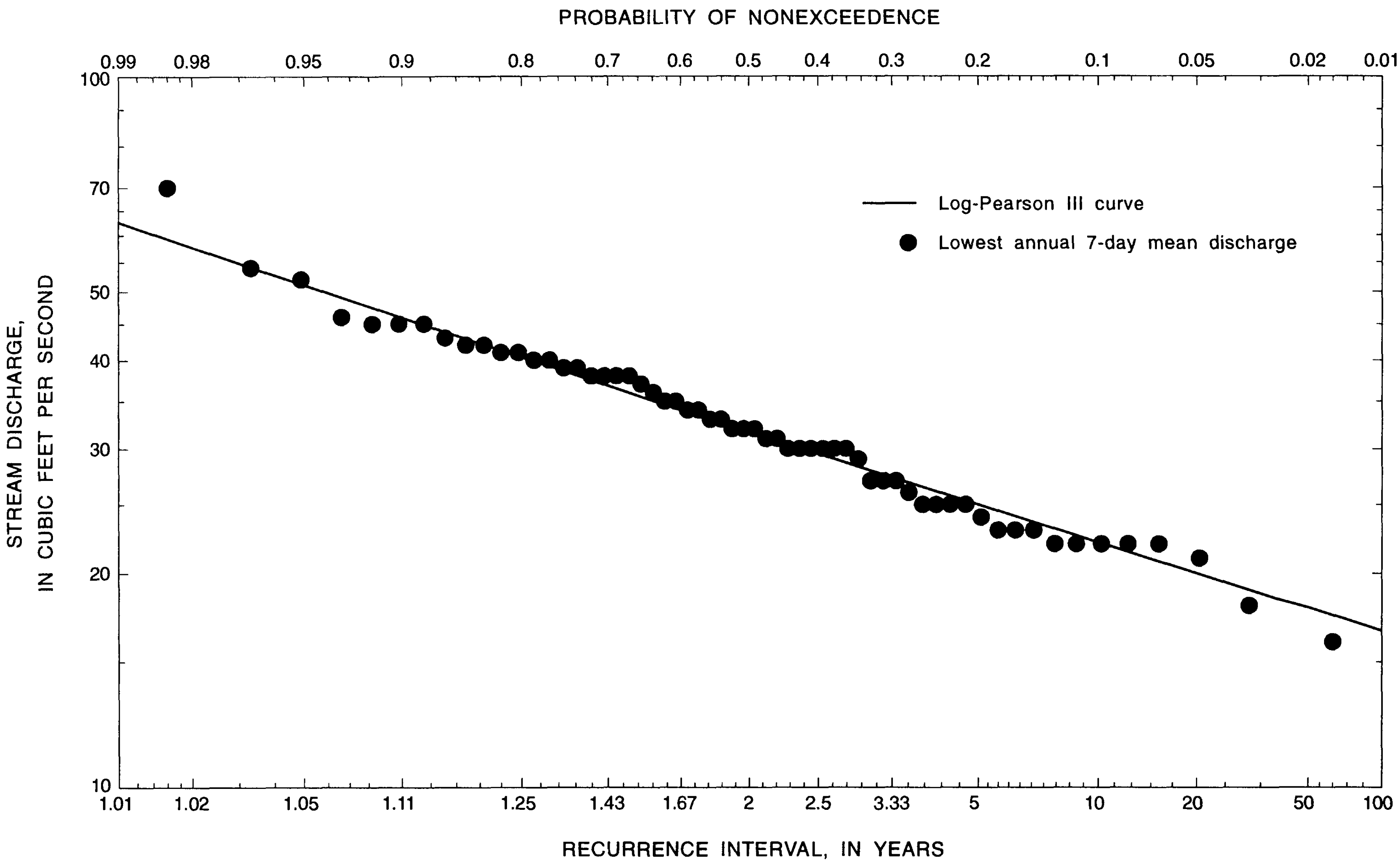


Figure 3.--Log-Pearson III curve and data for the lowest annual 7-day mean discharge at station 01411000, Great Egg Harbor River at Folsom, New Jersey, as a function of recurrence interval. (Data are for complete years, April 1926 through March 1989.)

the statistics at the partial-record stations. For stations in the basins of the estuaries of the Great Egg Harbor and Maurice Rivers, separate relations were developed with each of the following index stations: 01409400, Mullica River at Batsto; 01411000, Great Egg Harbor River at Folsom; and 01411500, Maurice River at Norma. For station 01408140, South Branch Metedeconk River at Lakewood, separate relations were developed with stations 01408120, North Branch Metedeconk River near Lakewood, and 01408500, Toms River near Toms River.

Relations were developed by use of the MOVE.1 technique (Hirsch, 1982) and are of the following form:

$$\frac{LQ_{PR} - u_{PR}}{S_{PR}} = \frac{LQ_{CR} - u_{CR}}{S_{CR}}, \qquad (2)$$

where LQ_{PR} is the base-10 logarithm of the partial-record discharge,
u_{PR} is the mean of the logarithms of partial-record discharge,
S_{PR} is the standard deviation of logarithms of partial-record discharge,
LQ_{CR} is the base-10 logarithm of the index continuous-record discharge,
u_{CR} is the mean of the logarithms of the index continuous-record discharges, and
S_{CR} is the standard deviation of logarithms of the index continuous-record discharge.

An example of one relation and the data from which it was calculated is shown in figure 4.

For all stations except 01408140, South Branch Metedeconk River at Lakewood, measurements of **base flow** were used to develop discharge relations. Use of base-flow measurements minimized the errors due to storms on the day of the partial-record measurement but before or after the time of measurement. For the purposes of this report, base-flow data were defined on the basis of the daily discharges at the "index" continuous-record station; discharge on a given day was considered base flow if between 85 and 105 percent, inclusive, of the previous day's discharge.

For station 01408140, South Branch Metedeconk River at Lakewood, two types of discharge relations were developed. The relations based on monthly discharges were used to estimate mean monthly and mean annual discharge. The relations based on daily discharge were used to estimate lowest annual 7-day mean discharges.

Discharge statistics at the partial-record stations were calculated from the discharge relations that showed the best agreement between the MOVE.1 curve and data. These relations were selected on the basis of (1) a visual examination of the relation shown by the data, (2) the correlation coefficient of the discharge data, and (3) comparison of discharge statistics with those calculated from relations with other index stations. For each selected relation, discharge at the partial-record station was

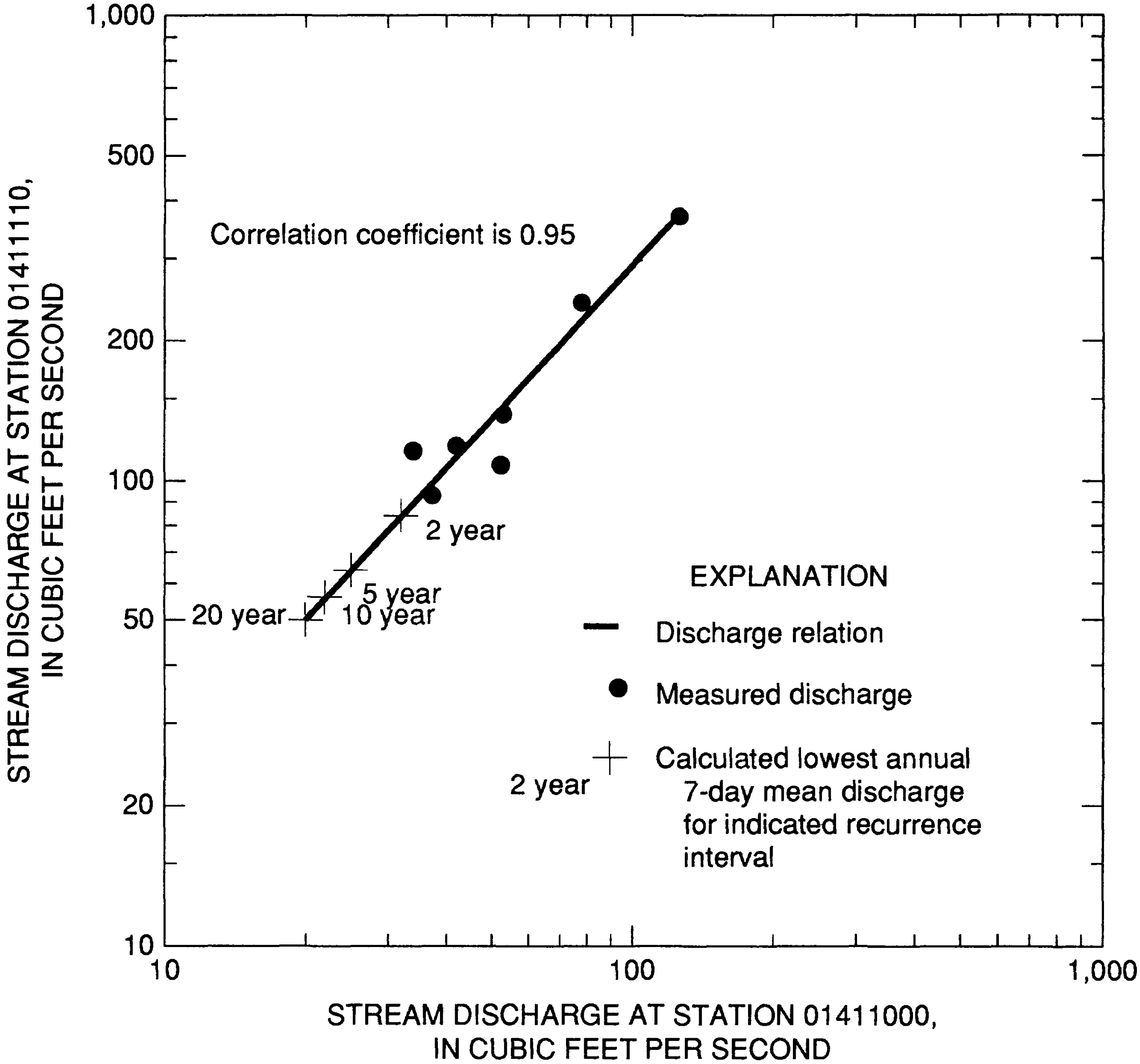


Figure 4.--Relation between base flow at partial-record station 01411110, Great Egg Harbor River at Weymouth, New Jersey, and at continuous-record station 01411000, Great Egg Harbor River at Folsom, New Jersey.

calculated from the corresponding value at the index station. For stations for which more than one relation was selected, values for each statistic were averaged. Discharge statistics at the partial-record stations were rounded to two significant figures.

Analysis of Discharge at Heads of Tide

Discharge statistics at the heads of tide were determined from the discharge statistics at selected upstream streamflow gaging stations. For each discharge statistic, the value for the head of tide was calculated by first summing the values for the stations. Then the sum is adjusted to account for discharge from areas not represented by streamflow gaging stations. For example, mean annual discharge at the head of tide is calculated with the following equation:

$$M_{Head} = M_G * ((A_{Head})/(A_G)) \qquad (3)$$

where M_{Head} is mean annual discharge at the head of tide,
M_G is the sum of mean annual discharges at selected upstream streamflow gaging stations,
A_{Head} is the drainage area of the head of tide, and
A_G is the sum of the drainage areas of the selected upstream streamflow gaging stations.

For each head of tide, the stations selected were those at which discharge statistics, converted to runoff, appeared to be applicable to areas not represented by a streamflow gaging station. This judgement was made on the basis of comparing discharge statistics, converted to runoff, of stations in and near the drainage basin in the estuary.

STATISTICAL CHARACTERISTICS OF STREAM DISCHARGE

Presented in this section are statistics that describe the long-term variation over time of streamflow discharge in major tributaries to the selected estuaries. Statistics include mean annual discharge, mean monthly discharge by month, and lowest 7-day mean discharge for the complete year and for the 3-, 4-, 5-, and 6-month periods of greatest discharge. Values of lowest 7-day mean discharge are given for selected recurrence intervals.

Discharge at Streamflow-Gaging Stations

Statistics of discharge at continuous-record and partial-record streamflow-gaging stations are listed in Appendixes A and B, respectively. Values of lowest annual discharges generally are similar to those reported in Gillespie and Schopp (1982); differences can be attributed to longer periods of record available for this study and, for partial-record stations, selection of different index stations. The values of lowest annual 7-day mean discharge for 2- and 10-year recurrence intervals at station 01408140, South Branch Metedeconk River at Lakewood, differ most; the statistics reported herein supercede those in Gillespie and Schopp (1982) for this station.

Monthly Variation

The monthly variation in discharge is similar for tributaries of all of the estuaries; mean monthly discharge is greatest during March and April and least in August, September, and October (fig. 5). The monthly variation in the ratio of mean monthly discharge to mean annual discharge is nearly identical for stations 01408500, Toms River near Toms River; 01411000, Great Egg Harbor at Folsom; and 01411500, Maurice River at Norma. The ratios for 01408140, North Branch Metedeconk River near Lakewood, and 01411300, Tuckahoe River at Head of River, do not agree as well with the other stations, possibly because of the shorter period of record and smaller drainage basins for these two stations.

The 3-, 5-, and 6-month periods of greatest discharge are, February through April, January through May, and December through May, respectively. The 4-month period for some streams was January through April and for others it was February through May, but the difference in mean discharge for the two periods was less than 3 percent. For example, the mean discharge for station 01408120, North Branch Metedeconk River near Lakewood, for the periods, January through April and February through May, are 81.2 and 79.0 cubic feet per second, respectively. For this paper, the 4-month period of greatest flow for all streams is assumed to be January through April.

The accuracy of the discharge statistics in describing the variation of tributary flow in the past is, in general, much better for the continuous-record stations than for the partial-record stations. The magnitudes of errors are illustrated by the results of Gillespie and Schopp (1982), who analyzed the errors of calculating the lowest annual 7-day mean discharge for a 10-year recurrence interval; the mean error for 15 partial-record stations was 56 percent, and the corresponding value for 36 continuous-record stations was 12 percent.

Much of the error associated with statistics for partial-record stations is related to the assumption that the discharge relation from the MOVE.1 method (Hirsch, 1982) accurately represents the relation between discharge at the partial-record and index stations. For some stations, it was necessary to make the additional assumption that the curve was valid at discharges smaller than those from which it was calculated (see fig. 4). For each relation used to calculate the discharge statistics at the partial-record stations, values of the correlation coefficient and the range of partial-record discharges are listed in Appendix B.

For all streamflow-gaging stations, the accuracy of the discharge statistics in describing future conditions depends on whether basin and weather characteristics remain unchanged. Changes in either could invalidate the values in this report as being representative of future conditions. Examples of basin characteristics include point-source discharges, diversions, basin-surface cover, and ground-water levels; examples of weather characteristics include air temperature and amount and intensity of precipitation. Changes in weather patterns during a short period could represent the natural year-to-year variation; changes in weather over a long-term period would constitute a change in climate.

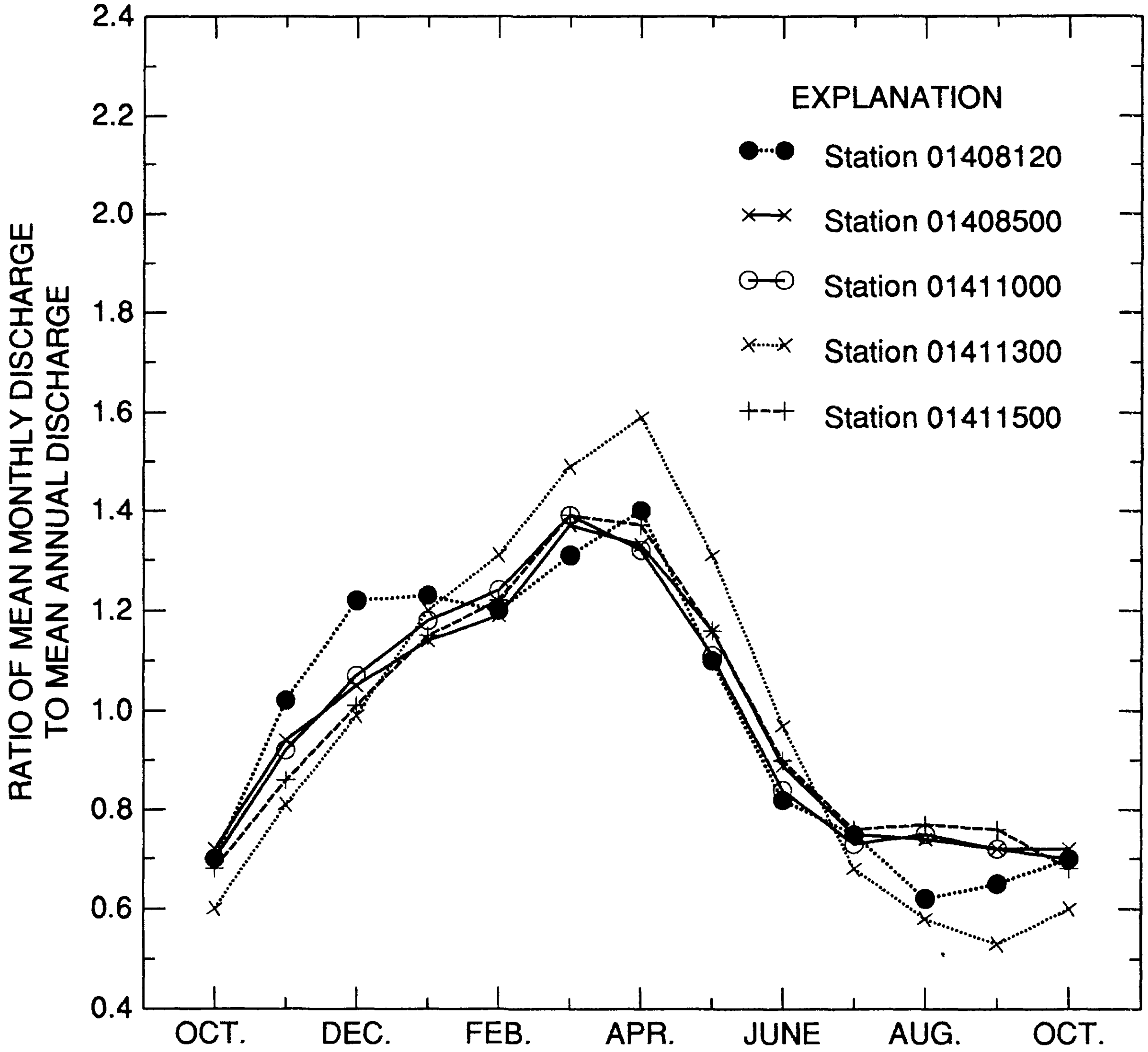


Figure 5.--Monthly variation in ratio of mean monthly discharge to mean annual discharge at selected continuous-record streamflow-gaging stations.

Temporal trends

Trends in discharge over a long period can be used to identify basins in which basin and (or) weather characteristics were changing during the period that the data were collected. It is important to note that trends in discharge in the past may or may not continue into the future. If such trends do continue, the discharge statistics calculated from data for the past will not be representative of the future.

Lowest annual discharges for specific recurrence intervals were tested for trends to identify changes in weather and (or) basin characteristics that occurred during periods when discharge was least. Such changes may not be identified by analyses of trends in year-round monthly data. For example, lowest annual 7-day and 30-day mean discharges are more likely to represent discharge made up entirely or almost entirely of base flow than are monthly discharges. As a result, an analysis of these lowest annual discharges is more likely to identify the effects of small changes in characteristics that affect base flow than is an analysis of monthly discharges.

Trends in either monthly discharge or lowest annual discharge were not apparent for any station during the period of record or water years 1980-89. For water years 1970-89, decreases in lowest annual discharges were noted for tributaries of all estuaries. Trends in lowest annual 183-day mean discharge for complete years, April 1, 1969, through March 31, 1989 (table 9), were apparent for four stations. These trends indicate decreasing discharge during summer and fall, the seasons of lowest discharge (see fig. 5). As an example, the trend for station 01411000, Great Egg Harbor River at Folsom, is shown in figure 6. Trends in lowest annual 7- or 30-day discharge during the winter-spring periods of greatest discharge were apparent for three stations (table 10); these trends indicate decreasing base flow. No trends were found in monthly discharge during water years 1970-89.

Trend slopes in tables 9 and 10 are considered approximate. The 95-percent confidence intervals for the trend slopes are wide and reflect the large amount of scatter in the data around the calculated trend slope; an example of the scatter is shown in figure 6.

The results of the trend tests indicate that there is no reason to doubt that the discharge statistics for the continuous-record stations are representative of future conditions. No changes are indicated in either weather or basin characteristics for more than 20 years; no trend for any station was found in period-of-record data longer than 20 years. The 20-year trends that were identified could be due to the natural year-to-year variation in weather. The existence of trends in more than one basin during the same 20-year period suggests that these trends were caused by changes in weather characteristics.

Station-to-Station Differences

The expression of discharge as runoff permits station-to-station comparison of characteristics, other than basin size, that determine discharge. Mean annual runoff at stations in the Metedeconk and Toms River

Table 9.--Results of trend tests of lowest annual 183-day mean discharge for complete years, April 1, 1969, through March 31, 1989

[Trend slope is in cubic feet per second per year; unless noted, reported trends are significant at the 0.05 level; data for station 01412000 were not analyzed for trends]

Station number	Station name	Trend slope	95-percent confidence interval of trend slope: Lower limit	Upper limit
01408120 [1/]	North Branch Metedeconk near Lakewood	No trend		
01408500	Toms River near Toms River	-4.4	-8.0	-1.2
01411000	Great Egg Harbor River at Folsom	-1.5	-3.0	- .1
01411300 [2/]	Tuckahoe River at Head of River	- .4	-1.6	.0
01411500 [3/]	Maurice River at Norma	-2.5	-6.3	.0

1/ Period of data tested is from April 1, 1973 through March 31, 1989.

2/ Period of data tested is from April 1, 1970 through March 31, 1989.

3/ Level of significance is 0.051.

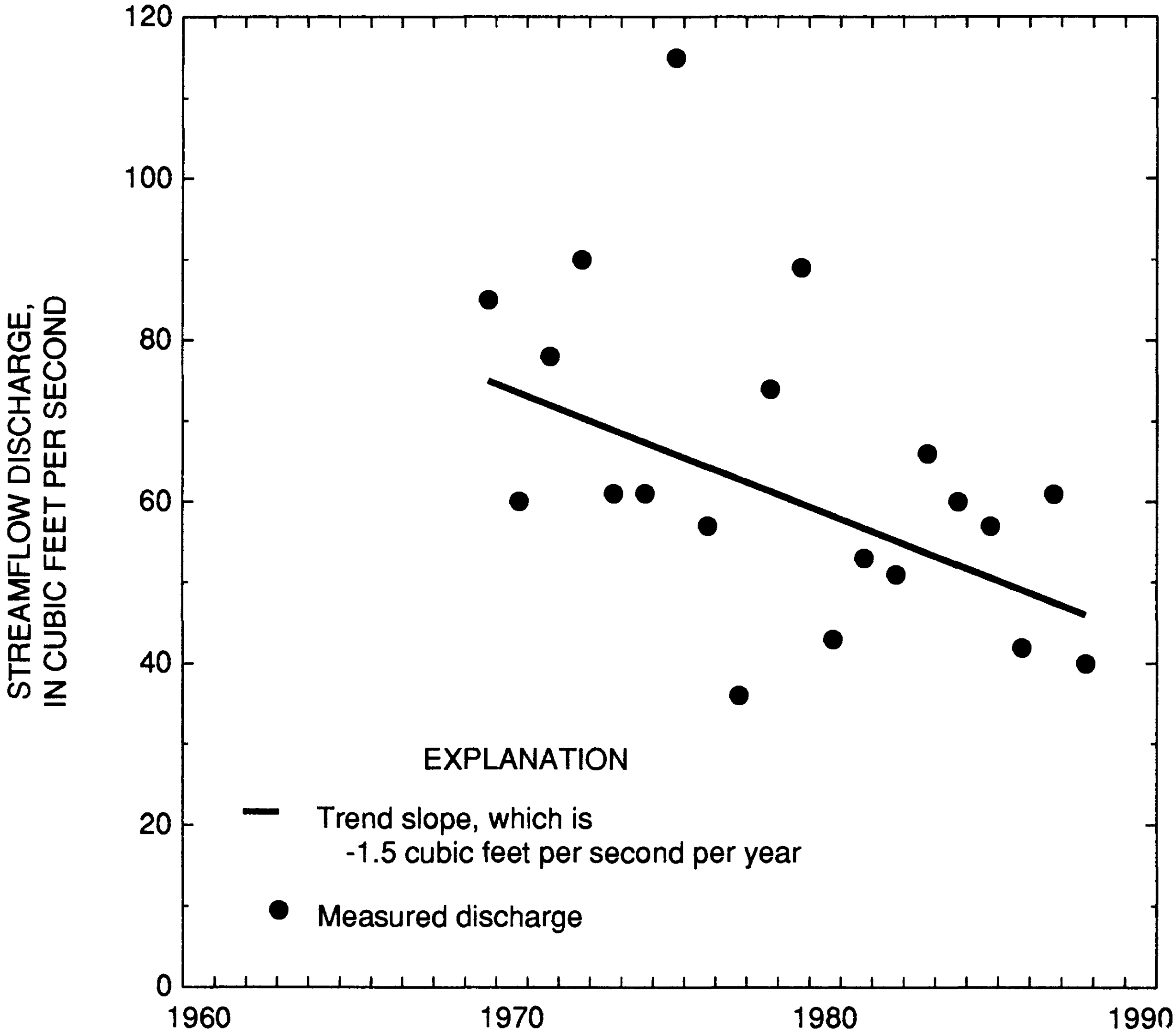


Figure 6.--Discharge data and trend for lowest annual 183-day mean discharge at station 01411000, Great Egg Harbor River at Folsom, New Jersey, April 1, 1969 through March 31, 1989. (Data are for complete years.)

Table 10.--Results of trend tests on lowest annual discharges during the winter-spring periods of greatest discharge, water years 1970-89

[Durations tested were 7, 30, and 90 days; trend slope is in cubic feet per second per year; only trends significant at the 0.05 level are reported; data for station 01412000 were not analyzed for trends]

Station number	Station name	Part of year for which data were included in test	Duration, in consecutive days	Trend slope	95-percent confidence interval of trend slope: Lower limit	95-percent confidence interval of trend slope: Upper limit
01408120[1]	North Branch Metedeconk near Lakewood	Jan.-Apr.	7	-1.2	-2.8	0.0
01408500	Toms River near Toms River	Feb.-Apr.	7	-4.4	-8.8	.0
			30	-5.0	-9.6	- .5
		Jan.-Apr.	7	-4.1	-8.3	- .5
			30	-4.4	-10.0	- .1
			90	-5.9	-12.3	- .3
		Jan.-May	7	-3.3	-7.3	- .5
			30	-4.0	-9.8	- .6
		Dec.-May	30	-4.5	-10.1	-1.0
01411000	Great Egg Harbor River at Folsom	Jan.-Apr.	7	-1.3	-2.2	.0
		Jan.-May	7	-1.2	-2.5	.0
01411300[2]	Tuckahoe River at Head of River			No trends		
01411500	Maurice River at Norma			No trends		

[1] Period is water years 1973-89.

[2] Period is water years 1971-89.

basins is greater than at stations in the basins of the other three estuaries (table 11). The range of mean annual runoff at the three stations in the Metedeconk and Toms River basins is 24 to 29 inches per year; the corresponding range for stations in the other basins is 16 to 23 inches per year.

Runoff values indicate that past basin characteristics of the South Branch Metedeconk River were different from those of the adjacent basins of the North Branch Metedeconk and Toms Rivers. During water years 1973-76, runoff from the South Branch Metedeconk River was 20 percent greater than that from either the North Branch Metedeconk River or Toms River (table 12).

Values of runoff at most stations in the basins of Great Egg Harbor, Tuckahoe, and Maurice River estuaries are similar (table 11). Mean annual runoff at 8 of 10 stations ranges from 19 to 23 inches. At 6 of 10 stations, the lowest annual 7-day mean runoff for 2-, 5-, 10-, and 20-year recurrences intervals, respectively, fall within the ranges of 0.13 to 0.16, 0.096 to 0.11, 0.080 to 0.10, and 0.069 to 0.092 inches per 7 days.

Discharge at Heads of Tide

The accuracy of the discharge statistics at the heads of tide is a function of (1) the accuracy of the statistics at the selected streamflow-gaging stations from which the statistics at the head of tide are calculated and (2) how well the basin characteristics of the drainage area contributing to ungaged runoff are represented by the characteristics of the drainage basins contributing to the stations. In general, the discharge statistics are likely to be most accurate if calculated from statistics at continuous-record stations rather than at partial-record stations; furthermore, the accuracy of the statistics tends to increase as the ratio of drainage areas of the stations to drainage area of the head of tide increases.

Discharge statistics for the heads of tide of the estuaries of the Metedeconk, Toms, and Great Egg Harbor Rivers were calculated from statistics at selected upstream streamflow-gaging stations and are listed in tables 13, 14, and 15, respectively. For each table, the form of equation 3 used to calculate the discharge characteristics is given in the footnotes. Characteristics for the Tuckahoe River at the head of tide are those for station 01411300, Tuckahoe River at Head of River (App. A).

Two sets of discharge statistics for the head of tide of the Maurice River were calculated. The first set consists of the values for station 01411880, Maurice River at Sharp Street at Millville (App. B). A second set was calculated from the statistics for upstream station 01411800, Maurice River near Millville (table 16).

The two sets of values for the mean annual and monthly discharges agree closely, but agreement for the values of lowest annual discharge is poorer. Values of mean annual and mean monthly values are within 10 percert of one another; errors in values of lowest annual discharge are as much as 50 percent. Values of lowest annual discharges calculated from statistics for station 01411880 (App. B) are about 30 cubic feet per second greater than the values calculated from statistics for station 01411800 (table 13). This difference could be the result of errors in the methods or of

Table 11.--Mean annual runoff and lowest annual 7-day mean runoff at streamflow-gaging stations

[C, continuous record; P, partial record; mean annual runoff is in inches per year; lowest annual 7-day mean runoff is in inches per 7 days; recurrence interval is in years]

Station number	Station name	Type of record	Mean annual runoff	Lowest annual 7-day mean runoff for given recurrence interval 2	5	10	20
	METEDECONK RIVER ESTUARY BASIN						
01408120	North Branch Metedeconk near Lakewood	C	24	0.15	0.11	0.088	0.086
01408140	South Branch Metedeconk at Lakewood	C	29	.18	.14	.12	.11
	TOMS RIVER ESTUARY BASIN						
01408500	Toms River near Toms River	C	24	.18	.15	.13	.12
	GREAT EGG HARBOR RIVER ESTUARY BASIN						
01411000	Great Egg Harbor River at Folsom	C	21	.16	.11	.10	.092
01411110	Great Egg Harbor River at Weymouth	P	23	.13	.096	.080	.069
01411140	Deep Run at Weymouth	P	22	.14	.10	.088	.078
01411200	Babcock Creek at Mays Landing	P	16	.067	.044	.036	.031
	TUCKAHOE RIVER ESTUARY BASIN						
01411300	Tuckahoe River at Head of River	C	19	.10	.082	.075	.067

Table 11.--Mean annual runoff and lowest annual 7-day mean runoff at streamflow-gaging stations--continued

[C, continuous record; P, partial record; mean annual runoff is in inches per year; lowest annual 7-day mean is in inches per 7 days; recurrence interval is in years]

Station number	Station name	Type of record	Mean annual runoff	Lowest annual 7-day mean runoff as given recurrence interval 2	5	10	20
	MAURICE RIVER ESTUARY BASIN						
01411500	Maurice River at Norma	C	20	0.14	0.10	0.088	0.077
01411800	Maurice River near Millville	P	20	.13	.098	.084	.075
01411880	Maurice River at Millville	P	19	.17	.13	.12	.11
01412000	Menantico Creek near Millville	C	23	.15	.10	.084	.071
01412100	Manumuskin River near Manumuskin	P	16	.11	.080	.071	.061

Table 12.--Mean annual runoff at continuous-record streamflow-gaging stations in the basins of the Metedeconk and Toms Rivers, water years 1973-76

[Runoff is in inches per year]

Station number	Station name	Mean annual runoff
01408120	North Branch Metedeconk River near Lakewood	27.2
01408140	South Branch Metedeconk River at Lakewood	32.5
01408500	Toms River near Toms River	26.5

Table 13.--Discharge statistics for the Metedeconk River at the Brick Township diversion[1]

[Discharge is in cubic feet per second; Ann., annual; recurrence interval is in years]

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
140	100	140	160	160	160	180	190	150	110	100	90	91

Lowest annual 7-day mean discharge for selected recurrence intervals

	Lowest annual 7-day mean discharge for selected parts of year				
Recurrence interval	Complete year	February-April	January-April	January-May	December-May
2	44	95	90	78	76
5	33	75	68	61	59
10	29	66	59	51	49
20	26	59	52	46	45

[1] Values were calculated by means of the following equation:

$$Q_{Div} = ((A_{Div})/(A_{01408120} + A_{01408140}))*(Q_{01408120} + Q_{01408140})$$

where A_{Div} is drainage area at Brick Township Diversion,

$A_{01408120}$ is drainage area at station 01408120,

$A_{01408140}$ is drainage area at station 01408140,

Q_{Div} is discharge at Brick Township diversion,

$Q_{01408120}$ is discharge at station 01408120 (App. A), and

$Q_{01408140}$ is discharge at station 01408140 (App. B).

Table 14.--Discharge statistics for the Toms River at the head of tide[1]

[Discharge is in cubic feet per second; Ann., annual; recurrence interval is in years]

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
220	160	210	230	250	260	300	290	260	200	170	160	160

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge for selected parts of year				
	Complete year	February-April	January-April	January-May	December-May
2	88	180	170	160	150
5	72	150	140	130	120
10	65	140	120	110	110
20	60	120	110	100	100

[1] Values were calculated with the following equation:

$$Q_{Head} = (A_{Head}/A_{01408500})*(Q_{01408500})$$

where A_{Head} is drainage area at the head of tide,

$A_{01408500}$ is drainage area at station 01408500,

Q is discharge at the head of tide, and

$Q_{01408500}$ is discharge at station 01408500 (App. A).

Table 15.--Discharge statistics for the Great Egg Harbor River at the head of tide at the outlet of Lake Lenape[1]

[Discharge is in cubic feet per second; Ann., annual; recurrence interval is in years]

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
340	230	300	360	410	440	490	480	400	300	250	250	250

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge for selected parts of year				
	Complete year	February-April	January-April	January-May	December-May
2	110	290	260	230	210
5	84	220	190	180	160
10	72	190	170	150	140
20	63	160	150	130	120

[1] Values were calculated with the following equation:

$$Q_{Head} = ((A_{Head})/(A_{01411110} + A_{01411140}))*(Q_{01411110} + Q_{01411140})$$

where A_{Head} is drainage area at head of tide,

$A_{01411110}$ is drainage area of station 01411110,

$A_{01411140}$ is drainage area of station 01411140,

Q_{Head} is discharge at head of tide,

$Q_{01411110}$ is discharge at station 01411110 (App. B), and

$Q_{01411140}$ is discharge at station 01411140 (App. B).

Table 16.--Discharge statistics for the Maurice River at the head of tide at the outlet of Union Lake, calculated from discharge statistics at station 01411800, Maurice River near Millville, New Jersey[1]

[Discharge is in cubic feet per second; Ann., annual; recurrence interval is in years]

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
320	210	280	330	370	380	440	430	360	270	230	240	230

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge for selected parts of year: Complete year	February-April	January-April	January-May	December-May
2	110	260	240	210	190
5	81	200	180	160	150
10	70	180	160	140	140
20	62	160	140	120	110

[1] Values were calculated with the following equation:

$$Q_{Head} = (A_{Head}/A_{01411800})*(Q_{01411800})$$

where A_{head} is drainage area at the head of tide,

$A_{01411800}$ is drainage area at station 01411800,

Q_{Head} is discharge at the head of tide, and

$Q_{01411800}$ is discharge at station 01411800 (App. B).

differences between basin characteristics downstream and upstream from station 01411800.

Discharge at the heads of the estuaries is directly related to drainage area. Drainage areas and mean annual discharges of the Great Egg Harbor River and the Maurice River are the greatest of those tributaries studied; mean annual discharges are 340 and 310 cubic feet per second, respectively. Mean annual discharges of the Toms and Metedeconk Rivers are 220 and 140 cubic feet per second, respectively. Drainage area and mean annual discharge of the Tuckahoe River are the smallest of any tributary considered; mean annual discharge is 43.9 cubic feet per second.

SUMMARY AND CONCLUSIONS

Statistics have been calculated to describe the long-term variation in discharge in tributaries of the estuaries of the Metedeconk, Toms, Great Egg Harbor, Tuckahoe, and Maurice Rivers. The information was developed as a basis for assessment of the major tributaries as sites for water-supply diversions, including an assessment of the effects of diversions on estuarine water quality and biota.

The following discharge statistics were determined for 13 selected streamflow-gaging stations in the drainage basins of the estuaries: (1) mean annual and mean monthly discharge and, (2) lowest annual 7-day mean discharge for selected recurrence intervals. Values of lowest annual discharge were calculated for the complete year and for the 3-, 4-, 5-, and 6-month periods of greatest discharge. The seasonal variation of discharge and station-to-station differences in discharge, as runoff, were examined. Monthly discharge and lowest annual discharge were tested for trends.

Examination of the seasonal variation of discharge at continuous-record stations indicates a similar pattern for major tributaries of all estuaries; discharge is greatest during March and April and least during August, September, and October. The 3-, 4-, 5-, and 6-month periods of greatest discharge for most streams are February through April, January through April, January through May, and December through May, respectively. Values of lowest annual discharge were calculated for these periods.

Mean annual runoff is greater in tributaries of the Metedeconk and Toms Rivers than in tributaries of the other estuaries. The range of mean annual runoff in tributaries of the Metedeconk and Toms Rivers is 24 to 29 inches; the corresponding range for tributaries of the other estuaries is 16 to 23 inches.

Runoff values indicate that basin characteristics of the South Branch of the Metedeconk River were different from those of the adjacent basins of the North Branch Metedeconk and Toms Rivers in the past. A basin's characteristics determine how much of precipitation leaves the basin as streamflow. During water years 1973-76, streamflow per unit area from the South Branch Metedeconk River was 20 percent greater than that from either the North Branch Metedeconk or Toms Rivers.

For continuous-record stations, trend tests were done on monthly discharge and on a number of types of lowest annual discharges during complete years and partial years. For complete years, the lowest annual 7-, 30-, 90-, and 183-day mean discharges were tested. The partial year periods considered were the 3-, 4-, 5-, and 6-month periods of greatest discharge; the tests were run on the lowest annual 7-, 30-, and 90-day mean discharge during these 3- to 6-month periods.

The tests on monthly discharge were run on data measured over the following three periods: the period of record of the station, during water years 1970-89, and during water years 1980-89. No tests identified any trends in data for any station for these periods.

The tests on lowest annual discharges were run on data measured over periods which approximated, but did not exactly coincide with, the three periods of the monthly discharge data. Tests for the period of record and for the 1980-89 water years did not identify any trends for any station.

For water years 1970-89, a number of trends in lowest annual discharges were identified; all trends indicated decreasing values. There was at least one trend for stations on tributaries of each estuary. Trends in 183-day lowest annual discharge during the complete year were apparent for four stations. At least one trend in lowest annual 7- or 30-day mean discharge during the 3-, 4-, 5-, and 6-month periods of greatest discharge was found for three stations. The cause of these trends was not identified; however, the existence of similar trends in different basins during the same period suggests that the downtrends in all basins are due to the same processes.

Discharge statistics at the heads of tide of the estuaries were calculated from the statistics for selected streamflow-gaging stations. Statistics for the heads of tide of the estuaries of the Tuckahoe and Maurice Rivers are represented by the statistics of streamflow-gaging stations at the heads of tide. Statistics for the heads of tide of the other estuaries were calculated from values at upstream stations; discharge statistics at the stations were summed and adjusted to account for unmeasured drainage area.

Results indicate that discharge at the heads of tide largely proportional to drainage area. Drainage areas and discharges are greatest for the Great Egg Harbor and Maurice Rivers; mean annual discharges of these rivers are 340 and 310 cubic feet per second, respectively. Mean annual discharges of the Toms and Metedeconk Rivers are 220 and 140 cubic feet per second, respectively. Drainage area and discharge of the Tuckahoe River are the smallest of any tributary studied; mean annual discharge for the Tuckahoe River is 43.9 cubic feet per second.

The discharge statistics in this report will not represent future conditions if future basin or weather characteristics differ from those in the past. Trend analysis of period-of-record discharge data at continuous-record stations does not identify any long-term changes in either weather or basin characteristics.

REFERENCES CITED

Carter, R.W., and Davidian, Jacob, 1968, General procedure for gaging streams: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A6, 13 p.

Dempster, G.R., 1984, Daily values statistics, in Hutchinson, N.E., WATSTORE user's guide: U.S. Geological Survey Open-File Report 75-426, v. I, chap. IV, p. G1-G38.

Gill, H.E., 1962, Ground-water resources of Cape May County, N.J.--Salt-water invasion of principal aquifers: State of New Jersey Department of Conservation and Economic Development, Division of Water Policy and Supply, Special Report 18, 171.p

Gillespie, B.D., and Schopp, R.D., 1982, Low-flow characteristics and flow duration of New Jersey streams: U.S. Geological Survey Open-File Report 81-1110, 164 p.

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v. 18, no. 4, p. 1081-1088.

Hirsch, R.M., and Slack, J.R., 1984, A nonparametric trend test for seasonal data with serial dependence: Water Resources Research, v. 20, no. 6, p. 727-732.

Hirsch, R.M., Slack, J.R., and Smith, R.A., 1982, Techniques of trend analysis for monthly water quality data: Water Resources Research, v. 18, no. 1, p. 107-121.

Hollander, Myles, and Wolfe, D.A., 1973, Nonparametric statistical methods: New York, John Wiley and Sons, 503 p.

Rantz, S.E, and others, 1982, Measurement and computation of streamflow, volumes 1 and 2: U.S. Geological Survey Water-Supply Paper 2175, 631 p.

Riggs, H.C., 1968, Frequency curves: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A2, 15 p.

____ 1972, Low-flow investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. B1, 18 p.

Velnich, A.J., 1982, Drainage areas in New Jersey--Delaware River Basin and streams tributary to Delaware Bay: U.S. Geological Survey Open-File Report 82-572, 48 p.

____ 1984, Drainage areas in New Jersey--Atlantic Coastal Basins, South Amboy to Cape May: U.S. Geological Survey Open-File Report 84-150, 33 p.

GLOSSARY

BASE FLOW. The stream discharge that occurs between storms. For most streams, it is composed mostly of ground water.

CLIMATIC YEAR. The 12-month period from April 1 through March 30, designated by the calendar year in which it begins. For example, the 1988 climatic year extends from April 1, 1988, through March 30, 1989.

CONFIDENCE INTERVAL. The range of values which has a given probability of containing the true value of a given parameter.

CONTINUOUS-RECORD STATION. A streamflow-gaging station at which stream discharge is continuously measured and recorded.

DIVERSION. The transfer of water from one body of water to a canal, pipe, or other conduit, or to a second water body as a result of human activity.

DRAINAGE AREA. The area of the drainage basin, measured in a horizontal plane.

DRAINAGE BASIN. That part of the surface of the earth that directs water originating as precipitation past a specified point on a river, lake, or reservoir.

PARTIAL-RECORD STATION. For this report, a streamflow-gaging station at which a limited number of individual measurements of streamflow are made.

RECURRENCE INTERVAL. For this report, the average time interval in years between years during which daily streamflow is equal to or less than a specified value. Recurrence interval is equal to the inverse of the probability of nonexceedence.

RUNOFF. The volume of stream discharge passing a specified point during a given period, expressed as a depth of water over the drainage area.

STREAMFLOW-GAGING STATION. A site on a stream or canal at which stream discharge is systematically measured and recorded.

TREND. A monotonic change in a variable over time. For this report, the time period is 10 years or more.

TREND SLOPE. The magnitude of a monotonic change in a variable over time.

WATER YEAR. The 12-month period from October 1 through September 30, designated by the calendar year in which it ends. For example, the 1989 water year extends from October 1, 1988, through September 30, 1989.

APPENDIX A

Discharge Statistics for Continuous-Record Streamflow-Gaging Stations

[Period of record is in water years; discharge is in cubic feet per second; Ann., annual; recurrence interval is in years; duration is in days; ND indicates values not determined because of insufficient days in the period]

Station 01408120
North Branch Metedeconk River near Lakewood, N.J.

Drainage area: 34.9 square miles   Period of record: 17 years, 1973-89

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
62.5	43.9	63.5	76.2	77.0	75.0	82.1	87.5	68.5	51.2	46.6	38.9	4C.4

Lowest annual discharge for selected recurrence intervals

Part of year	Recurrence interval	Lowest annual mean discharge for given duration 7	30	90	183	365
Complete year (April through March)	2	20	25	32	39	60
	5	15	19	24	31	49
	10	13	16	20	28	41
	20	12	14	18	25	36
	50	ND	ND	ND	ND	ND
February though April	2	43	56	ND	ND	ND
	5	33	45	ND	ND	ND
	10	29	40	ND	ND	ND
	20	26	36	ND	ND	ND
	50	ND	ND	ND	ND	ND
January through April	2	40	52	69	ND	ND
	5	30	38	53	ND	ND
	10	26	32	46	ND	ND
	20	23	25	40	ND	ND
	50	ND	ND	ND	ND	ND
January through May	2	35	48	66	ND	ND
	5	27	35	50	ND	ND
	10	22	30	43	ND	ND
	20	20	21	38	ND	ND
	50	ND	ND	ND	ND	ND
December through May	2	34	46	61	ND	ND
	5	26	34	46	ND	ND
	10	22	29	38	ND	ND
	20	20	25	35	ND	ND
	50	ND	ND	ND	ND	ND

APPENDIX A--Discharge Statistics for Continuous-Record Streamflow-Gaging Stations--Continued

Station 01408500
Toms River near Toms River, N.J.

Drainage area: 123 square miles   Period of record: 61 years, 1929-89

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
214	155	202	225	244	255	292	284	248	190	161	158	154

Lowest annual discharge for selected recurrence intervals

Part of year	Recurrence interval	Lowest annual mean discharge for given duration 7	30	90	183	365
Complete year (April through March)	2	85	98	122	153	210
	5	70	79	98	124	174
	10	63	71	87	111	158
	20	59	65	79	101	145
	50	54	59	71	91	132
February through April	2	176	217	ND	ND	ND
	5	144	175	ND	ND	ND
	10	129	157	ND	ND	ND
	20	118	143	ND	ND	ND
	50	106	128	ND	ND	ND
January through April	2	166	197	248	ND	ND
	5	134	157	203	ND	ND
	10	118	139	183	ND	ND
	20	106	125	167	ND	ND
	50	93	111	152	ND	ND
January through May	2	154	186	241	ND	ND
	5	124	150	197	ND	ND
	10	110	134	177	ND	ND
	20	100	123	162	ND	ND
	50	89	110	146	ND	ND
December through May	2	142	175	220	ND	ND
	5	115	140	178	ND	ND
	10	103	124	159	ND	ND
	20	94	112	144	ND	ND
	50	85	101	130	ND	ND

APPENDIX A--Discharge Statistics for Continuous-Record Streamflow-Gaging Stations--Continued

Station 01411000
Great Egg Harbor River at Folsom, N.J.

Drainage area: 57.1 square miles Period of record: 64 years, 1926-89

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
86.5	60.3	79.9	92.6	102	107	120	114	96.2	72.6	63.2	64.5	62.2

Lowest annual discharge for selected recurrence intervals

Part of year	Recurrence interval	Lowest annual mean discharge for given duration				
		7	30	90	183	365
Complete year (April through March)	2	32	36	45	59	84
	5	25	28	35	45	69
	10	22	25	31	40	61
	20	20	22	27	36	56
	50	18	20	24	32	50
February through April	2	70	88	ND	ND	ND
	5	57	71	ND	ND	ND
	10	51	64	ND	ND	ND
	20	46	59	ND	ND	ND
	50	42	54	ND	ND	ND
January through April	2	66	81	103	ND	ND
	5	53	64	83	ND	ND
	10	47	56	74	ND	ND
	20	42	50	67	ND	ND
	50	37	43	60	ND	ND
January through May	2	60	73	98	ND	ND
	5	48	58	79	ND	ND
	10	42	51	70	ND	ND
	20	38	46	64	ND	ND
	50	34	40	57	ND	ND
December through May	2	56	69	91	ND	ND
	5	45	54	72	ND	ND
	10	39	47	64	ND	ND
	20	35	42	57	ND	ND
	50	31	37	51	ND	ND

APPENDIX A--Discharge Statistics for Continuous-Record Streamflow-Gaging Stations--Continued

Station 01411300
Tuckahoe River at Head of River, N.J.

Drainage area: 30.8 square miles Period of record: 20 years, 1970-89

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
43.9	26.2	35.4	43.4	52.6	57.3	65.2	69.8	57.7	42.5	26.7	25.3	23.1

Lowest annual discharge for selected recurrence intervals

Part of year	Recurrence interval	Lowest annual mean discharge for given duration				
		7	30	90	183	365
Complete year (April through March)	2	12	15	18	24	41
	5	9.7	13	15	19	33
	10	8.8	12	13	17	29
	20	8.0	10	12	16	26
	50	ND	ND	ND	ND	ND
February through April	2	34	43	ND	ND	ND
	5	25	31	ND	ND	ND
	10	21	27	ND	ND	ND
	20	18	24	ND	ND	ND
	50	ND	ND	ND	ND	ND
January through April	2	30	38	53	ND	ND
	5	22	27	39	ND	ND
	10	18	22	33	ND	ND
	20	16	18	29	ND	ND
	50	ND	ND	ND	ND	ND
January through May	2	29	37	51	ND	ND
	5	20	26	37	ND	ND
	10	17	22	31	ND	ND
	20	15	18	27	ND	ND
	50	ND	ND	ND	ND	ND
December through May	2	26	33	44	ND	ND
	5	18	24	32	ND	ND
	10	16	20	27	ND	ND
	20	14	17	24	ND	ND
	50	ND	ND	ND	ND	ND

APPENDIX A--Discharge Statistics for Continuous-Record Streamflow-Gaging Stations--Continued

Station 01411500
Maurice River at Norma, N.J.

Drainage area: 112 square miles   Period of record: 57 years, 1933-89

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
166	112	143	168	191	203	231	227	192	149	126	127	126

Lowest annual discharge for selected recurrence intervals

Part of year	Recurrence interval	Lowest annual mean discharge for given duration 7	30	90	183	365
Complete year	2	59	70	87	112	161
(April through March)	5	44	52	65	83	128
	10	38	44	56	72	113
	20	33	39	49	63	102
	50	29	29	42	55	90
February through April	2	143	174	ND	ND	ND
	5	109	136	ND	ND	ND
	10	94	119	ND	ND	ND
	20	83	108	ND	ND	ND
	50	72	96	ND	ND	ND
January through April	2	131	158	196	ND	ND
	5	98	117	151	ND	ND
	10	83	99	131	ND	ND
	20	72	85	116	ND	ND
	50	61	72	101	ND	ND
January through May	2	119	146	190	ND	ND
	5	88	108	147	ND	ND
	10	74	92	127	ND	ND
	20	64	80	113	ND	ND
	50	54	68	99	ND	ND
December through May	2	106	134	171	ND	ND
	5	80	101	131	ND	ND
	10	68	87	113	ND	ND
	20	60	77	99	ND	ND
	50	52	66	86	ND	ND

APPENDIX A--Discharge Statistics for Continuous-Record Streamflow-Gaging Stations--Continued

Station 01412000
Menantico Creek near Millville, N.J.

Drainage area: 22.3 square miles   Period of record: 33 years, 1932-57 and 1978-84

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
37.5	25.6	32.7	36.2	42.2	45.0	51.2	48.9	42.7	35.8	28.8	33.0	28.3

Lowest annual discharge for selected recurrence intervals

Part of year	Recurrence interval	Lowest annual mean discharge for given duration				
		7	30	90	183	365
Complete year (April through March)	2	13	17	22	27	37
	5	8.8	13	17	21	30
	10	7.2	11	14	18	26
	20	6.0	10	12	16	24
	50	4.9	8.6	10	14	21
February through April	2	29	37	ND	ND	ND
	5	22	29	ND	ND	ND
	10	20	26	ND	ND	ND
	20	18	23	ND	ND	ND
	50	16	21	ND	ND	ND
January through April	2	27	34	43	ND	ND
	5	20	25	33	ND	ND
	10	17	21	29	ND	ND
	20	15	19	26	ND	ND
	50	13	16	23	ND	ND
January through May	2	25	31	41	ND	ND
	5	19	23	32	ND	ND
	10	16	20	28	ND	ND
	20	14	18	25	ND	ND
	50	12	15	22	ND	ND
December through May	2	22	28	37	ND	ND
	5	17	22	28	ND	ND
	10	15	19	25	ND	ND
	20	13	17	22	ND	ND
	50	11	15	19	ND	ND

APPENDIX B

Discharge Statistics for Partial-Record Streamflow-Gaging Stations

[Period of record is in water years, discharge is in cubic feet per second; Ann., annual; recurrence interval is in years; correlation coefficient is for logarithms of discharge at partial-record and index stations]

Station 01408140
South Branch Metedeconk River at Lakewood, N.J.

Drainage area: 26.0 square miles
Period of continuous record: 4 years, 1973-76

Summary of discharge data

[Continuous record for 1973-76 water years is available for station 01408140; the relation for monthly data was used to calculate mean annual discharge and mean monthly discharge; the relation for daily data was used to calculate values of lowest annual discharges]

Index station number	Record of discharge at station 01408140				Correlation coefficient
	Type of data	Number of data	Range of discharge		
			Minimum	Maximum	
01408120	Daily	1461	9.8	450	0.85
01408500	Daily	1461	9.8	450	.83
01408120	Monthly	48	22	164	.91
01408500	Monthly	48	22	164	.94

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
56	41	55	63	65	66	73	74	62	48	43	39	39

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge				
	Complete year	February-April	January-April	January-May	December-May
2	18	40	38	34	32
5	14	32	29	26	25
10	12	28	25	22	21
20	11	25	22	20	19

Station 01411110
Great Egg Harbor River at Weymouth, N.J.

Drainage area: 154 square miles

Summary of base-flow discharge measurements

Index station number	Partial-record station discharge measurements: Period of record	Number of data	Range of discharge: Minimum	Range of discharge: Maximum	Correlation coefficient
01411000	1979-87	7	93	369	0.95
01411500	1979-87	7	93	369	.97

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
250	170	220	260	300	320	360	350	290	220	180	180	180

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge: Complete year	February-April	January-April	January-May	December-May
2	82	210	190	170	150
5	67	160	140	130	120
10	52	140	120	110	100
20	46	120	110	94	87

APPENDIX B--Discharge Statistics for Partial-Record Streamflow-Gaging Stations--Continued

Station 01411140
Deep Run at Weymouth, N.J.

Drainage area: 20.0 square miles

Summary of base-flow discharge measurements

Index station number	Partial-record station discharge measurements: Period of record	Number of data	Range of discharge: Minimum	Maximum	Correlation coefficient
01411000	1976-86	18	8.5	48	0.88
01411500	1976-86	18	8.5	48	.91

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
32	21	28	34	38	40	46	44	37	27	23	24	23

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge: Complete year	February-April	January-April	January-May	December-May
2	11	26	24	22	20
5	7.9	19	18	16	15
10	6.8	18	16	14	13
20	6.0	16	14	12	11

APPENDIX B--Discharge Statistics for Partial-Record Streamflow-Gaging Stations--Continued

Station 01411200
Babcock Creek at Mays Landing, N.J.

Drainage area: 20.0 square miles

Summary of base-flow discharge measurements

Index station number	Partial-record station discharge measurements: Period of record	Number of data	Range of discharge: Minimum	Range of discharge: Maximum	Correlation coefficient
01409400	1959-63	9	6.4	34	0.93
01411000	1959-63	9	6.4	34	.94

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
24	14	21	28	32	34	39	37	29	18	15	16	14

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge: Complete year	February-April	January-April	January-May	December-May
2	5.2	17	16	14	13
5	3.4	12	11	9.7	8.8
10	2.8	10	9.2	7.9	7.1
20	2.3	8.8	7.6	6.6	5.4

APPENDIX B--Discharge Statistics for Partial-Record Streamflow-Gaging Stations--Continued

Station 01411800
Maurice River near Millville, N.J.

Drainage area: 191 square miles

Summary of base-flow discharge measurements

Index station number	Partial-record station discharge measurements				Correlation coefficient
	Period of record	Number of data	Range of discharge		
			Minimum	Maximum	
01411000	1965-71	9	38	492	0.98
01411500	1965-71	7	38	361	.99

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
280	190	250	290	330	340	390	380	320	240	200	210	200

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge				
	Complete year	February-April	January-April	January-May	December-May
2	95	230	210	190	170
5	72	180	160	140	130
10	62	160	140	120	120
20	55	140	120	110	100

APPENDIX B--Discharge Statistics for Partial-Record Streamflow-Gaging Stations--Continued

Station 01411880
Maurice River at Sharp Street, Millville, N.J., below outlet of Union Lake

Drainage area: 216 square miles

Summary of base-flow discharge measurements

Index station number	Partial-record station discharge measurements: Period of record	Number of data	Range of discharge: Minimum	Range of discharge: Maximum	Correlation coefficient
01411500	1973-89	6	168	401	0.95

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
310	230	280	310	350	360	400	390	350	290	250	250	250

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge: Complete year	February-April	January-April	January-May	December-May
2	140	280	260	240	220
5	110	230	200	190	180
10	100	200	180	170	160
20	92	180	170	150	140

APPENDIX B--Discharge Statistics for Partial-Record Streamflow-Gaging Stations--Continued

Station 01412100
Manumuskin River near Manumuskin, N.J.

Drainage area: 32.1 square miles

Summary of base-flow discharge measurements

Index station number	Partial-record station discharge measurements				Correlation coefficient
	Period of record	Number of data	Range of discharge		
			Minimum	Maximum	
01409400	1964-70	10	7.8	78	0.97
01411000	1964-71	14	7.8	78	.96
01411500	1964-71	14	7.8	78	.92

Mean annual and monthly discharge

Ann.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
39	26	34	41	46	48	54	52	44	32	28	29	27

Lowest annual 7-day mean discharge for selected recurrence intervals

Recurrence interval	Lowest annual 7-day mean discharge				
	Complete year	February-April	February-May	January-May	December-May
2	13	31	29	27	24
5	10	24	23	20	19
10	8.7	21	19	17	16
20	7.6	19	17	15	14