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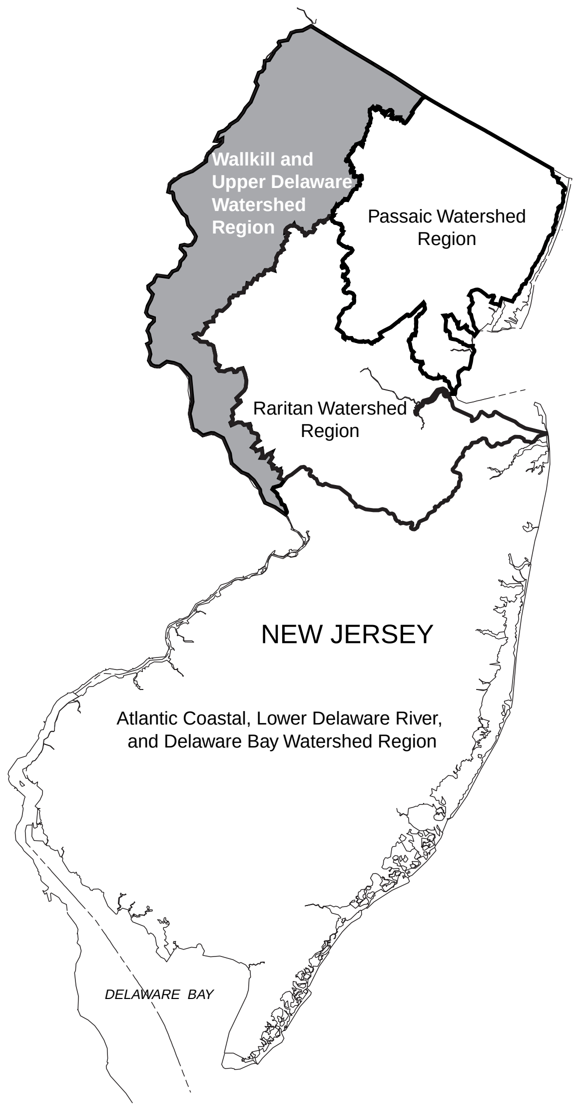
RELATIONS OF SURFACE-WATER QUALITY TO STREAMFLOW IN THE WALLKILL AND UPPER DELAWARE RIVER BASINS, NEW JERSEY AND VICINITY, WATER YEARS 1976-93

Water-Resources Investigations Report 99-4016



Prepared in cooperation with the

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

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By Debra E. Buxton, Kathryn Hunchak-Kariouk, and R. Edward Hickman

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West Trenton, New Jersey

1999

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science for a changing world

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	259.0	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
pounds per day (lb/d)	0.4536	kilograms per day
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram

Temperature given in degrees Fahrenheit (°F) and Celsius (°C) may be converted to degrees Celsius (°C) and Kelvin (°K) by the following equations:

$$°C = 5/9 \times (°F-32)$$
$$°K = 273.15 + °C$$

Water-quality abbreviations

µm - micrometer
s/d - seconds per day
mg/L - milligrams per liter
µg/L - micrograms per liter
MPN/100mL- most probable number of bacteria per 100 milliliters
ALK - alkalinity
HARD - hardness
TOC - total organic carbon
SS - suspended sediment
DS - dissolved solids
NA - dissolved sodium
CL - dissolved chloride
DO - dissolved oxygen

RELATIONS OF SURFACE-WATER QUALITY TO STREAMFLOW IN THE WALLKILL AND UPPER DELAWARE RIVER BASINS, NEW JERSEY AND VICINITY, WATER YEARS 1976-93

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ABSTRACT

Relations of water quality to streamflow were determined for 18 water-quality constituents at 18 surface-water stations within the drainage basins of the Wallkill and upper Delaware Rivers in New Jersey and vicinity for water years 1976-93. Surface-water-quality and streamflow data were evaluated for trends (through time) in constituent concentrations during high and low flows, and relations between constituent concentration and streamflow, and between constituent load and streamflow, were determined. Median concentrations were calculated for the entire period of study (water years 1976-93) and for the last 5 years of the period of study (water years 1989-93) to determine whether any large variation in concentration exists between the two periods. Medians also were used to determine the seasonal Kendall's tau statistic, which was then used to evaluate trends in concentrations during high and low flows.

Trends in constituent concentrations during high and low flows were evaluated to determine whether the distribution of the observations changes through time for intermittent (nonpoint storm runoff) or constant (point sources and ground water) sources, respectively. High- and low-flow trends in concentrations were determined for some constituents at 15 of the 18 water-quality stations; 3 stations have insufficient data to determine trends. Seasonal effects on the relations of concentration to streamflow are evident for 16 of the 18 constituents. Negative slopes of relations of concentration to streamflow, which indicate a decrease in concentration at high flows, predominate over positive slopes because of the dilution of instream concentrations by storm runoff.

The slopes of the regression lines of load to streamflow were determined in order to show the relative contributions to the instream load from constant (point sources and ground water) and intermittent (storm runoff) sources. Greater slope values indicate larger contributions from storm runoff to instream load, which most likely indicate an increased relative importance of nonpoint sources. The slopes of load-to-streamflow relations along a stream reach that tend to increase in a downstream direction indicate the increased relative importance of contributions from storm runoff. The slopes of load-to-streamflow relations for several nutrients and dissolved ions increase in the downstream direction at the Wallkill River, Paulins Kill, and Musconetcong River. Likewise, the slopes of load-to-streamflow relations along a stream reach that tend to decrease in a downstream direction indicate the increased relative importance of point sources and ground-water discharge. The slopes of load-to-streamflow relations for several dissolved ions decrease in the downstream direction at the Delaware River.

INTRODUCTION

The New Jersey Department of Environmental Protection (NJDEP) has initiated an innovative watershed approach to water-quality management in order to attain State-mandated goals for the quality of surface water (New Jersey Department of Environmental Protection, 1989). Water quality will be assessed and management practices will be executed on the basis of factors that adversely affect quality, such as nonpoint source contributions, headwaters destruction, and habitat degradation, within the watershed or basin. This approach requires evaluation of the effects of point-and-nonpoint source contributions on the quality of surface water within a watershed. To facilitate the assessment of surface-water quality, the State is divided into four regions on the basis of watershed-management issues and hydrogeologic boundaries defined by the U.S. Geological Survey (USGS) (fig. 1).

The USGS, in cooperation with the NJDEP, has developed a watershed-based method for relating water quality to streamflow to assess the relative contributions of constant (point sources and ground-water discharge) and intermittent (nonpoint storm runoff) sources of constituents to New Jersey streams in all four watershed regions. The initial study was conducted for the Passaic region, which comprises the Hackensack, Passaic, Elizabeth, and Rahway River Basins (Buxton and others, 1998). The other regions consist of (1) the Wallkill River and upper Delaware River Basins; (2) the Raritan River Basin; and (3) the Atlantic Coastal, lower Delaware River, and Delaware Bay Basins.

Purpose and Scope

This report presents the results of analyses for 18 water-quality constituents in samples collected at 18 surface-water-quality stations within the Wallkill and upper Delaware River Basins (referred to as the study area) during water years[1] 1976-93 (October 1, 1975, through September 30, 1993). Relations between each of the 18 constituents and streamflow at the 18 stations over the period of record were determined by testing for trends in the concentrations of constituents during low and high flows. Qualitative values of contributions from constant (point sources and ground water) and intermittent (nonpoint storm runoff) sources are estimated statistically by examining the relations between concentrations of constituents and streamflow, and load and streamflow.

Results of analyses are presented in three ways—in tables for each station with median concentrations, the regression slopes of concentration and load to streamflow, and the directions of the trends in concentrations during low and high flows for all constituents; in schematics for each constituent showing regional trends in concentrations during low and high flows and the slopes of load to streamflow; and in graphs for each constituent by station showing relations of concentration to streamflow, load to streamflow, and trends in concentrations during low and high flows.

[1] A water year is the 12-month period from October 1 through September 30 and is designated by the calendar year in which it ends.

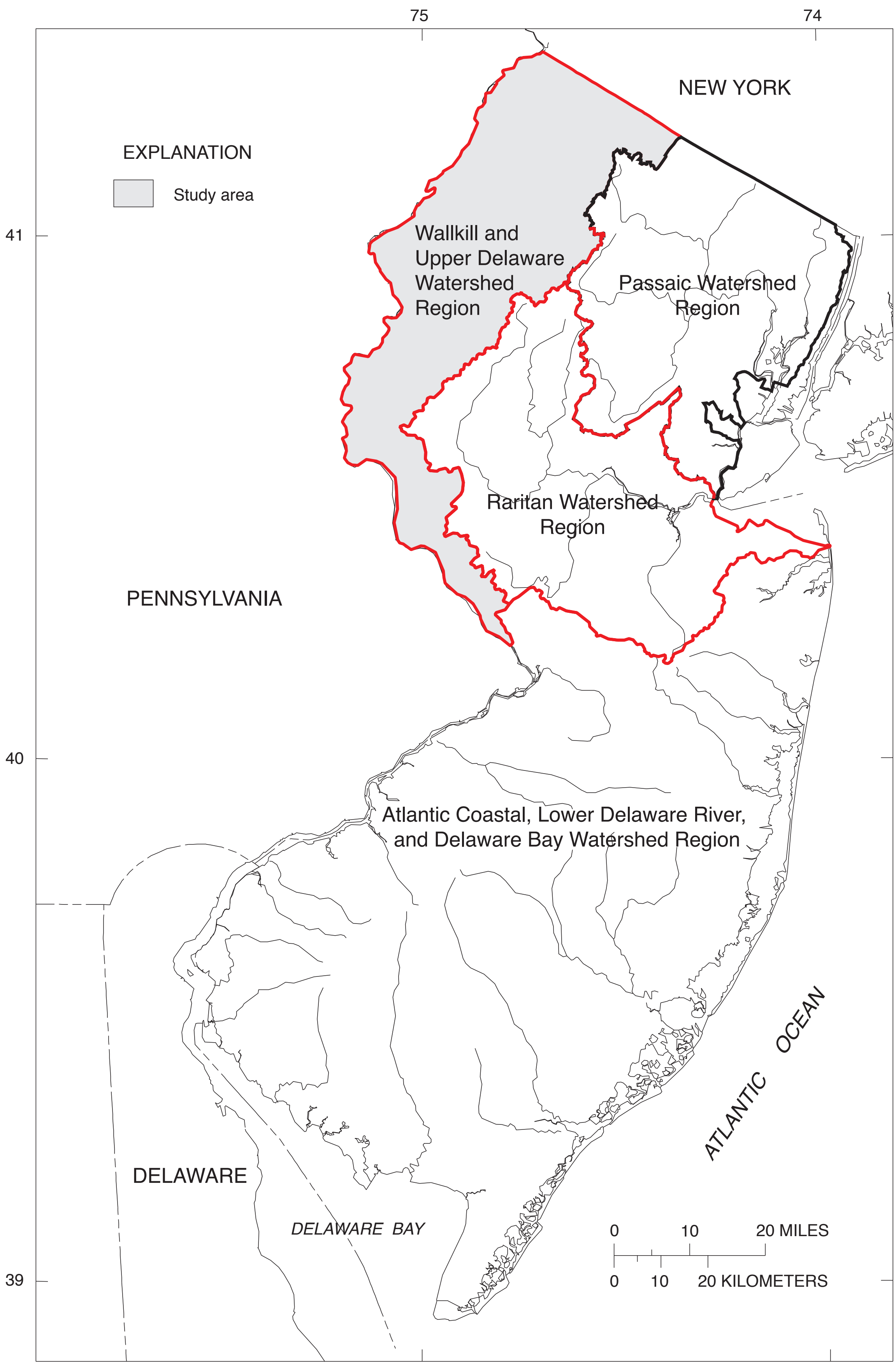


Figure 1. Four watershed regions in New Jersey.

Approach

A river receives constituents from point and nonpoint sources within the contributing drainage basin. Point sources are discrete, identifiable origins of constituents, such as permitted discharges from municipal- and industrial-wastewater treatment facilities, that contribute water to a stream at a constant rate, independent of streamflow conditions. Constituents from more diffuse, nonpoint sources are transported to the river by storm runoff from agricultural, residential, and urban areas and impervious surfaces (highways and parking lots), and by ground water that could contain effluent from leaking underground-storage tanks, septic systems, and landfills. Storm runoff, composed of overland runoff (water that flows overland when precipitation exceeds the infiltration rate) and interflow (infiltrated water that moves in a horizontal direction in the low permeable subsoil), contributes to a stream intermittently, depending on storm intensity and frequency, and only during high flows (Chow, 1964; Novotny and Chesters, 1981). Ground-water discharge to a stream is almost constant, although the rate of discharge varies slightly with season and precipitation rate. Instream concentrations of constituents are a summation of the contributions from constant (point sources and ground-water discharge) and intermittent (storm runoff) sources.

The magnitude, or steepness, of the slope of the regression line between constituent loads and streamflow indicates the relative contributions of constant and intermittent sources at a river location. The steeper the slope, the greater the contribution from nonpoint sources during increased streamflow. If the contributions to instream load are mainly from point sources and ground water, instream load will remain constant with increasing streamflow, and the regression slope of load to streamflow will be approximately zero (fig. 2). If, however, storm runoff contributes a disproportionate amount of material to instream load, instream load will increase with increasing streamflow, and the regression slope of load to streamflow will be greater than zero (fig. 2). A steep slope does not imply that contributions from constant sources are unimportant, but only that intermittent sources contribute more to instream load during high flows than do constant sources. Price and Schaefer (1995) used this approach (steepness of the load-to-streamflow regression line) to assess the relative contributions of permitted and nonpermitted sources in the Musconetcong, Rockaway, and Whippany River Basins. An idealized example of the relation of load to streamflow is shown in figure 3. For site 01380500, the Rockaway River above the reservoir at Boonton, the slope of the regression line is steeper (the estimated total median load from permitted point sources upstream was approximately 100 lb/d) than the slope for site 01381200, Rockaway River at Pine Brook (the estimated median load from permitted point sources was approximately 1,000 lb/d). In the example, the relative importance of nonpoint sources is greater at station 01380500 than at site 01381200, and the relative importance of point sources is greater at site 01381200 than at site 01380500.

Concentrations of constituents cannot be related to streamflow in this way because contributions from storm runoff are flow dependent, and a small concentration can represent a large instream load during high-flow conditions. If constituents are contributed to a stream mostly from constant sources, then instream concentrations will be diluted during periods of high flow. If, however, storm runoff contributes significant amounts of constituents to a stream, then the extent of dilution during periods of high flow will be reduced. The use of loads (mass per time) instead of concentrations (mass per volume) removes the influence of changing streamflow (volume per time) on instream constituent amounts (Buxton and others, 1998).

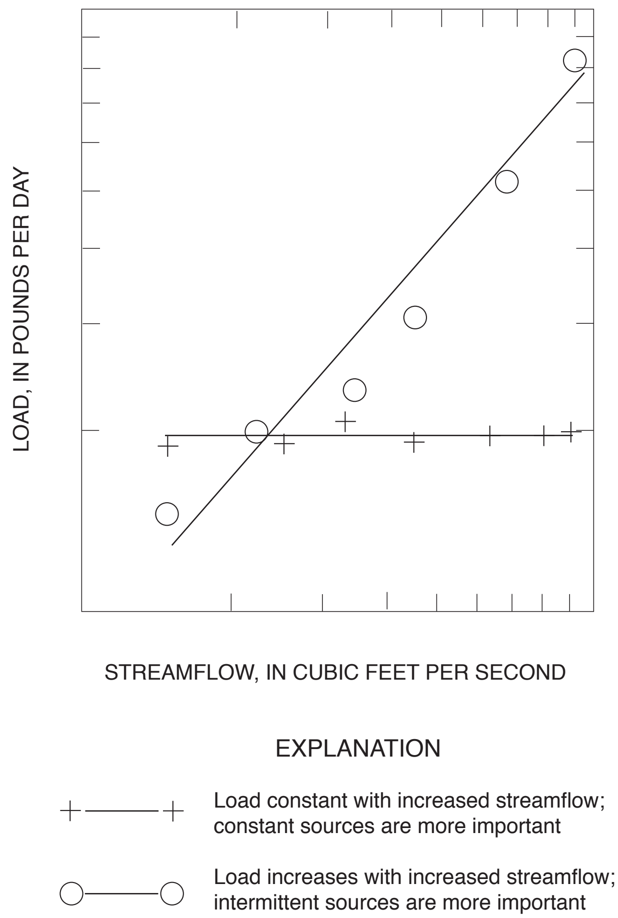


Figure 2. Hypothetical logarithmic plot of expected load-to-streamflow relations for a stream strongly affected by constant (point source and ground water) and intermittent (nonpoint storm runoff) sources.

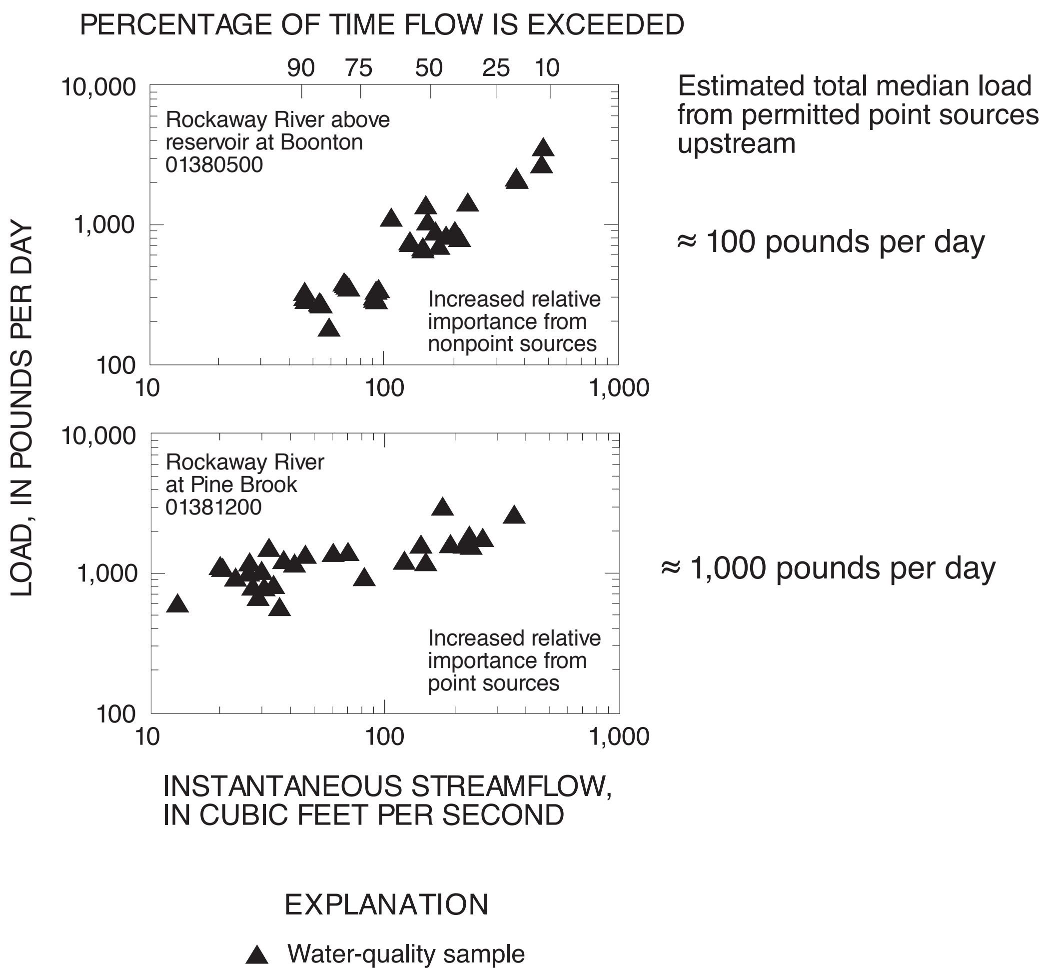


Figure 3. Relation of instream load of total nitrogen to instantaneous streamflow at water-quality stations in the Rockaway River Basin, New Jersey, 1985-91.

The instream load also can be affected by contributions from ground water and streambed sediment. Ground-water contributions to streams during low flow can be significant, but are less likely to affect surface-water quality during high-flow conditions when ground-water contributions are diluted. In some hydrologic systems, the scour of streambed sediment during high flows can contribute to the instream load. Rosensteel and Strom (1991) collected water samples from the Pompton and Passaic Rivers during storms and found that most of the observed increase in the load of total phosphorus at high flows was attributable to the dissolved fraction of the phosphorus load, indicating that the load contributed by sediment scour probably was significant.

Comparisons of trends in constituent concentrations during high and low flows can indicate changes through time in the contributions from intermittent and constant sources, respectively. Positive trends during high flows indicate an increase in the storm runoff contributions through time, whereas negative trends indicate a decrease in the storm runoff contributions. Positive trends during low flows indicate an increase in the contributions from point sources and ground water or both through time, whereas negative trends indicate a decrease in the contributions from point sources and ground water.

The study involved several phases of multidisciplinary activity starting with the selection of the surface-water-quality stations (table 1), constituents, and the period of record. Water-quality and instantaneous-streamflow data were retrieved from the National Water Information System (NWIS) data base (Hutchison, 1975), which is maintained by the USGS. The water-quality and instantaneous-streamflow data underwent extensive quality-assurance procedures.

The data base created for this study was maintained with the Statistical Analysis System (SAS), a statistically based integrated software system that provides data access, management, analysis, and presentation. With SAS, median concentrations and relations of surface-water quality to streamflow were determined for each constituent at each station. The types of relations analyzed are concentration to streamflow, load to streamflow, and concentration trends during low- and high-flow conditions.

Graphs, schematics, and tables were generated to show the statistical results. Results are presented in the text first by basin and compared with the impairment index generated by the NJDEP's Ambient Biomonitoring Network (AMNET) biological assessment, and then by constituent. Results of the three surface-water quality to streamflow analyses are presented graphically by constituent for each station in appendixes 1-18[2].

Previous Studies

Water-quality studies have been conducted in New Jersey by the USGS, in cooperation with State and local agencies, since the early 1960's. Three more recent USGS studies report the effects of nonpoint source contamination on New Jersey streams. Schornick and Fishel (1980) reported the effect of storm runoff on the surface-water quality of the Mill Creek Basin in

[2] Appendixes 1-18 containing relations of surface-water quality to streamflow are available on a CD-ROM; contact the New Jersey District Office of the USGS in West Trenton, N.J., for more information or to obtain copies of the CD-ROM.

Table 1. Description of, years of record for, and mean annual flow at selected surface-water-quality stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity

[All stations are in New Jersey unless otherwise indicated; ND, no data for site; mi^2, square miles; ft^3/s, cubic feet per second]

Station number	Station name	Latitude/ longitude	Drainage area in mi^2	Daily streamflow record (water years)	Mean annual flow in ft^3/s (period of record)
	Wallkill River Basin				
[1]01367770	Wallkill River near Sussex	411138/743432	60.8	ND	ND
[1]01367910	Papakating Creek at Sussex	411202/743559	59.4	ND	ND
01368000	Wallkill River near Unionville, N.Y.	411536/743258	140	1938-81	215
[1]01368950	Black Creek near Vernon	411321/742833	17.3	ND	ND
	Upper Delaware River Basin				
01438500	Delaware River at Montague	411833/744744	3,480	1940-93	5,686
01440000	Flat Brook near Flatbrookville	410624/745709	64.0	1924-93	110
[1]01443000	Delaware River at Portland, Pa.	405526/750546	4,165	ND	ND
[1]01443440	Paulins Kill at Balesville	410620/744519	67.1	ND	ND
01443500	Paulins Kill at Blairstown	405844/745715	126	1922-93	195
01445500	Pequest River at Pequest	404950/745843	106	1922-93	156
[1]01447000	Delaware River at Northampton Street, at Easton, Pa.	404130/751215	4,717	ND	ND
01455200	Pohatcong River at New Village	404257/750420	33.3	1960-69	26.6
[1]01456200	Musconetcong River at Beattystown	404848/745032	90.3	ND	ND
01457000	Musconetcong River near Bloomsbury	404020/750340	141	1904-93	236
[1]01457400	Musconetcong River at Riegelsville	403532/751120	156	ND	ND
01457500	Delaware River at Riegelsville	403536/751117	6,328	1906-71	10,827
[1]01461000	Delaware River at Lumberville	402427/750216	6,598	ND	ND
[2]01463500	Delaware River at Trenton	401318/744642	6,780	1913-93	11,620

[1]Water-quality station only.

[2]NASQAN (National Stream Quality Accounting Network) station.

Willingboro, Burlington County. Fusillo (1981) reported the effects of suburban residential development on surface- and ground-water quality in the upper Great Egg Harbor River Basin in Winslow Township, Camden County. Price and Schaefer (1995) reported estimated loads of selected constituents in the Musconetcong, Rockaway, and Whippany River Basins in northern New Jersey.

Several previous studies address surface-water issues in the river basins investigated in this study. Anderson and George (1966) reported the results of a statewide reconnaissance study of the water-quality characteristics of New Jersey streams. Anderson and McCarthy (1963) described the chemical characteristics of streams in the Delaware River Basin. Hely and Olmsted (1963) presented relations between streamflow characteristics and the environment in the Delaware River region. McCarthy and Keighton (1964) described the quality of water in the Delaware River at Trenton, and Parker and others (1964) discussed the water resources of the Delaware River Basin.

Several USGS studies were conducted to evaluate surface-water characteristics and water-quality trends in New Jersey. Low-flow characteristics and flow durations of New Jersey streams were reported by Gillespie and Schopp (1982). Hay and Campbell (1990) identified statewide water-quality trends in New Jersey streams. Robinson and Pak (1993) summarized the water quality of selected New Jersey streams for water years 1987-89. Statewide monthly statistical summaries of surface-water temperatures during 1955-93 were presented by Reed and Hunchak-Kariouk (1995). Buxton and others (1998) presented relations of surface-water quality to streamflow in the Hackensack, Passaic, Elizabeth, and Rahway River Basins for water years 1976-93. Hunchak-Kariouk and others (1999) presented relations of surface-water quality to streamflow in the Atlantic Coastal, lower Delaware River, and Delaware Bay Basins for water years 1976-93.

Acknowledgments

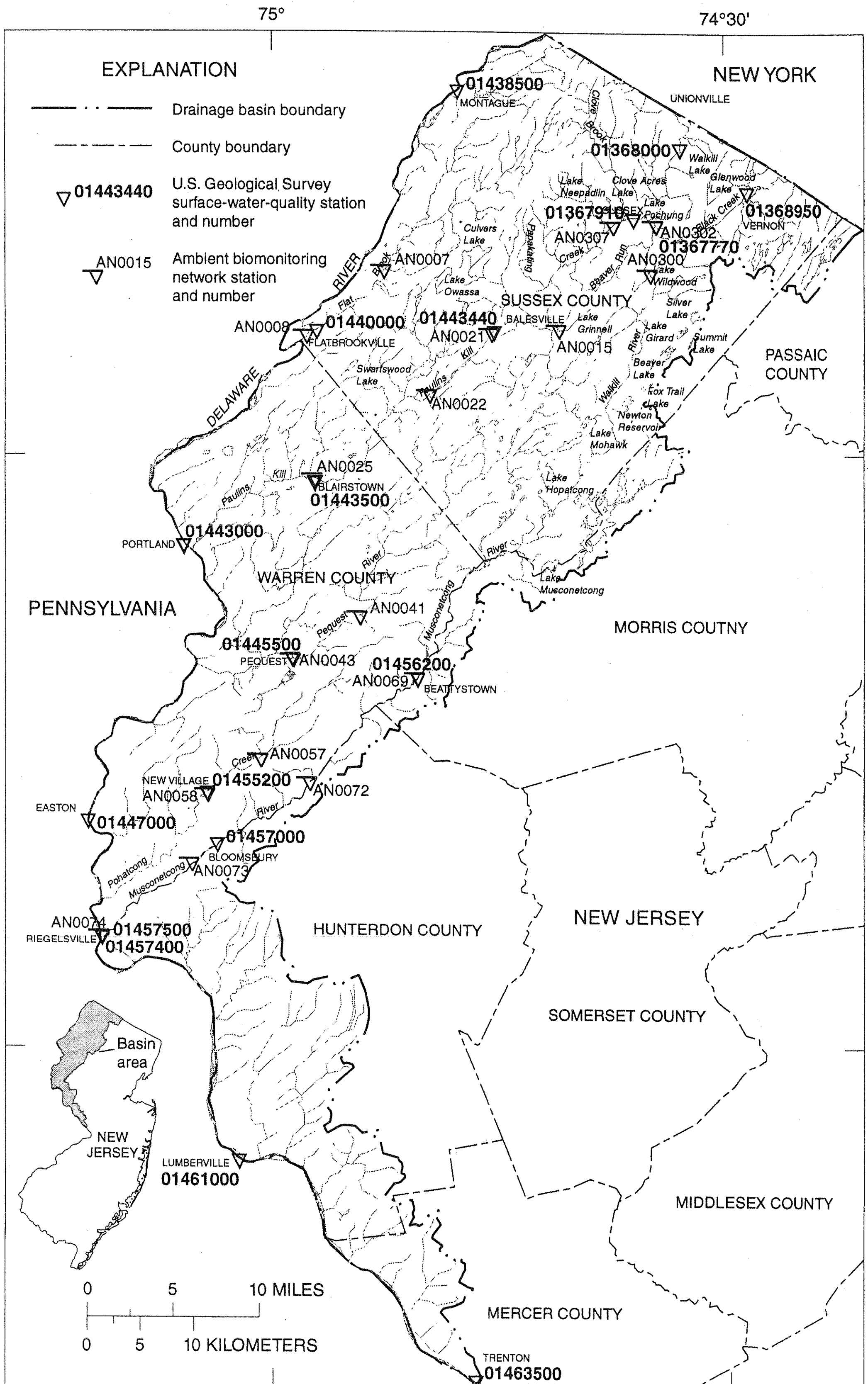
The authors thank Kevin Berry and Daniel VanAbs, NJDEP, Office of Environmental Planning, for their cooperation and assistance in planning this report; William Summer, USGS, for his extensive computer programming for data manipulation and schematics; and Denis Sun, USGS, for his computer expertise in the design and production of the CD-ROM.

Description of the Study Area

The study area, which is in northwestern New Jersey and nearby Pennsylvania and New York, encompasses two river basins—the Wallkill and upper Delaware (fig. 4). Water-quality stations are located within New Jersey unless otherwise indicated.

Wallkill River Basin

The Wallkill River (fig. 4) drains an area of 203 mi^2 and flows 27 miles in a generally northern direction from its headwaters at Lake Mohawk, New Jersey, into New York State (New Jersey Department of Environmental Protection and Energy, 1993). In New Jersey, the Wallkill



Base from U.S. Geological Survey digital data 1:1000,000, 1983, Universal Transverse Mercator projection, Zone 18

Figure 4. Locations of surface-water-quality stations and ambient biomonitoring network stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity.

River is located entirely within Sussex County. The river's major tributaries in New Jersey include Papakating and Black Creeks, and Beaver Run. The major impoundments and lakes in the basin include Lake Mohawk, Newton Reservoir, Fox Trail Lake, Beaver Lake, Lake Girard, Silver Lake, Glenwood Lake, and Lake Grinnel. A mean annual flow of 215 ft^3/s for water years 1938-1981 was estimated at the discontinued surface-water gaging station on the Wallkill River near Unionville, New York (01368000) (U.S. Geological Survey, 1982). Land use in the basin is predominately forested and agricultural, but the amount of developed land is increasing (New Jersey Department of Environmental Protection and Energy, 1993).

Four water-quality stations are located in the Wallkill River Basin (table 1). Two water-quality stations are located on the Wallkill River, and one water-quality station is located on each of the Papakating and Black Creeks. The period of record for water-quality-data collection for each station is shown in figure 5.

Upper Delaware River Basin

The upper Delaware River Basin within New Jersey, from Montague to Trenton, (fig. 4) encompasses six small watersheds that drain into the Delaware River. These watersheds total about 800 mi^2 of drainage area in parts of five New Jersey counties—Sussex, Warren, Morris, Hunterdon, and Mercer. Impoundments in the watersheds include Culvers Lake, Lake Owassa, Swartswood Lake, and Lake Musconetcong. A mean annual flow of 11,620 ft^3/s was estimated for water years 1913-1993 at the surface-water gaging station on the Delaware River at Trenton (01463500) (Bauersfeld and others, 1994).

The upper Delaware River Basin contains 14 water-quality stations (table 1). Six water-quality stations are located on the Delaware River, one of which, Delaware River at Trenton (01463500), is a National Stream Quality Accounting Network (NASQAN) station. Three water-quality stations are on the Musconetcong River, and two are on the Paulins Kill. Flat Brook, Pequest River, and Pohatcong Creek have one water-quality station each located along their reaches. The period of record for water-quality-data collection for each station is shown in figure 5.

Land use within the upper Delaware River Basin differs in each of the six smaller watersheds. Flat Brook is 10 miles long and has a drainage area of about 65 mi^2. The Flat Brook watershed is mostly undeveloped and mountainous, and contains state parks, state forests, and the Delaware Water Gap National Recreation area. The Paulins Kill is 39 miles long and drains an area of about 172 mi^2. Land use in the Paulins Kill watershed is primarily agricultural and forested with increasing amounts of suburban, residential, and commercial development. The Pequest River is 32 miles long with a drainage area of about 158 mi^2. Land use in the Pequest River watershed is mostly recreational with forested and agricultural areas; however, residential and commercial development is increasing. Pohatcong Creek is 28 miles long and drains an area of about 57 mi^2. Land use in the Pohatcong Creek watershed is primarily agricultural. The Musconetcong River drains an area of about 156 mi^2 and is 42 miles long from its headwaters at Lake Hopatcong to its point of discharge into the Delaware River at Riegelsville. Land use in the Musconetcong River watershed is primarily forested; some agricultural land with residential and commercial development is present around the larger towns. The Delaware River from

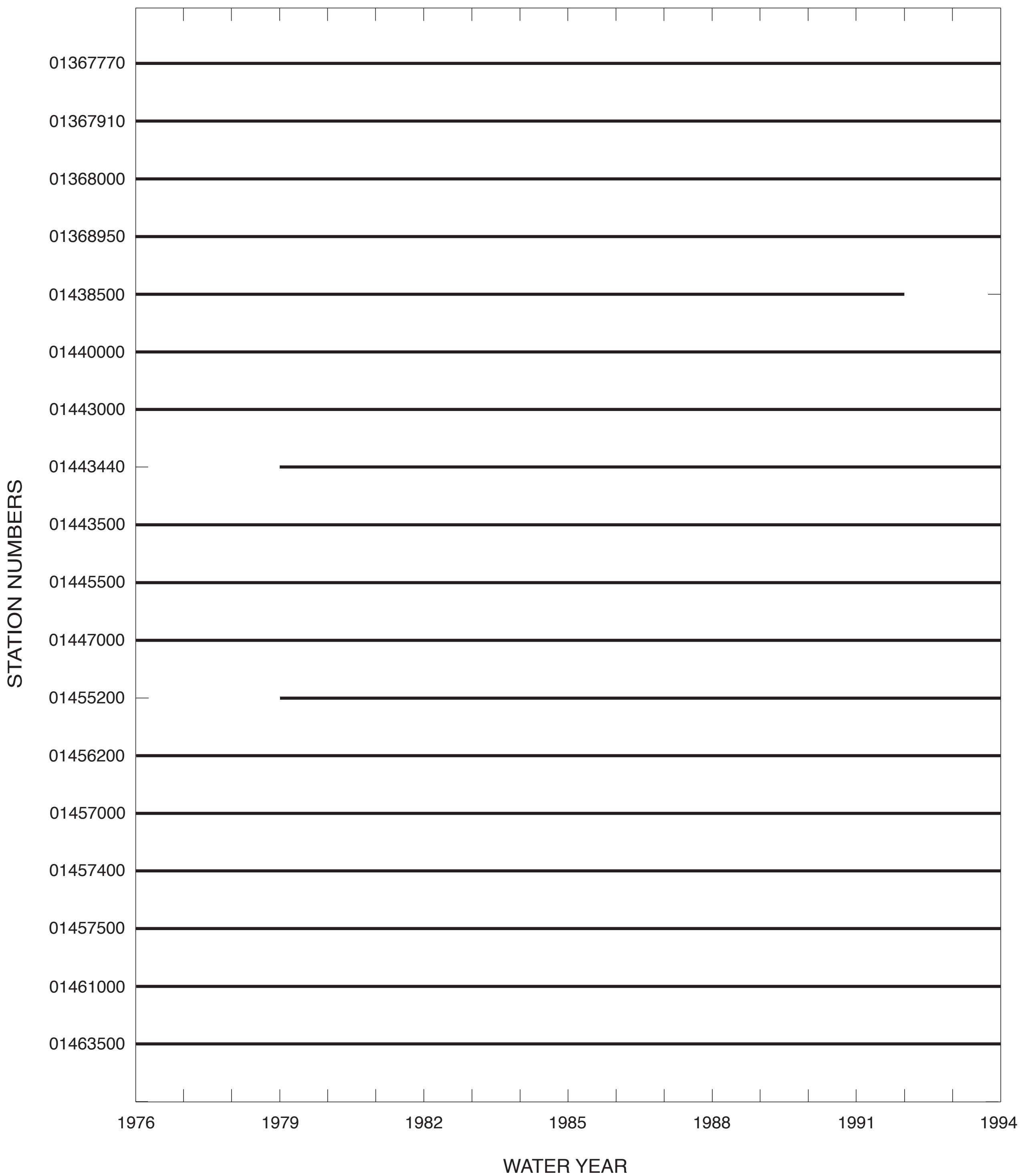


Figure 5. Period of record (at least one measurement per year) of water-quality data for selected stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity, for water years 1976-93. (Station names are given in table 1.)

Riegelsville to Trenton is about 45 miles long with a drainage area of about 200 mi^2 that encompasses about 75 miles of tributary streams. Land use is predominately agricultural and forested with scattered residential and commercial development on the rise (New Jersey Department of Environmental Protection and Energy, 1993).

METHODS OF STUDY

The following section describes the methods and criteria used for the selection of constituents, sites, and data sources. Methods for data preparation, quality assurance, and statistical analyses are described.

Selection of Constituents, Sites, and Data Sources

Constituents were chosen on the basis of their usefulness as indicators of the quality of the surface water and usefulness in developing effective surface-water-quality management practices. The 18 constituents selected include aggregate water properties (properties that include concentrations of several different chemical species), major ions, dissolved oxygen, nutrients, metals, and bacteria (table 2).

The Wallkill and upper Delaware River basins contain 17 water-quality stations (table 1) with data from water years 1976-93 that are part of the USGS/NJDEP Cooperative Ambient Surface Water Quality Network and 1 water-quality station that is part of NASQAN. Six of the stations also are operated as surface-water gaging stations. These stations were chosen on the basis of their locations and periods of record.

Water-quality and streamflow data were retrieved from the NWIS data base. Water-quality data for water years 1976-93 are available for 15 stations; partial records are available for the other 3 stations (fig. 5). Streamflow data are available for six water-quality stations for water years 1976-93.

Data Preparation

Water-quality and instantaneous-streamflow data retrieved from the NWIS data base were reviewed extensively for accuracy and were maintained in a SAS data base. Values of dissolved nitrate plus nitrite and dissolved nitrite were substituted for values of total nitrate plus nitrite and total nitrite where the latter were missing. This substitution is appropriate because nitrate and nitrite are anions that are poorly absorbed to mineral surfaces, and therefore, are present in ambient water almost exclusively as dissolved species (Hem, 1985). Where both dissolved and total concentration values were available for nitrate plus nitrite and nitrite, little or no difference was observed.

Water-Quality Data

Values for the fraction of dissolved oxygen at saturation and concentrations of hardness, total organic carbon, and total nitrogen were calculated.

Table 2. Selected constituents and reporting units

[mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium; Cl, chloride; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters]

Constituent	Reporting unit
Alkalinity	mg/L as $CaCO_3$
Hardness[1]	mg/L as $CaCO_3$
Total organic carbon[1]	mg/L as C
Suspended sediment	mg/L
Dissolved solids	mg/L
Dissolved sodium	mg/L as Na
Dissolved chloride	mg/L as Cl
Dissolved oxygen	mg/L
Fraction of dissolved oxygen at saturation[1]	Percent
Total phosphorus	mg/L as P
Total nitrogen[1]	mg/L as N
Total nitrate plus nitrite	mg/L as N
Total nitrite	mg/L as N
Total ammonia plus organic nitrogen	mg/L as N
Total ammonia	mg/L as N
Total boron	µg/L as B
Total lead	µg/L as Pb
Fecal coliform bacteria	MPN/100 mL

[1] Values of constituent or property are calculated.

The fraction of dissolved oxygen at saturation is the ratio of the measured dissolved oxygen concentration to the dissolved oxygen concentration at saturation, in percent, computed by using the following equation:

$$FDO = 100 \left[\frac{DO}{DO_{sat}}\right] , \qquad (1)$$

where

FDO = fraction of dissolved oxygen at saturation;
DO = dissolved oxygen concentration, in milligrams per liter; and
DO_{sat} = dissolved oxygen at saturation, in milligrams per liter.

The following evaluation by R.F. Weiss (R.J. Pickering, U.S. Geological Survey, written commun., 1981) was used to calculate the concentration of dissolved oxygen at saturation:

$$\ln\ DO_{sat} = A_1 + A_2 \frac{100}{T} + A_3 \ln\frac{T}{100} + A_4 \frac{T}{100} + S\left[B_1 + B_2\frac{T}{100} + B_3 \left(\frac{T}{100}\right)^2\right], \qquad (2)$$

where

ln = natural logarithm;
DO_{sat} = dissolved oxygen concentration at saturation;
A_1 = 173.4292;
A_2 = 249.6339;
A_3 = 143.3483;
A_4 = 21.8492;
B_1 = 0.033096;
B_2 = 0.014259;
B_3 = 0.001700;
T = temperature, in degrees Kelvin; and
S = salinity, in grams per kilogram.

The concentration of total hardness, expressed as calcium carbonate in milligrams per liter (mg/L as $CaCO_3$), was calculated as follows:

$$\text{Total hardness} = 2.497\ [\text{Ca}] + 4.118\ [\text{Mg}], \qquad (3)$$

where

Ca is the dissolved calcium concentration, in milligrams per liter, and
Mg is the dissolved magnesium concentration, in milligrams per liter.

Some total organic carbon concentrations were calculated as the sum of the dissolved and particulate organic carbon concentrations; all are expressed as carbon in milligrams per liter (mg/L as C). The concentration of total nitrogen was calculated as the sum of the total nitrate plus nitrite and total ammonia plus organic nitrogen concentrations; all are expressed as nitrogen in milligrams per liter (mg/L as N).

Estimated loads were calculated for each of 16 constituents (no loads were calculated for the fraction of dissolved oxygen at saturation or fecal coliform bacteria) by multiplying the concentration by the instantaneous streamflow and applying unit conversions to yield an instream load in pounds per day, as follows:

$$\text{load (lb/d)} = \text{concentration (mg/L)} \times \text{streamflow (ft}^3\text{/s)} \times 2.20462 \times 10^{-6}\ \text{lb/mg} \times 86{,}400\ \text{s/d} \times 28.316\ \text{L/ft}^3. \quad (4)$$

When concentrations are in micrograms per liter, the conversion is

$$\text{load (lb/d)} = \text{concentration (}\mu\text{g/L)} \times \text{streamflow (ft}^3\text{/s)} \times 2.20462 \times 10^{-9}\ \text{lb/}\mu\text{g} \times 86{,}400\ \text{s/d} \times 28.316\ \text{L/ft}^3. \quad (5)$$

Steps were taken to ensure consistent data quality because of the long period over which the data were collected. Water-quality data for the period of record, water years 1976 to 1993, were reviewed to identify any obvious data inconsistencies (that is, data outliers), because of changes in laboratory remark codes, reporting levels, analytical methods, project data-entry protocols, project data-quality review protocols, sample preservation, and sample processing. Many of these factors were known to have changed over the 18-year period of record; this may have affected the quality of the data (in this study, only data outliers were of concern). Breidt and others (1991) reported finding similar water-quality-data anomalies in this period of record. This review resulted in the removal from the data base of less than 1 percent of the original data set. Most of the corrections (removal) were for field measurements made prior to 1985 and for data that had been entered into the data base manually from paper records.

No attempt was made to identify data-biasing effects on the median values. The data review was performed prior to statistical analysis and interpretation. Data in the 0.025 and 0.975 percentiles for each station were candidates for being data outliers. In addition, plots of constituent concentrations by month, as well as constituent concentrations as a function of streamflow, were visually inspected for potential outliers. Data were evaluated by month of sample collection to determine whether a value was a seasonal outlier, and by discharge to determine whether the value was an outlier because it was affected by dilution during high flow. In addition, changes in laboratory reporting remark codes and censoring limits were reviewed. The analytical method used for the years in which the censored data were collected was determined from tables reported by Friedman and Fishman (1989) and Fishman and others (1994), and the analytical method lower-reporting limit was checked against those reported for that analytical method in Skougstad and others (1979), Fishman and Friedman (1989), and Wershaw and others (1987). The outliers were evaluated by considering:

(1) concentrations of related constituents in the same sample,
(2) the constituent concentration at sites upstream or downstream,
(3) the effects of an early or late change of season,
(4) the number of measurements for the month or season,
(5) the presence of point-source discharges upstream of the sampling site,
(6) the possibility of constituent inputs from seasonal nonpoint-source runoff,
(7) streamflow regulation,
(8) the streamflow discharge, and
(9) surrounding geology and physiographic province.

Outliers were deleted only if no plausible explanation based on the factors listed above was found.

Streamflow Data

Instantaneous-streamflow values were used when available to calculate instream loads; when those values were not available, an estimated daily mean value was used. Continuous streamflow records from gages were available for six water-quality stations and were used to determine instantaneous streamflows. For the 12 stations with no streamflow data, a correlation with an adjacent gaging station was developed, and a daily mean streamflow was estimated from the correlation.

As with the water-quality data, steps were taken to ensure consistent data quality because of the long period over which the data were collected. Streamflow data for the period of record, water years 1976 to 1993, were reviewed to identify any apparent or obvious data inconsistencies (that is, data outliers), many of which were due to data entry errors. The review was performed prior to statistical analysis and interpretation. This review resulted in the removal from the data base of less than 2 percent of the original data set.

Streamflow data from each surface-water-quality monitoring station were regressed on daily mean values from the NWIS data base to ensure that the values were consistent. Residuals of plots of streamflow as a function of gage height, and streamflow at adjacent or nearby continuous-record stations, were evaluated. Outliers were identified as those values with studentized residuals larger than an absolute value of 2 and were further evaluated by considering:

(1) the time of sample collection,
(2) upstream flow regulation, and
(3) streamflow at nearby stations.

If no plausible explanation for the apparent inconsistency of a data point (an outlier), based on the factors listed above, was found, the daily mean values were used. These new values were double-checked by plotting them on a graph of field specific conductance as a function of flow duration. Specific conductance would be expected to be inversely proportional to streamflow, except during times of snow melt. The measurement of specific conductance is independent of the measurement of streamflow.

Flow-Duration Data

Flow durations for each water-quality station were retrieved as data from WATSTORE (National Water Data Storage and Retrieval System), as output from computer simulation using MOVE.1 (Maintenance of Variance Extension, Type 1) (Hirsch, 1982), and as drainage area adjustments from nearby surface-water gaging stations (table 3).

Flow-duration tables were developed by using the Daily Value Statistics (DVSTAT) computer program in the WATSTORE data base for 6 of the 18 surface-water-quality stations that had continuous streamflow records. Flow-duration curves show the percentage of time that a particular discharge is exceeded, and a flow-duration point is a discharge value, in cubic feet per second, interpolated from a duration table for a particular percentage of time. For the purpose of this study, the 25-percent duration point was used to determine high-flow conditions, and the 75-percent duration point was used to determine the low-flow conditions. The resulting values for each station are shown in table 3.

Table 3. Estimated flow-duration values of mean daily discharge and data source for surface-water-quality stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity

[ft^3/s, cubic feet per second; %, percent; WATSTORE, National Water Data Storage and Retrieval System; MOVE.1, Maintenance of Variance Extension, Type 1; Drainage Area, adjusted on basis of drainage area from nearby streamgaging stations]

Station number	Flow duration values of mean daily discharge, in ft^3/s 25%	Flow duration values of mean daily discharge, in ft^3/s 75%	Source
01367770	105	28.4	MOVE.1
01367910	80.9	12.5	MOVE.1
01368000	272	53.0	WATSTORE
01368950	32.3	9.0	MOVE.1
01438500	6,800	2,080	WATSTORE
01440000	137	32.7	WATSTORE
01443000	8,920	2,572	Drainage area
01443440	146	35.4	MOVE.1
01443500	252	63.2	WATSTORE
01445500	206	60.2	WATSTORE
01447000	10,100	2,912	Drainage area
01455200	45.1	9.8	MOVE.1
01456200	211	58.1	MOVE.1
01457000	306	110	WATSTORE
01457400	334	124	MOVE.1
01457500	13,600	4,040	WATSTORE
01461000	14,200	4,390	Drainage area
01463500	14,600	4,510	WATSTORE

Base-flow relations were determined for 7 of the 18 water-quality gaging stations by correlating instantaneous low-flow discharge at the partial-record station with the mean daily discharge at a nearby “index” continuous-record gaging station. A streamflow record extension technique, MOVE.1, was used to develop the correlations (Hirsch, 1982). MOVE.1 was used because it was adequate for the purposes of this study, in which flow duration was used only to divide streamflow data into groups of high, moderate, and low ranges for trend analysis. The relations are made in the following form:

$$LQ_{PR} = u_{PR} + \left(\frac{S_{PR}}{S_{CR}}\right)[LQ_{CR} - u_{CR}], \qquad (6)$$

where

LQ_{PR} = the base-10 logarithm of the partial-record streamflow,
u_{PR} = the mean of the logarithms of partial-record streamflow,
S_{PR} = the standard deviation of logarithms of partial-record streamflow,
LQ_{CR} = the base-10 logarithm of the index continuous-record streamflow,
u_{CR} = the mean of the logarithms of the index continuous-record streamflows, and
S_{CR} = the standard deviation of logarithms of the index continuous-record streamflow.

The flow-duration values for three partial-record stations on the Delaware River—01443000, at Portland, Pennsylvania; 01447000, at Northampton Street, at Easton, Pennsylvania; and 01461000, at Lumberville—were estimated using drainage-area adjustments from nearby surface-water gaging stations (table 3).

Statistical Analyses

Concentration measurements were selected for use in the analyses only if they had an associated, nonzero value of streamflow (instantaneous or estimated); only one observation per constituent per day was used. Concentration values were reported as “uncensored,” “less-than,” and “greater-than”. Concentrations of constituents other than fecal coliform bacteria were either uncensored or less-than values; some measurements of fecal coliform bacteria were greater-than values.

Median concentrations and relations of surface-water quality to streamflow were determined for each constituent and station. The following types of relations of surface-water quality to streamflow are presented graphically by constituent for each station in appendixes 1-18: concentration to streamflow, load to streamflow, and trends concentrations during low and high flows.

Calculation of Medians

Medians were calculated for measurements made during two periods—the entire period of study (water years 1976-93) and the last 5 years of the period of study (water years 1989-93). The method of calculation depended upon whether the data set contained censored values. For data sets with only uncensored data, the values were ranked and the median was calculated as the 50th percentile. For data sets with less-than values but no greater-than values, medians were calculated by using the adjusted maximum likelihood method described in Cohn (1988) and in Helsel and Cohn (1988). If the data set contained either an insufficient number of observations needed to use this method or contained greater-than values, the median was determined by manually ranking and identifying the 50th percentile value.

Determination of Relations of Surface-Water Quality to Streamflow

The processes used to determine relations between concentration and streamflow, relation between load and streamflow, and trends in concentrations during high and low flows, are described in this section.

Relations of concentration to streamflow

Water quality is strongly influenced by biological activity, which is seasonal; therefore, relations between concentration and streamflow were developed by using (1) all measurements, (2) growing-season measurements only, and (3) nongrowing-season measurements only. The growing season in New Jersey is from April 1 through October 31; the nongrowing season is from November 1 through March 31. The dates for the growing and nongrowing seasons were based on the average times of the first and final frosts in New Jersey (Ruffner and Bair, 1977). All relations take the following form:

$$\log(CONC) = SLOPE \times \log(FLOW) + INT \ , \qquad (7)$$

where

log = base-10 logarithm;
CONC = constituent concentration, in indicated units;
SLOPE = the slope of the relation;
FLOW = streamflow, in cubic feet per second; and
INT = the intercept of the relation.

These relations were developed by using Tobit regression (Cohn, 1988), which includes less-than values. For Tobit regression in this report, greater-than values were considered to be uncensored. Where there were no less-than values, this method resulted in the same values of SLOPE and INT as those calculated by ordinary least-squares regression. A goodness-of-fit value such as the correlation coefficient is not presented; the Tobit method does not generate such a value.

A relation of water quality to streamflow at a given station was developed only if at least nine uncensored concentration values were available. T.A. Cohn (U.S. Geological Survey, written commun., 1995) noted that at least nine uncensored values were needed to use the Tobit method with two unknowns. Nine uncensored values were sometimes insufficient to calculate statistically significant results.

A relation using all measurements is reported only if the value of SLOPE was different from zero at the 0.05 level of significance; otherwise, a SLOPE of “0” is reported. A “not determined” value of SLOPE is reported if the data were insufficient to conduct the analysis. A value of INT was calculated only if the value of SLOPE was different from zero.

Each set of seasonal relations was developed and reported by using the methods just described if an analysis of covariance (described below) indicated that the seasonal relations were different from one another at the 0.05 level of significance. The analysis of covariance was conducted only if there were at least nine uncensored measurements during each season.

The analysis of covariance followed the approach in Helsel and Hirsch (1992), except that Tobit regression was used in place of ordinary least-squares regression. The analysis determined whether a complex model with a seasonal component was significantly better than a simple model without a seasonal component. The simple model is given in equation 7; the complex model is given in equation 8.

$$\log(CONC) = [SLOPE_1 \times \log(FLOW) + INT_1] + [SLOPE_2 \times \log(FLOW) + INT_2 \times I] , \quad (8)$$

where

- log = base-10 logarithm;
- $CONC$ = constituent concentration, in indicated units;
- $FLOW$ = streamflow, in cubic feet per second;
- I = an index for season (I = 0 for the nongrowing season, and I = 1 for the growing season);
- $SLOPE_1$ = the slope for the nongrowing season;
- INT_1 = the intercept for the nongrowing season;
- $SLOPE_2$ = the difference between the growing- and nongrowing-season slopes; and
- INT_2 = the difference between the growing- and nongrowing-season intercepts.

A test statistic different from that used by Helsel and Hirsch (1992) was calculated because of the use of Tobit regression in the analysis of covariance (T.A. Cohn, written commun., 1995). The value, X, was determined from the results of the simple and complex models, then compared to the value of the chi-square distribution with 2 degrees of freedom and a 0.05 level of significance. If the value of X equalled or exceeded the corresponding value of chi-square distribution, the seasonal relations differed from one another in SLOPE or INT or both. Whether SLOPE was different or INT was different was not determined. The value of X was calculated as follows:

$$X = -2 \times \ln[(LKHD_S)/(LKHD_C)] , \quad (9)$$

where

- X = the test statistic,
- ln = natural logarithm,
- $LKHD_S$ = the likelihood of the simple relation, and
- $LKHD_C$ = the likelihood of the complex relation.

The detection level of each constituent at each station is required to conduct Tobit regression. The detection limits for constituents with only uncensored values were determined by considering the method of analysis and the smallest concentration measured at all stations. These values (table 4) are either equal to the smallest less-than value or slightly less than the smallest uncensored value measured at all stations during water years 1976-93.

Relations of load to streamflow

The relation of load to streamflow was developed by using the same procedures as those used to develop the relation of concentration to streamflow for all measurements. Loads were not determined for fraction of dissolved oxygen at saturation and fecal coliform bacteria. For each constituent and station, the detection limit was set equal to the smallest uncensored load measured at the station. The load relation takes the following form:

$$\log(LOAD) = SLOPE \times \log(FLOW) + INT , \quad (10)$$

where

log = base-10 logarithm;
LOAD = constituent load, in pounds per day;
SLOPE = the slope of the relation;
FLOW = streamflow, in cubic feet per second; and
INT = the intercept of the relation.

A smoothed relation of load to streamflow is shown for a constituent at each station at which there were 10 or more values. This relation was determined by using the SM smoothing routine in SAS (SAS Institute, Inc., 1990, p. 416).

Trends in concentrations during low and high flows

Trends in concentrations during low and high flows were tested to determine whether the probability distribution from which the observations come increased or decreased during water years 1976-93. The 75-percent and 25-percent values of the flow durations were used to divide the measurements for each station into a low- or high-flow group, respectively. Concentrations during low flows were designated as those measured at streamflows less than or equal to the daily mean streamflow that was exceeded 75 percent of the time; concentrations during high flows were designated as those measured at streamflows greater than the daily mean streamflow that was exceeded 25 percent of the time.

For both the low- and high-flow data sets, trend tests were conducted only if there was at least one measurement in each data set consisting of not less than four of the six water years in each one-third of the period of study (18 years). This requirement followed a recommendation made in Helsel and Hirsch (1992) that there be no less than 20 percent of the total measurements in each one-third of the period being tested for trends. Therefore, 12 is the minimum number of low- or high-flow measurements used in a test. Fewer data could have been tested for trends. The fewer the data, however, the less likely it is that the measured concentrations represent conditions during the period tested and, therefore, the less likely that the results of the trend test are accurate.

Table 4. Estimated detection limits for selected constituents measured in the Wallkill and upper Delaware River Basins, New Jersey and vicinity, water years 1976-93

[mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium; Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters]

Constituent	Estimated detection limit
Alkalinity, mg/L as $CaCO_3$	1
Hardness, mg/L as $CaCO_3$	10
Total organic carbon, mg/L as C	.2
Suspended sediment, mg/L	1
Dissolved solids, mg/L	10
Dissolved sodium, mg/L as Na	1
Dissolved chloride, mg/L as Cl	1
Dissolved oxygen, mg/L	.5
Fraction of dissolved oxygen at saturation, %	5
Total phosphorus, mg/L as P	.01
Total nitrogen, mg/L as N	.1
Total nitrate plus nitrite, mg/L as N	.05
Total nitrite, mg/L as N	.002
Total ammonia plus total organic nitrogen, mg/L as N	.03
Total ammonia, mg/L as N	.01
Total boron, mg/L as B	10
Total lead, mg/L as Pb	1
Fecal coliform bacteria, MPN/100 mL	2

The seasonal Kendall's tau method (Hirsch and others, 1982) was used to examine the data for trends. For both the low- and high-flow data sets, the test was run on the median of the measured concentrations for each water year because of variations in sampling frequency (Hirsch and others, 1982). The test statistic, tau, was calculated from the relative sizes of the annual median concentrations, then tested to see whether it was significantly different from zero. For this report, a trend is indicated if the value of tau was significantly different from zero at the 0.05 level. Seasonality was not included in the test.

A value of SLOPE is reported for constituent concentrations during either low or high flows if a trend was indicated. The value of SLOPE is the median of the slopes of all pairs of annual median concentrations. A SLOPE value of "0" is reported if sufficient data were available for a trend test, but a trend was not indicated; a "not determined" value is reported if there were insufficient data for a test. The units of SLOPE are units of concentration per year.

No value is reported for the intercept of the relation showing the trend of concentration through time. An intercept value is calculated by the trend test only for the purpose of showing the trend in a plot.

Multiple trend tests were conducted on data sets with censored values; the censored values were set at their minimum and maximum possible values. Two tests were conducted on data sets with less-than values but no greater-than values—one with the less-than values set to the reporting limit and one with the less-than values set to zero. Two tests were conducted on data sets with greater-than values but no less-than values—one with the greater-than values set to the reporting limit and one with the greater-than values set to 10^7 (a value greater than all reported uncensored values). Four tests were conducted on data sets with both less-than and greater-than values—one with each of the permutations of the greater-than and less-than values discussed above.

For each data set with censored values, the results are reported only for the trend relation with the least significant value for tau. Because of the uncertainty of the censored data, a significant trend slope is reported only if a slope is determined when the censored data are set equal to both their minimum and maximum values.

RELATIONS OF SURFACE-WATER QUALITY TO STREAMFLOW

An understanding of the relation of surface-water quality to streamflow is important for assessment of the relative contributions of point sources, ground water, and storm runoff to instream loads (Buxton and others, 1998). Point sources (permitted discharges) release constituents to a stream at a relatively constant rate, independent of the receiving streamflow conditions. Ground-water contributions to a stream are somewhat constant, although they vary slightly with season and precipitation rate. Storm-runoff contributions to a stream are intermittent, depending on storm intensity and frequency, and occur only during high flows. Instream constituent concentrations are a summation of the contributions from these constant (point source and ground water) and intermittent (storm runoff) sources.

To describe the relation of surface-water quality to streamflow, the data analyses are presented in three ways. First, three aspects of the relation of surface-water quality to streamflow (concentration to streamflow, load to streamflow, and trends in concentrations during low and high flows) are presented graphically by constituent for each station in appendixes 1-18 (on CD-ROM). Second, the data analyses are presented by basin in the text; tables for each station list the median concentrations, the regression slopes of concentration and load to streamflow, and the directions of the trends in concentrations during low and high flows for all constituents along with the AMNET impairment status at and near the station. Third, relations are presented in schematics showing the regional trends in concentrations during low and high flows and the slopes of load to streamflow by constituent.

Appendixes 1-18 illustrate the relations of surface-water quality to streamflow by constituent for each station with three graphs. Figure 6 is an example page from appendix 12. The first graph shows the relation of concentration to streamflow. Plots of concentration to streamflow indicate how instream constituent concentrations vary with streamflow, but do not indicate the relative contributions of constant and intermittent sources. Data for stations on streams that drain developed areas show the most scatter, especially for inorganic constituents such as sodium, chloride, and hardness. Relations between concentration and streamflow were developed by using (1) all measurements, (2) only measurements collected during the growing season, and (3) only measurements collected during the nongrowing season. Growing-season measurements are shown with open symbols, and nongrowing-season measurements are shown with crisscrossed symbols. Different symbols are used to show uncensored and censored values. For each group of measurements, the number of observations and values of slope and intercept are listed, and a regression line is shown when the slope of concentration to streamflow is different from zero at the 0.05 significance level. A seasonal dependency is indicated when the relations of concentration to streamflow for the growing- and nongrowing-season measurements are different. The 75 and 25 percentiles of the flow duration also are indicated.

The second graph in figure 6 shows the relation of load to streamflow. The regression slope of load to streamflow indicates the relative contributions of constant and intermittent sources to the instream load. The steeper the slope, the greater the contribution during increased streamflow from storm runoff (intermittent sources). Relations between load and streamflow were developed using all measurements. Different symbols are used to show uncensored and censored values. The number of observations and values of slope and intercept are shown, and a regression line is drawn when the slope is different from zero at the 0.05 significance level. A smoothed relation between load and streamflow is shown when there are 10 or more observations. The 75 and 25 percentiles of the flow duration also are indicated.

The third graph in figure 6 shows the trends in concentrations during low and high flows. Trends in constituent concentrations during high and low flows can indicate changes through time in the contributions from intermittent and constant sources, respectively. Positive trends during high flows indicate an increase in the storm runoff contributions through time, whereas negative trends indicate a decrease in the storm runoff contributions. Positive trends during low flows indicate an increase in the contributions from point sources and ground water through time, whereas negative trends indicate a decrease in the contributions from point sources and ground water. Measurements during low flows are shown with open symbols, and measurements during

APPENDIX 12. Relations of constituent concentration and load to streamflow and trends in concentration with time

TOTAL NITRATE PLUS NITRITE

01367770 WALLKILL RIVER NEAR SUSSEX, N.J.

[NVALUES, number of values; LOG, base-10 logarithm; CONC, concentration in indicated units; INT, intercept; FLOW, streamflow in cubic feet per second; NWYS, number of water years during which at least one measurement was made; a slope value of '0' indicates that the slope is not significantly different from zero; ND, not determined; CaCO3, calcium carbonate; C, carbon; N, nitrogen; P, phosphorus; Pb, lead; B, boron; Cl, chloride; Na, sodium; MOST PROBABLE NUMBER INDEX is per 100 milliliters]

RELATION OF CONCENTRATION TO STREAMFLOW

CONCENTRATION

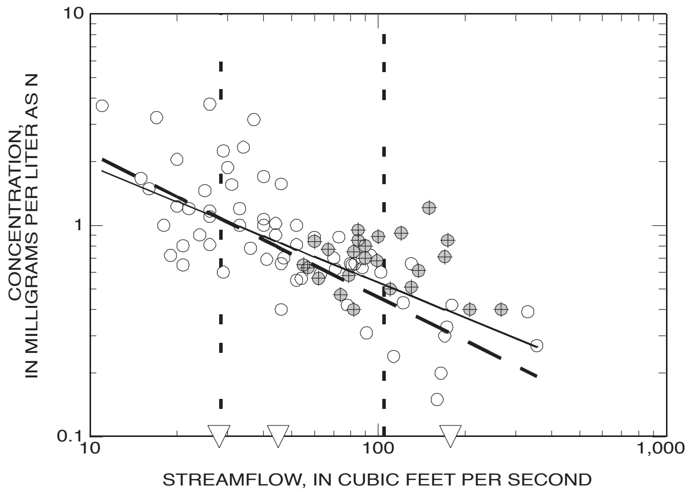
GROWING SEASON		NONGROWING SEASON
○	UNCENSORED VALUE	⊕
▽	'LESS-THAN' VALUE	▽
△	'GREATER-THAN' VALUE	△

RELATION: LOG(CONC) = SLOPE*LOG(FLOW) + INT

	VALUES	NVALUES	SLOPE	INT
———	ALL VALUES	91	-0.55	0.83
	[SEASONAL RELATIONS DETERMINED; THEY ARE DIFFERENT FROM ONE ANOTHER]			
— —	GROWING SEASON	67	-0.68	1.02
	NONGROWING SEASON	24	0	ND

STREAMFLOW EXCEEDED
INDICATED PERCENTAGE OF TIME

- - 75 PERCENT   - - - 25 PERCENT



RELATION OF LOAD TO STREAMFLOW

LOAD

×	UNCENSORED VALUE
▼	'LESS-THAN' VALUE

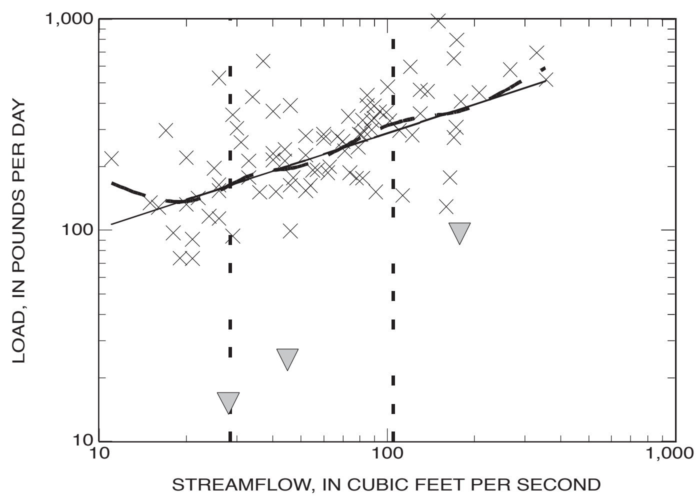
RELATION: LOG(LOAD) = SLOPE*LOG(FLOW) + INT

	VALUES	NVALUES	SLOPE	INT
———	ALL VALUES	91	0.45	1.56

— — SMOOTHED RELATION BETWEEN LOAD AND FLOW (SHOWN IF THERE ARE 10 OR MORE VALUES)

STREAMFLOW EXCEEDED
INDICATED PERCENTAGE OF TIME

- - 75 PERCENT   - - - 25 PERCENT



TRENDS IN LOW- AND HIGH-FLOW CONCENTRATIONS

CONCENTRATION

LOW FLOW		HIGH FLOW
○	UNCENSORED VALUE	⊕
▽	'LESS-THAN' VALUE	▽
△	'GREATER-THAN' VALUE	△

TRENDS IN CONCENTRATION

	VALUES	NVALUES	NWYS	SLOPE
— —	LOW FLOW	18	13	0.13
- - -	HIGH FLOW	20	14	0.04

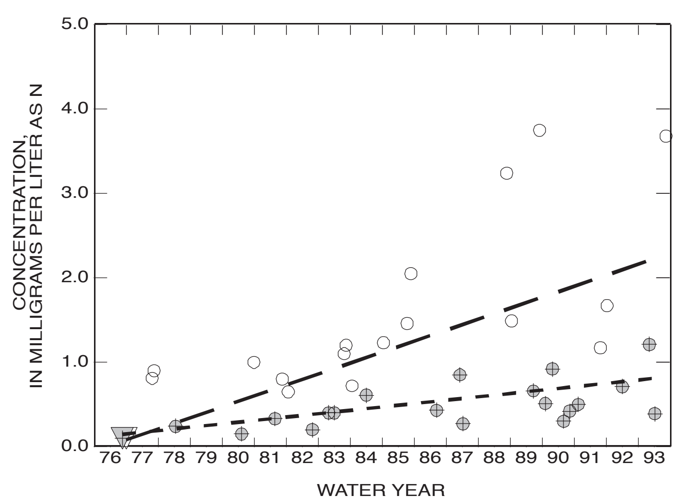


Figure 6. Example page from Appendix 12 of graphs showing relation of concentration to streamflow, relation of load to streamflow, and trends in low- and high-flow concentrations for nitrate plus nitrite at a station on the Wallkill River near Sussex, New Jersey, for water years 1976-93. (Available on CD-ROM)

high flows are shown with crisscrossed symbols. Different symbols are used to show uncensored and censored values. The numbers of observations and water years during which at least one measurement was made are shown for each group of measurements. Trends are indicated by regression lines and slope values when the seasonal Kendall tau value is significant.

Analysis of Relations by Basin

Median concentrations, regression slopes of concentration and load to streamflow, and directions of the trends in concentrations during low and high flows for each constituent are presented in tables 5 through 22. Constituents that show seasonal dependency (the relations of concentration to streamflow for the growing and nongrowing seasons are different) and the 1993 AMNET impairment status in the vicinity (at and within five miles upstream and downstream) of the surface-water-quality station also are listed. Median concentrations were calculated for two periods, the entire period of study (water years 1976-93) and the last five years of the period of study (water years 1989-93) to provide a visual comparison of water quality to the AMNET impairment status. In tables 5 through 22, the direction of trends in concentrations during low and high flows are represented by +, -, 0, and NA symbols. Results of statistical tests are discussed for each river basin. One- to four-letter abbreviations are used for each water-quality constituent throughout the discussion. (See Conversions Factors and Abbreviated Water-Quality Units, p. ix.)

Slopes of load to streamflow for each constituent are divided into three ranges in order to describe the relative contributions of constant (point source and ground water) and intermittent (storm runoff) sources to instream load. High-range slopes are greater than or equal to 75 percent of the interval between the minimum and maximum slopes. For stations with slopes in the high range, a larger contribution from storm runoff to instream load occurs than at other sites, indicating an increased relative importance of nonpoint sources at these sites. Moderate-range slopes are greater than 25 percent and less than 75 percent of the interval between the minimum and maximum slopes. Low-range slopes are less than or equal to 25 percent of the interval between the minimum and maximum slopes. For stations with slopes in the low range, a smaller contribution from storm runoff to instream load occurs than at other sites, indicating an increased relative importance of continuous sources at these sites. For constituents with large slopes of load to streamflow (greater than 0.8), however, storm runoff is most likely the more significant contributor to instream loads, even for stations with load slopes in the low range.

In 1992, the Bureau of Water Monitoring of the NJDEP reactivated the AMNET to monitor benthic-macroinvertebrate populations at 457 stations in the major drainage basins in New Jersey. The objective of this biomonitoring program is to provide long-term, basin-wide, biological data for surface water (New Jersey Department of Environmental Protection, 1994a and 1994b). Stations will be monitored every 5 to 6 years, a realistic temporal lag between the cessation and recovery of a biological community from a perturbation. Biomonitoring uses instream populations of benthic macroinvertebrates as indicators of the quality of the surface water. Species of the instream macroinvertebrate community occupy distinct niches based on their tolerance to environmental conditions; these communities can change as environmental conditions change. Benthic-community biological impairment is indicated by (1) the absence of contaminant-sensitive macroinvertebrate taxa, (2) excessive dominance by certain taxon, (3) low overall taxa richness, or (4) perceptible shifts in community structure relative to a reference condition.

The NJDEP sampling techniques and biometric assessments were modified from U.S. Environmental Protection Agency protocols to integrate community, population, and functional parameters into one easily understood evaluation of biological integrity (New Jersey Department of Environmental Protection, 1994a and 1994b). The integrated assessment results at each station were given an AMNET impairment status rating of non-impaired—the benthic community is comparable to communities found in other undisturbed streams within the region and is characterized by a maximum taxa richness, balanced taxa groups, and good representation of intolerant individuals; moderately impaired—the macroinvertebrate richness and community balance are reduced and intolerant taxa are absent because of taxa composition changes; or severely impaired—the benthic community has dramatically changed and macroinvertebrates are dominated by a few tolerant taxa. When used together with chemical and physical monitoring, benthic macroinvertebrate monitoring is a good indicator of stream quality and possible sources of impairment.

Wallkill River Basin

The Wallkill River Basin has four water-quality stations (tables 5a and b through 8a and b), two on the Wallkill River and one each on Papakating and Black Creeks.

Wallkill River

The two water-quality stations on the Wallkill River are station 01367770 near Sussex and station 01368000 near Unionville, New York. Comparisons of the 5-year and period-of-record medians at each station show slight to moderate differences (tables 5a and 6a). The largest differences are for TP, NH4, and BACT at station 01367770 and for NH4 and PB at station 01368000. DO, FDO, NO32, and BACT show seasonal dependency at both stations, as do ALK, TOC, NA, and CL at station 01367770 and NH4 at station 01368000. The regression slopes of load to streamflow for SS, DS, CL, TP, TN, NO32, and TAON at station 01367770 and TOC, SS, and TAON at station 01368000 are in the low range. The regression slopes of load to streamflow are smaller for TN and NO32 at the upstream station (01367770) and for SS at the downstream station (01368000) than those at any other station in the study area. In the downstream direction (stations 01367770 to 01368000), the regression slopes of load to streamflow decrease for SS and PB and increase for DS, NA, CL, TP, TN, NO32, and TAON.

At station 01367770, trends in concentrations during low flows are positive for NA, CL, TN, and NO32, and insignificant for HARD, TOC, DS, TAON, and BACT. At station 01368000, trends in concentrations during low flows are positive for NO32 and BACT; negative for NH4; and insignificant for DO, FDO, TN, NO2, and TAON. Insufficient data are available to determine trends during low flows for all other constituents. At station 01367770, the trend in concentrations during high flows is positive for NA, CL, and NO32 and insignificant for HARD, TOC, DS, DO, FDO, TP, TN, TAON, NH4, and BACT. Insufficient data are available to determine trends during high flows for all other constituents at station 01367770 and for all

Table 5a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01367770, Wallkill River near Sussex, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY						
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	146	(26)	142	(72)	-0.276	*	0.724	NA	NA
Hardness, mg/L as $CaCO_3$	175	(25)	176	(101)	-.280		.720	0	0
Total organic carbon, mg/L as C	3.8	(27)	4.4	(101)	0	*	1.018	0	0
Suspended sediment, mg/L	9	(10)	9	(21)	0		1.034	NA	NA
Dissolved solids, mg/L	250	(25)	252	(99)	-.244		.756	0	0
Dissolved sodium, mg/L as Na	23	(25)	20	(101)	-.189	*	.811	+	+
Dissolved chloride, mg/L as Cl	44	(26)	36	(103)	-.221	*	.778	+	+
Dissolved oxygen, mg/L	9.7	(26)	9.7	(103)	.122	*	1.122	NA	0
Fraction of dissolved oxygen at saturation, %	91	(23)	91	(98)	0	*	ND	NA	0
Total phosphorus, mg/L as P	.03	(24)	.05	(91)	-.483		.516	NA	0
Total nitrogen, mg/L as N	1.4	(27)	1.3	(88)	-.387		.613	+	0
Total nitrate plus nitrite, mg/L as N	.88	(27)	.71	(91)	-.547	*	.452	+	+
Total nitrite, mg/L as N	.011	(27)	.011	(82)	-.270		.730	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.48	(27)	.60	(99)	0		.961	0	0
Total ammonia, mg/L as N	.05	(27)	.08	(90)	0		.905	NA	0
Total boron, µg/L as B	20	(6)	20	(17)	0		.547	NA	NA
Total lead, µg/L as Pb	2	(6)	2	(17)	0		1.027	NA	NA
Fecal coliform bacteria, MPN/100 ml	230	(25)	330	(101)	0	*	ND	0	0

Table 5b. 1993 AMNET impairment status in the vicinity of water-quality station 01367770, Wallkill River near Sussex, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0300	AN0302	None
Impairment status	Non-impaired	Non-impaired	ND

Table 6a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01368000, Wallkill River near Unionville, N.Y.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY							
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	110	(11)	110	(11)	-0.256		0.744	NA	NA
Hardness, mg/L as $CaCO_3$	142	(13)	140	(60)	-.243		.757	NA	NA
Total organic carbon, mg/L as C	4.8	(11)	5.9	(31)	0		.940	NA	NA
Suspended sediment, mg/L	13	(11)	12	(12)	0		.851	NA	NA
Dissolved solids, mg/L	226	(9)	205	(29)	-.172		.828	NA	NA
Dissolved sodium, mg/L as Na	20	(13)	16	(60)	-.148		.852	NA	NA
Dissolved chloride, mg/L as Cl	38	(14)	29	(61)	-.138		.862	NA	NA
Dissolved oxygen, mg/L	9.4	(20)	8.6	(101)	.104	*	1.104	0	NA
Fraction of dissolved oxygen at saturation, %	86	(20)	83	(100)	0	*	ND	0	NA
Total phosphorus, mg/L as P	.06	(21)	.06	(55)	-.249		.750	NA	NA
Total nitrogen, mg/L as N	1.6	(21)	1.5	(81)	0		.945	0	NA
Total nitrate plus nitrite, mg/L as N	.93	(21)	.74	(82)	0	*	.966	+	NA
Total nitrite, mg/L as N	.018	(21)	.016	(84)	-.141		.859	0	NA
Total ammonia plus organic nitrogen, mg/L as N	.62	(21)	.66	(102)	0		1.059	0	NA
Total ammonia, mg/L as N	.08	(21)	.12	(80)	0	*	.905	-	NA
Total boron, µg/L as B	20	(4)	20	(5)	ND		ND	NA	NA
Total lead, µg/L as Pb	2	(7)	8	(40)	0		.809	NA	NA
Fecal coliform bacteria, MPN/100 ml	270	(21)	230	(102)	0	*	ND	+	NA

Table 6b. 1993 AMNET impairment status in the vicinity of water-quality station 01368000, Wallkill River near Unionville, N.Y.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	None	None
Impairment status	ND	ND	ND

constituents at station 01368000. The AMNET impairment status upstream from and at station 01367770 is non-impaired (table 5b). No AMNET stations are in the vicinity of station 01368000 (table 6b).

Papakating Creek

For the one water-quality station on the Papakating Creek, station 01367910 at Sussex, the 5-year and period-of-record medians differ only slightly for all constituents (table 7a). The largest variation is for BACT. The period-of-record medians for SS and NH4 are larger at this station than at any other station in the study area. The regression slopes of concentration to streamflow for ALK, HARD, TOC, DS, CL, DO, FDO, TP, TN, NO32, NO2, and BACT show seasonal dependency. The regression slopes of load to streamflow are in the low range for TOC, SS, NO2, TAON, NH4, PB, and B and in the high range for DO. The slopes are smaller for TOC, NO2, TAON, B, and PB and larger for DO than those at other stations in the study area.

Insufficient data are available for all constituents at station 01367910 for analysis of trends during low flows. Trends in concentrations during high flows are positive for NA and CL and insignificant for HARD, TOC, DO, FDO, TAON, and BACT. For all other constituents, insufficient data are available to determine trends during high flows. The AMNET impairment status upstream from station 01367910 is non-impaired (table 7b).

Black Creek

For the one water-quality station on the Black Creek, station 01368950 near Vernon, the 5-year and period-of-record medians differ only slightly for all constituents (table 8a). The largest variations are for NH4 and BACT. The period-of-record medians are larger for HARD, DS, NA, and CL and smaller for DO and FDO than those at any other station in the study area. The regression slopes of concentration to streamflow for ALK, HARD, TOC, DS, NA, DO, NO32, NO2, and BACT show seasonal dependency. The regression slopes of load to streamflow are in the low range for TOC, SS, CL, NO2, TAON, NH4, and PB and in the high range for ALK. Slope values for NH4 and PB are smaller than those at other stations in the study area.

The trends in concentrations during low flows at station 01368950 were positive for FDO and insignificant for HARD, TOC, DS, NA, CL, DO, TN, NO32, TAON, NH4, and BACT; for all other constituents, insufficient data are available to determine low-flow trends. The trends during high flows were negative for TAON and insignificant for HARD, TOC, DS, NA, CL, DO, FD, and BACT. For all other constituents, insufficient data are available to determine high-flow trends. No AMNET stations are in the vicinity of station 01368950 (table 8b).

Upper Delaware River Basin

The upper Delaware River Basin has 14 water-quality stations (tables 9a and b through 22a and b) on the upper Delaware River, Flat Brook, Paulins Kill, Pequest River, Pohatcong Creek, and Musconetcong River.

Table 7a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01367910, Papakating Creek at Sussex, N.Y.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY						
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	56	(27)	56	(74)	-0.354	*	0.646	NA	NA
Hardness, mg/L as $CaCO_3$	81	(27)	84	(104)	-.257	*	.743	NA	0
Total organic carbon, mg/L as C	4.8	(26)	5.0	(102)	0	*	.926	NA	0
Suspended sediment, mg/L	23	(11)	23	(21)	0		.894	NA	NA
Dissolved solids, mg/L	142	(26)	151	(102)	-.186	*	.814	NA	NA
Dissolved sodium, mg/L as Na	14	(27)	13	(104)	-.123		.877	NA	+
Dissolved chloride, mg/L as Cl	25	(27)	24	(105)	-.104	*	.896	NA	+
Dissolved oxygen, mg/L	8.6	(27)	8.3	(102)	.226	*	1.226	NA	0
Fraction of dissolved oxygen at saturation, %	84	(26)	81	(100)	.110	*	ND	NA	0
Total phosphorus, mg/L as P	.08	(26)	.09	(70)	-.404	*	.596	NA	NA
Total nitrogen, mg/L as N	1.6	(26)	1.6	(88)	-.145	*	.855	NA	NA
Total nitrate plus nitrite, mg/L as N	.94	(26)	.85	(89)	0	*	.997	NA	NA
Total nitrite, mg/L as N	.020	(27)	.025	(83)	-.686	*	.313	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.71	(27)	.77	(101)	-.202		.798	NA	0
Total ammonia, mg/L as N	.17	(27)	.17	(91)	0		.802	NA	NA
Total boron, µg/L as B	20	(5)	20	(19)	-.617		0	NA	NA
Total lead, µg/L as Pb	3	(4)	4	(17)	0		0	NA	NA
Fecal coliform bacteria, MPN/100 ml	1,300	(25)	790	(101)	-.582	*	ND	NA	0

Table 7b. 1993 AMNET impairment status in the vicinity of water-quality station 01367910, Papakating Creek at Sussex, N.Y.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0307	None	None
Impairment status	Non-impaired	ND	ND

Table 8a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01368950, Black Creek near Vernon, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

	1989-93 WY	1976-93 WY				
Constituent	Median concentration	Median concentration	Regression slope of concentration to streamflow	Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	190 (27)	189 (71)	-0.168 *	0.832	NA	NA
Hardness, mg/L as $CaCO_3$	212 (27)	220 (99)	-.183 *	.817	0	0
Total organic carbon, mg/L as C	5.0 (26)	5.3 (98)	0 *	.968	0	0
Suspended sediment, mg/L	11 (11)	11 (20)	0	.948	NA	NA
Dissolved solids, mg/L	302 (27)	318 (99)	-.209 *	.790	0	0
Dissolved sodium, mg/L as Na	29 (27)	29 (99)	-.249 *	.750	0	0
Dissolved chloride, mg/L as Cl	56 (27)	54 (100)	-.247	.752	0	0
Dissolved oxygen, mg/L	8.7 (27)	7.9 (100)	.144 *	1.143	0	0
Fraction of dissolved oxygen at saturation, %	82 (27)	75 (99)	0	ND	+	0
Total phosphorus, mg/L as P	.04 (27)	.05 (71)	-.323	.676	NA	NA
Total nitrogen, mg/L as N	1.3 (27)	1.3 (89)	-.161	.839	0	NA
Total nitrate plus nitrite, mg/L as N	.60 (27)	.72 (92)	0 *	.848	0	NA
Total nitrite, mg/L as N	.015 (27)	.019 (85)	-.597 *	.402	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.59 (27)	.67 (98)	-.143	.817	0	-
Total ammonia, mg/L as N	.07 (27)	.11 (92)	0	.767	0	NA
Total boron, µg/L as B	20 (6)	20 (15)	0	.733	NA	NA
Total lead, µg/L as Pb	1 (6)	2 (16)	0	0	NA	NA
Fecal coliform bacteria, MPN/100 ml	490 (25)	250 (98)	-.567 *	ND	0	0

Table 8b. 1993 AMNET impairment status in the vicinity of water-quality station 01368950, Black Creek near Vernon, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	None	None
Impairment status	ND	ND	ND

Upper Delaware River

Six water-quality stations are located on the upper Delaware River from Montague to Trenton—stations 01438500 at Montague; 01443000 at Portland, Pennsylvania; 01447000 at Northampton Street, at Easton, Pennsylvania; 01457500 at Riegelsville; 01461000 at Lumberville; and 01463500 at Trenton. The 5-year and period-of-record medians at each station differ only slightly for all constituents (tables 9a through 14a). The greatest differences are in NH4 and PB at station 01438500; in SS, PB, and BACT at station 01443000; in SS and PB at station 01447000; in NH4, PB, and BACT at station 01457500; and in NH4, B, and BACT at station 01461000. Period-of-record medians for ALK, HARD, SS, DS, NA, CL, and BACT at station 01438500; for TOC, B, and BACT at station 01443000; for NH4 at station 01447000; and for BACT at station 01463500 are the largest for these constituents at all stations in the study area. The period-of-record median for PB at station 01457500 is the largest for this constituent at all stations in the study area.

The regression slope of concentration to streamflow shows seasonal dependency for DO, TN, NO32, and BACT at station 01438500; for HARD, TOC, DS, NA, CL, DO, NO32, and TAON at station 01443000; for TOC, NA, CL, DO, FDO, and NO32 at station 01447000; for DO, TP, NO32, NO2, and NH4 at station 01457500; for NA, CL, DO, and NO32 at station 01461000; and for ALK, SS, NA, CL, DO, TP, NO32, and NH4 at station 01463500.

The regression slopes of load to streamflow are in the low range for ALK and NH4 at station 01438500; for NH4 at station 01443000; for PB at station 01447000; for HARD, DS, NA, CL, TP, NO2, NH4, and PB at station 01457500; for ALK, HARD, DS, NA, CL, and NO2 at station 01461000; and for HARD, DS, NA, CL, and DO at station 10463500. The load-to-streamflow slopes are in the high range for HARD, TOC, SS, DS, TP, TN, NO2, TAON, and PB at station 01438500; for SS, DS, TN, NO32, and PB at station 01443000; for SS at station 01447000; for ALK, TOC, and SS at station 01457500; for SS, B, and PB at station 01461000; and for TOC, TAON, NH4, and PB at station 01463500. The slopes of load to streamflow for ALK at station 01438500; for PB at station 01447000; for NA, CL, TP, and PB at station 01457500; and for HARD and DS at station 01461000 are the smallest and for TOC, DS, TP, and TAON at station 01438500 and NH4 at station 01463500 are the largest for these constituents at all stations in the study area. In the downstream direction (station 01438500 to 01443000 to 01447000 to 01457500 to 01461000 to 01463500), the regression slopes of load to streamflow increase for HARD and NH4 and decrease for DS, NA, Cl, and NO32.

At station 01438500, trends in concentrations during low flows are positive for NA; negative for TAON; and insignificant for HARD, CL, DO, FDO, TN, NO32, NH4, and BACT. At stations 01443000 and 01447000, trends in concentrations during low flows are positive for NA and CL and insignificant for HARD, TOC, DS, DO, FDO, TN, NO32, TAON, NH4, and BACT. For all constituents at station 01457500, insufficient data are available to determine trends in concentrations during low flows. At station 01461000, trends in concentrations during low flows are positive for CL; negative for DS, TN, and TAON; and insignificant for HARD, TOC, NA, DO, FDO, NO32, and BACT. At station 01463500, trends during low flows are positive for NA

Table 9a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01438500, Delaware River at Montague, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY						
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	16	(11)	16	(11)	-0.499		0.501	NA	NA
Hardness, mg/L as $CaCO_3$	27	(12)	24	(54)	-.144		.855	0	NA
Total organic carbon, mg/L as C	2.8	(11)	3.6	(31)	.244		1.244	NA	NA
Suspended sediment, mg/L	1	(11)	1	(14)	1.352		2.352	NA	NA
Dissolved solids, mg/L	51	(11)	48	(32)	-.073		.926	NA	NA
Dissolved sodium, mg/L as Na	6	(12)	4	(59)	-.155		.845	+	NA
Dissolved chloride, mg/L as Cl	10	(13)	6	(62)	-.194		.806	0	NA
Dissolved oxygen, mg/L	10.8	(21)	10.6	(93)	.125	*	1.125	0	NA
Fraction of dissolved oxygen at saturation, %	96	(21)	97	(90)	0		ND	0	NA
Total phosphorus, mg/L as P	.03	(21)	.03	(54)	0		1.130	NA	NA
Total nitrogen, mg/L as N	.6	(21)	.7	(78)	0	*	1.080	0	NA
Total nitrate plus nitrite, mg/L as N	.34	(21)	.30	(79)	0	*	1.139	0	NA
Total nitrite, mg/L as N	.006	(21)	.006	(77)	0		.960	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.29	(21)	.40	(95)	.209		1.209	-	NA
Total ammonia, mg/L as N	.02	(21)	.06	(76)	0		.854	0	NA
Total boron, µg/L as B	10	(3)	10	(3)	ND		ND	NA	NA
Total lead, µg/L as Pb	2	(5)	8	(36)	0		1.316	NA	NA
Fecal coliform bacteria, MPN/100 ml	14	(21)	20	(91)	.621	*	ND	0	NA

Table 9b. 1993 AMNET impairment status in the vicinity of water-quality station 01438500, Delaware River at Montague, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	None	None
Impairment status	ND	ND	ND

Table 10a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01443000, Delaware River at Portland, Pa.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY Median concentration		1976-93 WY Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	19	(27)	18	(71)	-0.295		0.705	NA	NA
Hardness, mg/L as $CaCO_3$	31	(27)	28	(100)	-.185	*	.815	0	NA
Total organic carbon, mg/L as C	2.9	(27)	3.1	(98)	0	*	1.102	0	NA
Suspended sediment, mg/L	2	(11)	20	(20)	1.150		2.150	NA	NA
Dissolved solids, mg/L	56	(24)	54	(92)	-.096	*	.904	0	NA
Dissolved sodium, mg/L as Na	6	(27)	4	(101)	-.176	*	.824	+	NA
Dissolved chloride, mg/L as Cl	10	(27)	7	(101)	-.141	*	.859	+	NA
Dissolved oxygen, mg/L	10.7	(27)	9.9	(100)	.130	*	1.130	0	NA
Fraction of dissolved oxygen at saturation, %	98	(24)	97	(92)	0		ND	0	NA
Total phosphorus, mg/L as P	.04	(23)	.04	(65)	-.321		.677	NA	NA
Total nitrogen, mg/L as N	.7	(27)	.7	(85)	0		1.079	0	NA
Total nitrate plus nitrite, mg/L as N	.35	(27)	.30	(87)	.262	*	1.262	0	NA
Total nitrite, mg/L as N	.006	(26)	.007	(79)	0		.891	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.36	(27)	.40	(99)	0	*	1.100	0	NA
Total ammonia, mg/L as N	.03	(27)	.06	(88)	0		.803	0	NA
Total boron, µg/L as B	<10	(5)	8	(12)	ND		ND	NA	NA
Total lead, µg/L as Pb	1	(6)	13	(15)	0		1.503	NA	NA
Fecal coliform bacteria, MPN/100 ml	50	(25)	20	(101)	0		ND	0	NA

Table 10b. 1993 AMNET impairment status in the vicinity of water-quality station 01443000, Delaware River at Portland, Pa.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0012	AN0032	AN0034
Impairment status	Non-impaired	Non-impaired	Non-impaired

Table 11a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01447000, Delaware River at Northampton Street, at Easton, Pa.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

	1989-93 WY		1976-93 WY						
Constituent	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	36	(27)	34	(74)	-0.307		0.692	NA	NA
Hardness, mg/L as $CaCO_3$	51	(27)	49	(102)	-.250		.750	0	NA
Total organic carbon, mg/L as C	3.1	(27)	3.2	(102)	0	*	1.048	0	NA
Suspended sediment, mg/L	2	(10)	4	(20)	1.171		2.171	NA	NA
Dissolved solids, mg/L	80	(25)	79	(97)	-.214		.786	0	NA
Dissolved sodium, mg/L as Na	7	(27)	7	(103)	-.259	*	.741	+	NA
Dissolved chloride, mg/L as Cl	12	(27)	10	(103)	-.204	*	.796	+	NA
Dissolved oxygen, mg/L	10.8	(26)	9.6	(96)	.149	*	1.149	0	NA
Fraction of dissolved oxygen at saturation, %	98	(23)	97	(90)	0	*	ND	0	NA
Total phosphorus, mg/L as P	.05	(24)	.04	(92)	-.249		.750	NA	NA
Total nitrogen, mg/L as N	1.0	(27)	1.0	(89)	0		.992	0	NA
Total nitrate plus nitrite, mg/L as N	.61	(27)	.57	(91)	0	*	1.036	0	NA
Total nitrite, mg/L as N	.008	(26)	.010	(83)	0		.883	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.34	(27)	.44	(99)	0		1.031	0	NA
Total ammonia, mg/L as N	.03	(27)	.05	(89)	0		.947	0	NA
Total boron, µg/L as B	<10	(7)	11	(15)	ND		ND	NA	NA
Total lead, µg/L as Pb	3	(7)	8	(15)	0		0	NA	NA
Fecal coliform bacteria, MPN/100 ml	80	(25)	50	(99)	0		ND	0	NA

Table 11b. 1993 AMNET impairment status in the vicinity of water-quality station 01447000, Delaware River at Northampton Street, at Easton, Pa.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	None	None
Impairment status	ND	ND	ND

Table 12a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01457500, Delaware River at Riegelsville, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY						
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	45	(10)	45	(10)	0		0.812	NA	NA
Hardness, mg/L as $CaCO_3$	62	(11)	67	(53)	-.306		.694	NA	NA
Total organic carbon, mg/L as C	2.8	(10)	3.6	(29)	0		1.179	NA	NA
Suspended sediment, mg/L	2	(10)	3	(11)	0		2.222	NA	NA
Dissolved solids, mg/L	110	(10)	97	(29)	-.276		.723	NA	NA
Dissolved sodium, mg/L as Na	10	(11)	8	(57)	-.366		.634	NA	NA
Dissolved chloride, mg/L as Cl	14	(12)	12	(62)	-.314		.686	NA	NA
Dissolved oxygen, mg/L	9.9	(18)	10.5	(98)	.133	*	1.133	NA	NA
Fraction of dissolved oxygen at saturation, %	94	(18)	97	(100)	0		ND	NA	NA
Total phosphorus, mg/L as P	.07	(19)	.08	(52)	-.489	*	.511	NA	NA
Total nitrogen, mg/L as N	1.5	(19)	1.5	(87)	-.122		.878	NA	NA
Total nitrate plus nitrite, mg/L as N	1.04	(19)	1.00	(90)	-.173	*	.826	NA	NA
Total nitrite, mg/L as N	.018	(19)	.022	(80)	-.594	*	.406	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.44	(19)	.62	(97)	0		1.010	NA	NA
Total ammonia, mg/L as N	.06	(19)	.16	(83)	0	*	.782	NA	NA
Total boron, µg/L as B	20	(3)	20	(3)	ND		ND	NA	NA
Total lead, µg/L as Pb	2	(5)	14	(36)	0		0	NA	NA
Fecal coliform bacteria, MPN/100 ml	80	(19)	170	(99)	0		ND	NA	NA

Table 12b. 1993 AMNET impairment status in the vicinity of water-quality station 01457500, Delaware River at Riegelsville, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	None	None
Impairment status	ND	ND	ND

Table 13a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01461000, Delaware River at Lumberville, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY							
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	43	(27)	42	(75)	-0.417		0.583	NA	NA
Hardness, mg/L as $CaCO_3$	65	(27)	66	(101)	-.352		.648	0	0
Total organic carbon, mg/L as C	2.9	(27)	3.3	(101)	.121		1.121	0	0
Suspended sediment, mg/L	3	(11)	6	(20)	1.192		2.192	NA	NA
Dissolved solids, mg/L	107	(26)	107	(96)	-.298		.702	-	0
Dissolved sodium, mg/L as Na	9	(27)	9	(102)	-.341	*	.659	0	+
Dissolved chloride, mg/L as Cl	15	(27)	12	(102)	-.276	*	.724	+	+
Dissolved oxygen, mg/L	10.1	(27)	9.6	(101)	.150	*	1.150	0	0
Fraction of dissolved oxygen at saturation, %	98	(26)	97	(98)	0		ND	0	0
Total phosphorus, mg/L as P	.07	(27)	.08	(70)	-.289		.711	NA	NA
Total nitrogen, mg/L as N	1.4	(27)	1.6	(89)	-.189		.811	-	NA
Total nitrate plus nitrite, mg/L as N	1.04	(27)	1.03	(91)	-.213	*	.787	0	NA
Total nitrite, mg/L as N	.015	(27)	.021	(83)	-.528		.472	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.40	(27)	.60	(100)	0		.986	-	0
Total ammonia, mg/L as N	.04	(27)	.10	(90)	0		1.142	NA	NA
Total boron, µg/L as B	11	(6)	20	(17)	0		.899	NA	NA
Total lead, µg/L as Pb	10	(6)	11	(18)	0		1.572	NA	NA
Fecal coliform bacteria, MPN/100 ml	40	(25)	75	(100)	.960		ND	0	0

Table 13b. 1993 AMNET impairment status in the vicinity of water-quality station 01461000, Delaware River at Lumberville, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	AN0089	AN0095
Impairment status	ND	Non-impaired	Non-impaired

Table 14a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01463500, Delaware River at Trenton, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY						
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	39	(31)	40	(81)	-0.329	*	0.670	NA	NA
Hardness, mg/L as $CaCO_3$	59	(31)	62	(151)	-.315		.684	0	0
Total organic carbon, mg/L as C	3.2	(10)	3.8	(79)	.173		1.173	NA	NA
Suspended sediment, mg/L	8	(31)	12	(145)	1.093	*	2.093	NA	0
Dissolved solids, mg/L	102	(31)	104	(143)	-.273		.727	0	+
Dissolved sodium, mg/L as Na	9	(31)	8	(144)	-.295	*	.705	+	+
Dissolved chloride, mg/L as Cl	14	(31)	12	(154)	-.248	*	.752	+	+
Dissolved oxygen, mg/L	12.0	(30)	11.6	(136)	.051	*	1.051	0	0
Fraction of dissolved oxygen at saturation, %	104	(30)	103	(135)	-.063		ND	0	0
Total phosphorus, mg/L as P	.07	(31)	.09	(139)	-.109	*	.891	0	0
Total nitrogen, mg/L as N	1.3	(31)	1.5	(124)	0		.963	0	+
Total nitrate plus nitrite, mg/L as N	.91	(31)	.94	(129)	-.143	*	.857	0	0
Total nitrite, mg/L as N	.020	(30)	.020	(61)	0		.882	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.40	(31)	.50	(124)	.146		1.146	0	+
Total ammonia, mg/L as N	.04	(25)	.06	(113)	.445	*	1.445	NA	NA
Total boron, µg/L as B	10	(3)	10	(3)	ND		ND	NA	NA
Total lead, µg/L as Pb	<1	(3)	6	(29)	0		1.405	NA	NA
Fecal coliform bacteria, MPN/100 ml	20	(11)	20	(13)	1.791		ND	NA	NA

Table 14b. 1993 AMNET impairment status in the vicinity of water-quality station 01463500, Delaware River at Trenton, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0107	None	None
Impairment status	Non-impaired	ND	ND

and CL and insignificant for HARD, DS, DO, FDO, TP, TN, NO32, and TAON. For all other constituents at stations on the upper Delaware River, insufficient data are available to determine trends in concentrations during low flows.

Insufficient data are available for all constituents at stations 01438500, 01443000, 01447000, and 01457500 to determine trends in concentrations during high flows. At station 01461000, trends in concentrations during high flows are positive for NA and CL and insignificant for HARD, TOC, DS, DO, FDO, TAON, and BACT. At station 01463500, trends during high flows are positive for DS, NA, CL, TN and TAON and insignificant for HARD, SS, DO, FDO, TP, and NO32. For all other constituents at stations on the upper Delaware River, insufficient data are available to determine trends in concentrations during high flows.

No AMNET stations are located at, upstream from or downstream from stations 01438500, 01447000, and 01457500 (tables 9b, 11b, and 12b). The AMNET impairment status at, upstream from and downstream from station 01443000 is non-impaired (table 10b). The AMNET impairment status is non-impaired at and downstream from station 01461000 (table 13b). The AMNET impairment status is non-impaired upstream from station 01463500 (table 14b).

Flat Brook

For the one water-quality station on the Flat Brook, station 01440000 near Flatbrookville, the 5-year and period-of-record medians differ only slightly for all constituents (table 15a). The largest differences are for TOC, NA, TAON, and NH4. Of all 18 stations, this station has the smallest period-of-record medians for 8 constituents—SS, TP, TN, NO32, NO2, TAON, PB, and BACT—and the largest period-of-record median for TOC (table 15a). The regression slopes of concentration to streamflow for CL, DO, NO32, and BACT show seasonal dependency. The regression slopes of load to streamflow are in the low range for HARD, DS, CL, DO, NH4, and PB and in the high range for TN, NO32, and NO2. The slope value for PB is zero which is the smallest for this constituent in the study area. Insufficient data are available for all constituents at this station to determine trends in concentrations during low flows. During high flows, trends are positive for DO and FDO and insignificant for BACT; for all other constituents, insufficient data are available to determine trends. The AMNET impairment status upstream from and at station 01440000 is moderately impaired (table 15b).

Paulins Kill

Two water-quality stations are located on the Paulins Kill—stations 01443440 at Balesville and 01443500 at Blairstown. The 5-year and period-of-record medians are slightly to moderately different for all constituents at both stations (tables 16a and 17a). The greatest differences are for TP, NH4, and B at station 01443440 and for TP and NH4 at station 01443500. The regression slopes of concentration to streamflow for NA, CL, FDO, NO2, TAON, and NH4 at station 01443440; for ALK, HARD, DS, and TN at station 01443500; and for TOC, DO, NO32, and BACT at both stations indicate seasonal dependency. The regression slopes of load to streamflow are in the high range for TAON at station 01443440 and for ALK, TN, NO32, and NO2 at station 01443500. Slopes of load to streamflow for TN, NO32, and NO2 are larger at

Table 15a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01440000, Flat Brook near Flatbrookville, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY Median concentration		1976-93 WY Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	71	(5)	71	(5)	ND		ND	NA	NA
Hardness, mg/L as $CaCO_3$	67	(6)	69	(58)	-.310		.690	NA	NA
Total organic carbon, mg/L as C	3.4	(5)	6.0	(26)	.152		1.152	NA	NA
Suspended sediment, mg/L	3	(5)	1	(14)	0		1.448	NA	NA
Dissolved solids, mg/L	120	(5)	92	(27)	-.277		.722	NA	NA
Dissolved sodium, mg/L as Na	8	(6)	5	(60)	-.187		.813	NA	NA
Dissolved chloride, mg/L as Cl	10	(7)	9	(64)	-.224	*	.776	NA	NA
Dissolved oxygen, mg/L	11.4	(15)	11.3	(101)	.054	*	1.054	NA	+
Fraction of dissolved oxygen at saturation, %	101	(15)	99	(99)	0		ND	NA	+
Total phosphorus, mg/L as P	.02	(15)	.02	(50)	0		.889	NA	NA
Total nitrogen, mg/L as N	.4	(15)	.4	(76)	0		1.077	NA	NA
Total nitrate plus nitrite, mg/L as N	.12	(15)	.11	(78)	.392	*	1.392	NA	NA
Total nitrite, mg/L as N	.005	(15)	.004	(82)	0		1.077	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.19	(15)	.35	(99)	0		1.093	NA	NA
Total ammonia, mg/L as N	.03	(15)	.06	(77)	0		.874	NA	NA
Total boron, µg/L as B	10	(2)	10	(2)	ND		ND	NA	NA
Total lead, µg/L as Pb	<2	(4)	1	(41)	0		0	NA	NA
Fecal coliform bacteria, MPN/100 ml	20	(15)	20	(100)	0	*	ND	NA	0

Table 15b. 1993 AMNET impairment status in the vicinity of water-quality station 01440000, Flat Brook near Flatbrookville, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0007	AN0008	None
Impairment status	Moderately impaired	Moderately impaired	ND

Table 16a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01443440, Paulins Kill at Balesville, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY Median concentration		1976-93 WY Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	128	(27)	124	(74)	-0.297		0.703	NA	NA
Hardness, mg/L as $CaCO_3$	165	(27)	162	(84)	-.278		.722	NA	NA
Total organic carbon, mg/L as C	5.0	(27)	5.0	(83)	.142	*	1.142	NA	NA
Suspended sediment, mg/L	5	(11)	6	(21)	.481		1.480	NA	NA
Dissolved solids, mg/L	242	(26)	252	(82)	-.241		.759	NA	NA
Dissolved sodium, mg/L as Na	22	(27)	22	(84)	-.194	*	.806	NA	NA
Dissolved chloride, mg/L as Cl	39	(27)	40	(84)	-.195	*	.804	NA	NA
Dissolved oxygen, mg/L	10.7	(27)	10.6	(83)	.128	*	1.128	NA	NA
Fraction of dissolved oxygen at saturation, %	100	(27)	97	(77)	.039	*	ND	NA	NA
Total phosphorus, mg/L as P	.05	(27)	.09	(59)	-.273		.727	NA	NA
Total nitrogen, mg/L as N	1.5	(25)	1.7	(77)	0		.953	NA	NA
Total nitrate plus nitrite, mg/L as N	1.00	(26)	1.00	(81)	-.164	*	.836	NA	NA
Total nitrite, mg/L as N	.019	(25)	.023	(74)	-.211	*	.789	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.50	(26)	.68	(80)	.160	*	1.160	NA	NA
Total ammonia, mg/L as N	.06	(27)	.10	(80)	0	*	1.125	NA	NA
Total boron, µg/L as B	15	(6)	25	(16)	0		.728	NA	NA
Total lead, µg/L as Pb	1	(6)	2	(17)	0		1.048	NA	NA
Fecal coliform bacteria, MPN/100 ml	330	(25)	490	(82)	-.468	*	ND	NA	NA

Table 16b. 1993 AMNET impairment status in the vicinity of water-quality station 01443440, Paulins Kill at Balesville, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0020	AN0021	An0022
Impairment status	Non-impaired	Non-impaired	Moderately impaired

Table 17a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01443500, Paulins Kill at Blairstown, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY						
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	119	(26)	119	(72)	-0.198	*	0.802	NA	NA
Hardness, mg/L as $CaCO_3$	141	(27)	148	(105)	-.201	*	.799	0	0
Total organic carbon, mg/L as C	4.1	(25)	4.4	(100)	0	*	1.014	0	0
Suspended sediment, mg/L	5	(11)	4	(29)	.606	*	1.607	NA	NA
Dissolved solids, mg/L	200	(25)	211	(103)	-.160		.840	0	0
Dissolved sodium, mg/L as Na	17	(27)	16	(105)	-.140		.860	+	+
Dissolved chloride, mg/L as Cl	30	(27)	30	(105)	-.158		.842	+	0
Dissolved oxygen, mg/L	10.5	(27)	10.3	(102)	.092	*	1.092	0	0
Fraction of dissolved oxygen at saturation, %	102	(26)	100	(98)	0		ND	0	+
Total phosphorus, mg/L as P	.03	(27)	.06	(96)	0		.950	NA	0
Total nitrogen, mg/L as N	1.1	(27)	1.1	(89)	.125	*	1.125	-	NA
Total nitrate plus nitrite, mg/L as N	.60	(27)	.52	(92)	.393	*	1.393	0	NA
Total nitrite, mg/L as N	.011	(26)	.010	(84)	.140		1.140	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.49	(27)	.58	(100)	0		1.038	0	-
Total ammonia, mg/L as N	.03	(27)	.06	(92)	0		1.241	0	NA
Total boron, µg/L as B	20	(7)	20	(14)	0		.822	NA	NA
Total lead, µg/L as Pb	1	(7)	1	(15)	ND		ND	NA	NA
Fecal coliform bacteria, MPN/100 ml	80	(25)	110	(102)	0	*	ND	0	-

Table 17b. 1993 AMNET impairment status in the vicinity of water-quality station 01443500, Paulins Kill at Blairstown, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	AN0025	AN0027
Impairment status	ND	Non-impaired	Moderately impaired

station 01443500 than at any other station in the study area. In the downstream direction (stations 01443440 to 01443500), the regression slopes of load to streamflow increase for ALK, TP, TN, NO32, and NO2; decrease for TAON; and remain stable for HARD, TOC, SS, DS, NA, CL, DO, NH4, and B.

At station 01443440, insufficient data are available for all constituents to determine trends in concentrations during low and high flows. At station 01443500, trends in concentrations during low flows are positive for NA and CL; negative for TN; and insignificant for HARD, TOC, DS, DO, FDO, NO32, TAON, NH4, and BACT. At station 01443500, trends in concentrations during high flows are positive for NA and FDO; negative for TAON and BACT; and insignificant for HARD, TOC, DS, CL, DO, and TP. For all other constituents at station 01443500, insufficient data are available to determine trends in concentrations during low and high flows.

The AMNET impairment status upstream from and at station 01443440 is non-impaired, and the status downstream from the station is moderately impaired (table 16b). The AMNET impairment status is non-impaired at station 01443500 and moderately impaired downstream from the station (table 17b).

Pequest River

For the one water-quality station on the Pequest River, station 01445500 at Pequest, the 5-year and period-of-record medians differ only slightly for all constituents (table 18a). The largest difference is for CL. The period-of-record median for ALK is the largest for this constituent of all stations in the study area. The regression slopes of concentration to streamflow show seasonal dependency for HARD, DO, NO2, TAON, and BACT. The regression slopes of load to streamflow are in the low range for DO and in the high range for ALK, HARD, SS, TP, and PB. The load-to-streamflow slopes for ALK and HARD are the largest for these constituents at all stations in the study area. All constituents at this station have insufficient data to determine trends in concentrations during low flows. The trends in concentrations during high flows are insignificant for DO, FDO, TAON, and BACT; insufficient data are available to determine trends of all other constituents. The AMNET impairment status upstream from and at station 01445500 is non-impaired (table 18b).

Pohatcong Creek

For the one station on the Pohatcong Creek, station 01455200 at New Village, the 5-year and period-of-record medians differ only slightly for all constituents (table 19a). TP, NO32, and BACT have the largest period-of-record medians of all stations in the study area. The regression slopes of concentration to streamflow for ALK, HARD, DS, NA, CL, DO, NO2, NH4, and BACT show seasonal dependency (table 19a). The regression slopes of load to streamflow are in the low range for TOC, DO, and TP and in the high range for TAON and NH4. For all constituents, insufficient data are available to determine trends during low and high flows. The AMNET impairment status upstream from station 01455200 is moderately impaired, and the status at the station is non-impaired (table 19b).

Table 18a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01445500, Pequest River at Pequest, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY Median concentration		1976-93 WY Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	187	(11)	187	(11)	-0.167		0.833	NA	NA
Hardness, mg/L as $CaCO_3$	231	(12)	212	(64)	-.124	*	.876	NA	NA
Total organic carbon, mg/L as C	4.3	(10)	5.0	(32)	0		1.060	NA	NA
Suspended sediment, mg/L	7	(11)	6	(20)	1.283		2.283	NA	NA
Dissolved solids, mg/L	284	(11)	284	(33)	-.165		.835	NA	NA
Dissolved sodium, mg/L as Na	14	(12)	12	(66)	-.182		.818	NA	NA
Dissolved chloride, mg/L as Cl	29	(13)	20	(69)	-.111		.889	NA	NA
Dissolved oxygen, mg/L	12.2	(21)	11.2	(108)	.042	*	1.042	NA	0
Fraction of dissolved oxygen at saturation, %	105	(21)	100	(107)	0		ND	NA	0
Total phosphorus, mg/L as P	.07	(21)	.08	(57)	0		1.058	NA	NA
Total nitrogen, mg/L as N	1.9	(21)	1.8	(93)	0		.964	NA	NA
Total nitrate plus nitrite, mg/L as N	1.27	(21)	1.12	(95)	0		.979	NA	NA
Total nitrite, mg/L as N	.021	(21)	.016	(89)	0	*	.855	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.57	(21)	.71	(107)	0	*	1.012	NA	0
Total ammonia, mg/L as N	.06	(21)	.08	(85)	0		.993	NA	NA
Total boron, µg/L as B	20	(3)	20	(3)	ND		ND	NA	NA
Total lead, µg/L as Pb	<1	(5)	2	(40)	0		1.350	NA	NA
Fecal coliform bacteria, MPN/100 ml	170	(21)	170	(109)	0	*	ND	NA	0

Table 18b. 1993 AMNET impairment status in the vicinity of water-quality station 01445500, Pequest River at Pequest, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0041	AN0043	None
Impairment status	Non-impaired	Non-impaired	ND

Table 19a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01455200, Pohatcong Creek at New Village, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY Median concentration		1976-93 WY Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	52	(26)	52	(74)	-0.309	*	0.691	NA	NA
Hardness, mg/L as $CaCO_3$	80	(27)	73	(85)	-.214	*	.786	NA	NA
Total organic carbon, mg/L as C	3.2	(27)	3.4	(84)	0		.985	NA	NA
Suspended sediment, mg/L	7	(11)	8	(16)	.485		1.485	NA	NA
Dissolved solids, mg/L	130	(27)	131	(85)	-.146	*	.854	NA	NA
Dissolved sodium, mg/L as Na	10	(27)	10	(85)	-.135	*	.865	NA	NA
Dissolved chloride, mg/L as Cl	16	(27)	14	(85)	-.096	*	.904	NA	NA
Dissolved oxygen, mg/L	11.6	(26)	11.0	(84)	0	*	1.036	NA	NA
Fraction of dissolved oxygen at saturation, %	106	(23)	103	(79)	-.045		ND	NA	NA
Total phosphorus, mg/L as P	.21	(25)	.21	(57)	-.408		.592	NA	NA
Total nitrogen, mg/L as N	2.6	(27)	2.4	(82)	-.090		.910	NA	NA
Total nitrate plus nitrite, mg/L as N	1.94	(27)	1.75	(85)	-.196		.804	NA	NA
Total nitrite, mg/L as N	.039	(27)	.040	(75)	-.371	*	.628	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.48	(27)	.58	(82)	0		1.106	NA	NA
Total ammonia, mg/L as N	.10	(27)	.14	(80)	.325	*	1.325	NA	NA
Total boron, µg/L as B	20	(7)	25	(16)	-.457		.541	NA	NA
Total lead, µg/L as Pb	1	(7)	2	(16)	0		.997	NA	NA
Fecal coliform bacteria, MPN/100 ml	1100	(25)	1300	(83)	-.581	*	ND	NA	NA

Table 19b. 1993 AMNET impairment status in the vicinity of water-quality station 01455200, Pohatcong Creek at New Village, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0057	AN0058	None
Impairment status	Moderately impaired	Non-impaired	ND

Musconetcong River

Three water-quality stations are located on the Musconetcong River—stations 01456200 at Beattysville, 01457000 near Bloomsbury, and 01457400 at Riegelsville. The 5-year and period-of-record medians for all constituents at each station differ only slightly (tables 20a, 21a, and 22a). The greatest differences are in TP at all stations and NH4 at stations 01456200 and 01457000. FDO, NO2, NH4, and B at station 01456200; DO at station 01457000; and TN and TAON at station 01457400 have the largest period-of-record medians for these constituents for all stations in the study area.

The regression slopes of concentration to streamflow show seasonal dependency for ALK, HARD, TOC, DS, NA, CL, DO, NO2, TAON, NH4, and BACT at station 01456200; for HARD, DO, NH4, and BACT at station 01457000; and for ALK, HARD, NA, CL, DO, and BACT at station 01457400. The regression slopes of load to streamflow are in the low range for TOC, DO, TP, and NO2 at station 01456200; for ALK, TOC, and DO at station 01457000; and for TOC and TAON at station 01457400. The load-to-streamflow slopes are in the high range for PB at station 01456200; for SS, NA, CL, NO2, TAON, NH4, and PB at station 01457000; and for NA, CL, B, and PB at station 01457400. The slopes of load to streamflow are smaller for DO at station 01457000, larger for SS and PB at station 0145700, and larger for NA, CL, and B at station 01457400 than at all other stations in the study area. In the downstream direction (stations 01456200 to 01457000 to 01457400), the regression slopes of load to streamflow increase for DS, NA, CL, and NO32.

Insufficient data are available for all constituents at stations 01456200 to determine trends in concentrations during low flows. At station 01457000, trends in concentrations during low flows are positive for CL and insignificant for DO, FDO, TN, NO32, NH4, and BACT. At station 01457400, trends in concentrations during low flows are positive for DS, NA, and CL and insignificant for HARD, TOC, DO, FDO, TN, NO32, TAON, NH4, and BACT. Insufficient data are available for all other constituents at stations 01457000 and 01457400 to determine trends in concentrations during low flows. Insufficient data are available for all constituents at station 01457000 to determine trends in concentrations during high flows. At station 01456200, trends in concentrations during high flows are positive for NA and insignificant for HARD, TOC, DS, CL, DO, FDO, TN, TAON, NH4, and BACT. At station 01457400, trends in concentrations during high flows are insignificant for HARD, TOC, DS, NA, CL, DO, FDO, TAON, and BACT. For all other constituents at stations 01456200 and 01457400, insufficient data are available to determine trends in concentrations during low flows.

The AMNET impairment status at and upstream from station 01456200 is non-impaired and downstream is moderately impaired (table 20b). The AMNET impairment status downstream from station 01457000 (table 21b) and at station 01457400 is non-impaired (table 22b).

Table 20a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01456200, Musconetcong River at Beattystown, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY Median concentration		1976-93 WY Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	77	(25)	78	(72)	-0.340	*	0.660	NA	NA
Hardness, mg/L as $CaCO_3$	104	(25)	106	(102)	-.274	*	.726	NA	0
Total organic carbon, mg/L as C	3.6	(25)	3.8	(100)	0	*	.979	NA	0
Suspended sediment, mg/L	6	(9)	6	(19)	.559		1.556	NA	NA
Dissolved solids, mg/L	180	(25)	180	(101)	-.195	*	.805	NA	0
Dissolved sodium, mg/L as Na	21	(25)	18	(101)	-.074	*	.926	NA	+
Dissolved chloride, mg/L as Cl	39	(25)	33	(101)	-.058	*	.941	NA	0
Dissolved oxygen, mg/L	11.6	(25)	10.6	(102)	.053	*	1.053	NA	0
Fraction of dissolved oxygen at saturation, %	108	(22)	104	(97)	0		ND	NA	0
Total phosphorus, mg/L as P	.05	(25)	.13	(97)	-.407		.593	NA	0
Total nitrogen, mg/L as N	1.6	(25)	1.5	(90)	-.228		.772	NA	NA
Total nitrate plus nitrite, mg/L as N	.80	(25)	.80	(91)	-.260		.740	NA	NA
Total nitrite, mg/L as N	.031	(25)	.032	(84)	-.590	*	.409	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.63	(25)	.69	(101)	0	*	.927	NA	0
Total ammonia, mg/L as N	.21	(25)	.17	(89)	0	*	.984	NA	0
Total boron, µg/L as B	35	(8)	40	(17)	-.435		.562	NA	NA
Total lead, µg/L as Pb	2	(8)	2	(18)	0		1.249	NA	NA
Fecal coliform bacteria, MPN/100 mL	170	(23)	130	(100)	0	*	ND	NA	0

Table 20b. 1993 AMNET impairment status in the vicinity of water-quality station 01456200, Musconetcong River at Beattystown, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	AN0068	AN0069	AN0070
AN0070	Non-impaired	Non-impaired	Moderately impaired

Table 21a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01457000, Musconetcong River near Bloomsbury, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY		1976-93 WY						
	Median concentration		Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	90	(11)	90	(11)	-0.450		0.550	NA	NA
Hardness, mg/L as $CaCO_3$	118	(12)	116	(60)	-.281	*	.719	NA	NA
Total organic carbon, mg/L as C	2.9	(11)	3.9	(32)	0		.957	NA	NA
Suspended sediment, mg/L	6	(11)	6	(19)	1.516		2.516	NA	NA
Dissolved solids, mg/L	187	(11)	180	(33)	-.192		.808	NA	NA
Dissolved sodium, mg/L as Na	18	(12)	12	(65)	0		1.015	NA	NA
Dissolved chloride, mg/L as Cl	31	(13)	22	(68)	0		1.034	+	NA
Dissolved oxygen, mg/L	11.5	(20)	11.6	(108)	0	*	.996	0	NA
Fraction of dissolved oxygen at saturation, %	105	(20)	104	(105)	-.054		ND	0	NA
Total phosphorus, mg/L as P	.04	(20)	.09	(56)	0		.944	NA	NA
Total nitrogen, mg/L as N	2.1	(19)	2.1	(98)	-.148		.852	NA	NA
Total nitrate plus nitrite, mg/L as N	1.70	(20)	1.51	(102)	-.238		.763	0	NA
Total nitrite, mg/L as N	.014	(20)	.015	(90)	0		1.012	0	NA
Total ammonia plus organic nitrogen, mg/L as N	.47	(19)	.54	(108)	0		1.119	NA	NA
Total ammonia, mg/L as N	.04	(20)	.08	(88)	0	*	1.298	0	NA
Total boron, µg/L as B	20	(3)	20	(4)	ND		ND	NA	NA
Total lead, µg/L as Pb	1	(5)	2	(43)	0		1.659	NA	NA
Fecal coliform bacteria, MPN/100 ml	700	(20)	460	(111)	0	*	ND	0	NA

Table 21b. 1993 AMNET impairment status in the vicinity of water-quality station 01457000, Musconetcong River near Bloomsbury, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	None	AN0073
Impairment status	ND	ND	Non-impaired

Table 22a. Median concentrations, relations of concentration and load to streamflow, and directions of concentration trends for selected water-quality constituents at water-quality station 01457400, Musconetcong River at Riegelsville, N.J.

[Number in parenthesis is the number of available data values; WY, water years; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; C, carbon; Na, sodium, Cl, chloride; %, percent; P, phosphorus; N, nitrogen; µg/L, micrograms per liter; B, boron; Pb, lead; MPN/100 mL, most probable number per 100 milliliters. Regression slopes and trend directions are zero when the slope is not different from zero at the 0.05 significance level; *, indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level); +, a positive trend direction; -, a negative trend direction; NA, insufficient data for analysis; ND, undetermined value]

Constituent	1989-93 WY Median concentration		1976-93 WY Median concentration		Regression slope of concentration to streamflow		Regression slope of load to streamflow	Low-flow trend direction	High-flow trend direction
Alkalinity, mg/L as $CaCO_3$	94	(27)	96	(74)	-0.316	*	0.684	NA	NA
Hardness, mg/L as $CaCO_3$	121	(27)	126	(105)	-.281	*	.719	0	0
Total organic carbon, mg/L as C	3.4	(26)	3.3	(104)	0		.974	0	0
Suspended sediment, mg/L	8	(11)	12	(22)	.711		1.709	NA	NA
Dissolved solids, mg/L	184	(26)	188	(102)	-.172		.828	+	0
Dissolved sodium, mg/L as Na	15	(27)	13	(105)	0	*	1.051	+	0
Dissolved chloride, mg/L as Cl	28	(27)	24	(105)	.069	*	1.069	+	0
Dissolved oxygen, mg/L	10.9	(27)	10.2	(104)	.088	*	1.087	0	0
Fraction of dissolved oxygen at saturation, %	100	(26)	100	(100)	0		ND	0	0
Total phosphorus, mg/L as P	.04	(24)	.08	(68)	0		.832	NA	NA
Total nitrogen, mg/L as N	2.7	(27)	2.5	(94)	-.170		.830	0	NA
Total nitrate plus nitrite, mg/L as N	1.78	(27)	1.65	(96)	-.156		.843	0	NA
Total nitrite, mg/L as N	.027	(27)	.020	(84)	-.264		.736	NA	NA
Total ammonia plus organic nitrogen, mg/L as N	.89	(27)	.81	(103)	0		.855	0	0
Total ammonia, mg/L as N	.08	(27)	.08	(92)	0		.946	0	NA
Total boron, µg/L as B	15	(6)	20	(18)	0		1.153	NA	NA
Total lead, µg/L as Pb	1	(6)	3	(20)	0		1.484	NA	NA
Fecal coliform bacteria, MPN/100 ml	270	(25)	410	(102)	0	*	ND	0	0

Table 22b. 1993 AMNET impairment status in the vicinity of water-quality station 01457400, Musconetcong River at Riegelsville, N.J.

[AMNET, Ambient Biomonitoring Network; WQ, water-quality. Upstream from WQ station is within 5 miles upstream from the WQ station; at WQ-station location is within 0.5 miles upstream or downstream from the WQ station; downstream from WQ station is within 5 miles downstream from the WQ station; ND, undetermined impairment status]

	Upstream from WQ station	At WQ-station location	Downstream from WQ station
AMNET station	None	AN0074	None
Impairment status	ND	Non-impaired	ND

Analysis of Relations by Constituent

Schematics of the trends in concentrations during low and high flows and the values of the slopes of load to streamflow are shown for each constituent. Schematics depicting the slopes of load to streamflow are presented for each constituent except dissolved oxygen saturation and fecal coliform bacteria because loads were not calculated for these two constituents. The 01 prefix and any extraneous ending zeros have been removed from station numbers on the schematics and in the text that follows. Schematics are not drawn to scale. Only results from stations with sufficient data for analysis are discussed. Three of the 18 water-quality stations—44344 on the Paulins Kill, 4552 on the Pohatcong Creek, and 4575 on the Delaware River—have insufficient data for all constituents to determine trends in concentrations during high and low flows.

In the schematics showing trends of concentrations during low and high flows, symbols are used to indicate a positive (increasing concentrations), negative (decreasing concentrations), or no (insignificant change in concentrations) trend (figs. 7-24). Trends in concentrations during high and low flows indicate trends in contributions from intermittent (storm runoff) and constant (point sources and ground water) sources, respectively. Trends in concentrations during high flows indicate changes in the relative contributions from nonpoint sources because storm runoff contributes to a stream during high flows. Trends in concentrations during low flows indicate changes in the relative contributions from point sources and ground water because storm runoff does not contribute to a stream during low flows.

The steepness of the slope of load to streamflow at a site indicates the relative contributions to the instream load from constant and intermittent sources relative to that at other sites in the study area. The larger the contribution from storm runoff, the larger the slope will be because the load will increase with increasing streamflow. Likewise, the larger the contribution from constant sources, the smaller the slope will be because the instream load will be constant with increasing streamflow. In the schematics, symbols are used to indicate the range category of the slope at each station. Filled circles represent stations with slopes in the high range, hashed circles represent stations with slopes in the moderate range, and quartered circles represent stations with slopes in the low range. Open circles indicate stations for which slopes could not be determined because of insufficient data. Only results from stations with slopes in either the high or low range are discussed.

An increase in the magnitude of the slope in the downstream direction along a stream would indicate an increase in the relative contribution to the instream load from storm runoff and would be evident if the order of circles proceeded from quartered to hashed to solid in the downstream direction. Likewise, a decrease in the magnitude of the slope in the downstream direction along a stream would indicate an increase in the relative contribution to the instream load from point sources and ground water and would be evident if the order of circles proceeded from solid to hashed to quartered in the downstream direction.

Alkalinity

Alkalinity, an aggregate property of water, is a measure of the capacity of water to neutralize acids and is the sum of all the titratable bases in solution (Eaton and others, 1995). The carbonate contributors to alkalinity, carbonate and bicarbonate, result from the dissociation of dissolved carbon dioxide. The important noncarbonate contributors to alkalinity include hydroxides, silicates, borates, phosphates, and organic ligands, especially acetate and propionate. In many surface-water bodies, alkalinity is primarily a function of carbonate, bicarbonate, and hydroxide, and represents their combined concentrations. Alkalinity measurements are important in the evaluation and control of potable water and wastewater processes, including chemical coagulation, water softening, corrosion control, and buffer capacity evaluation. In surface water that supports extensive algal blooms, consumption of carbon dioxide by algae for photosynthesis causes an increase in pH due to a shift in the forms of alkalinity, although there is no change in the total alkalinity (Sawyer and McCarty, 1978). Alkalinity in excess of alkaline-earth element concentrations could make water unsuitable for irrigation. Carbonate concentrations can be estimated from alkalinity measurements and used to compute the ion balance when checking water analyses.

Relation of trends in concentration to flow conditions

Insufficient data are available to determine trends in alkalinity during low and high flows at all stations in the study area (figs. 7a and b).

Relation of load to streamflow

The range categories of regression slopes of alkalinity load to streamflow are depicted in figure 7c. The slopes range from 0.501 at station 4385 on the Delaware River (table 9a) to 0.833 at station 4455 on the Pequest River (table 18a). Slopes are in the high range at the station on the Black Creek (36895), a downstream station on the Delaware River (4575), the downstream station on the Paulins Kill (4435), and the one station on the Pequest River (4455). At these sites, the contributions to instream alkalinity loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. Slopes are in the low range at the farthest upstream station and a downstream station on the Delaware River (4385 and 4610) and station 4570 on the Musconetcong River. At these sites, the contributions to instream alkalinity loads from point sources and ground water are larger and less influenced by storm runoff than at other sites in the study area.

Hardness

Hardness, an aggregate property of water, is an important consideration in determining the suitability of water for domestic and industrial uses. Hardness, historically described as a measure of the capacity of water to precipitate soap, is typically caused by divalent metallic cations, namely calcium, magnesium, strontium, ferrous iron, and manganous ions (Sawyer and McCarty, 1978). Other polyvalent cations also can precipitate soap, but they often are in complex forms, frequently with organic constituents, and their role in water hardness may be minimal and difficult to define (Eaton and others, 1995). Cation concentrations can be estimated from hardness measurements and used to compute the ion balance when checking water analyses.

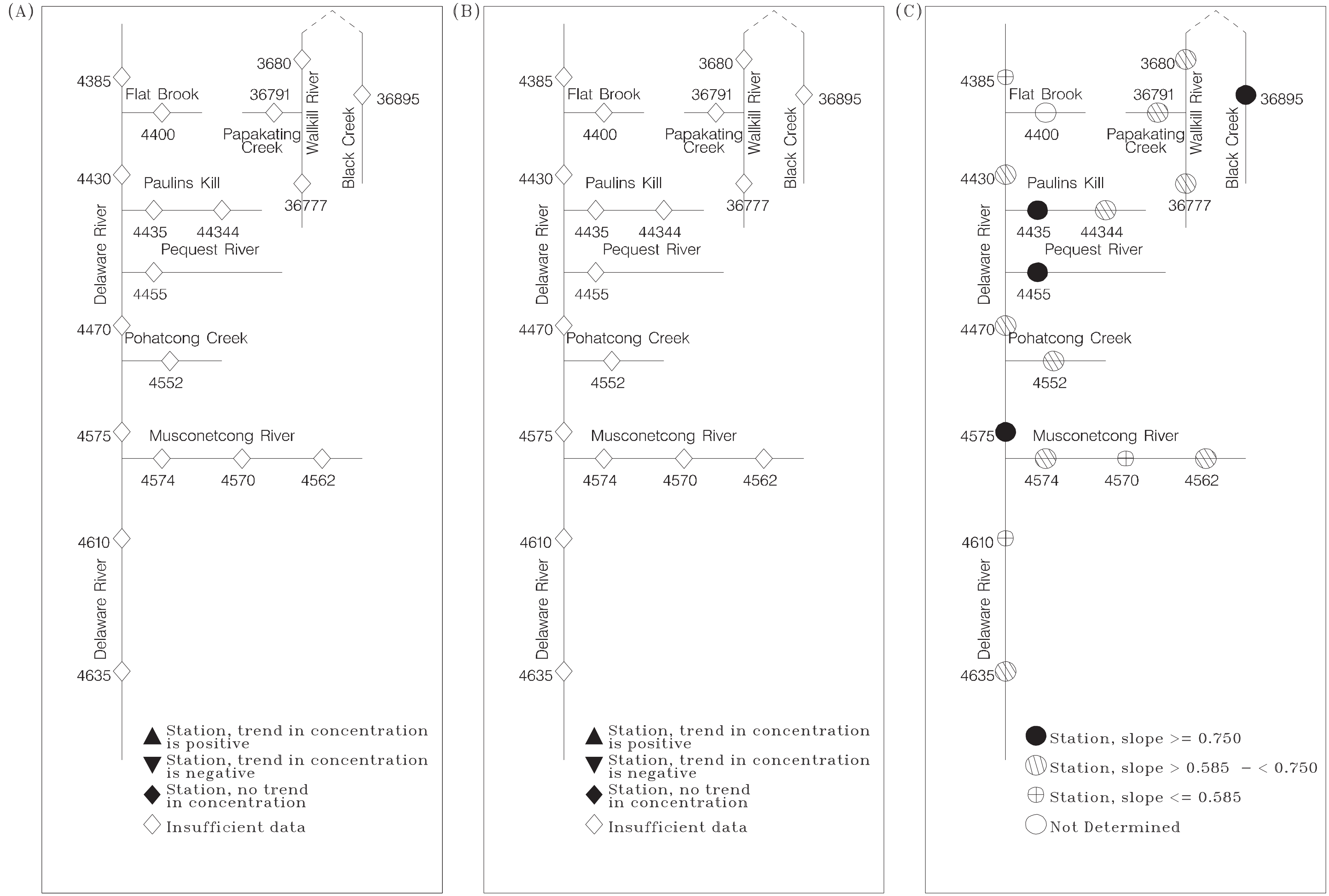


Figure 7. Trends in alkalinity concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of alkalinity load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Calcium and magnesium, the major contributors to hardness, are often the major cations in surface water. Calcium is the most abundant of the alkaline-earth elements and is a major constituent of many common rock minerals; it is an essential element for plant and animal life. Calcium geochemical behavior is governed by the availability of soluble calcium-containing minerals, solution- and gas-phase equilibria that involve carbon dioxide species, and the availability of sulfur in the form of sulfate (Hem, 1985). Calcium also participates in cation-exchange equilibria at aluminosilicate and other mineral surfaces. Calcium salts used for deicing highways can be carried to surface water with storm runoff and melting snow. Magnesium is an alkaline-earth element and is essential in plant and animal nutrition. The water chemistry of calcium and magnesium is similar; however, the geochemical behavior is different. The cation-exchange behavior of magnesium is similar to that of calcium.

Relation of trends in concentration to flow conditions

Hardness concentrations during high flows show no trends at the upstream station on the Wallkill River (36777), the stations on the Papakating (36791) and Black (36895) Creeks, the two downstream stations on the Delaware River (4610 and 4635), the downstream station on Paulins Kill (4435), and the upstream (4562) and downstream (4574) stations on the Musconetcong River (fig. 8a). Hardness concentrations during low flows show no trends at the upstream station on the Wallkill River (36777), the station on the Black Creek (36895), the three upstream (4385, 4430, and 4470) and two downstream (4610 and 4635) stations on the Delaware River, and the downstream stations on the Paulins Kill (4435) and the Musconetcong River (4574) (fig. 8b).

Relation of load to streamflow

The range categories of regression slopes of hardness load to streamflow are depicted in fig. 8c. The slopes range from 0.648 at station 4610 on the Delaware River (table 13a) to 0.876 at station 4455 on the Pequest River (table 18a). Slopes are in the high range at an upstream station on the Delaware River (4385) and the one station on the Pequest River (4455). At these sites, the contributions to instream hardness load from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. Slopes are in the low range at the three downstream stations on the Delaware River (4575, 4610, and 4635) and the one station on the Flat Brook (4400). At these sites, the contributions to instream hardness loads from point sources and ground water are larger than at other sites and less influenced by storm runoff. Slopes at stations on the Delaware River decrease in the downstream direction, indicating a decrease in the relative contributions from storm runoff along the river.

Total Organic Carbon

The concentration of total organic carbon (TOC), an aggregate property of water, is a measure of the organic compounds in various oxidation states in surface water (Eaton and others, 1995). TOC concentrations in most surface water are small compared to dissolved inorganic solute concentrations. Although the presence of organic compounds in surface water can cause an oxygen demand as organisms decompose the compounds, a measure of TOC does not represent a measure of other organically bound elements, such as nitrogen and hydrogen, or inorganics that can contribute to the oxygen demand as measured by the biochemical or chemical oxygen demands.

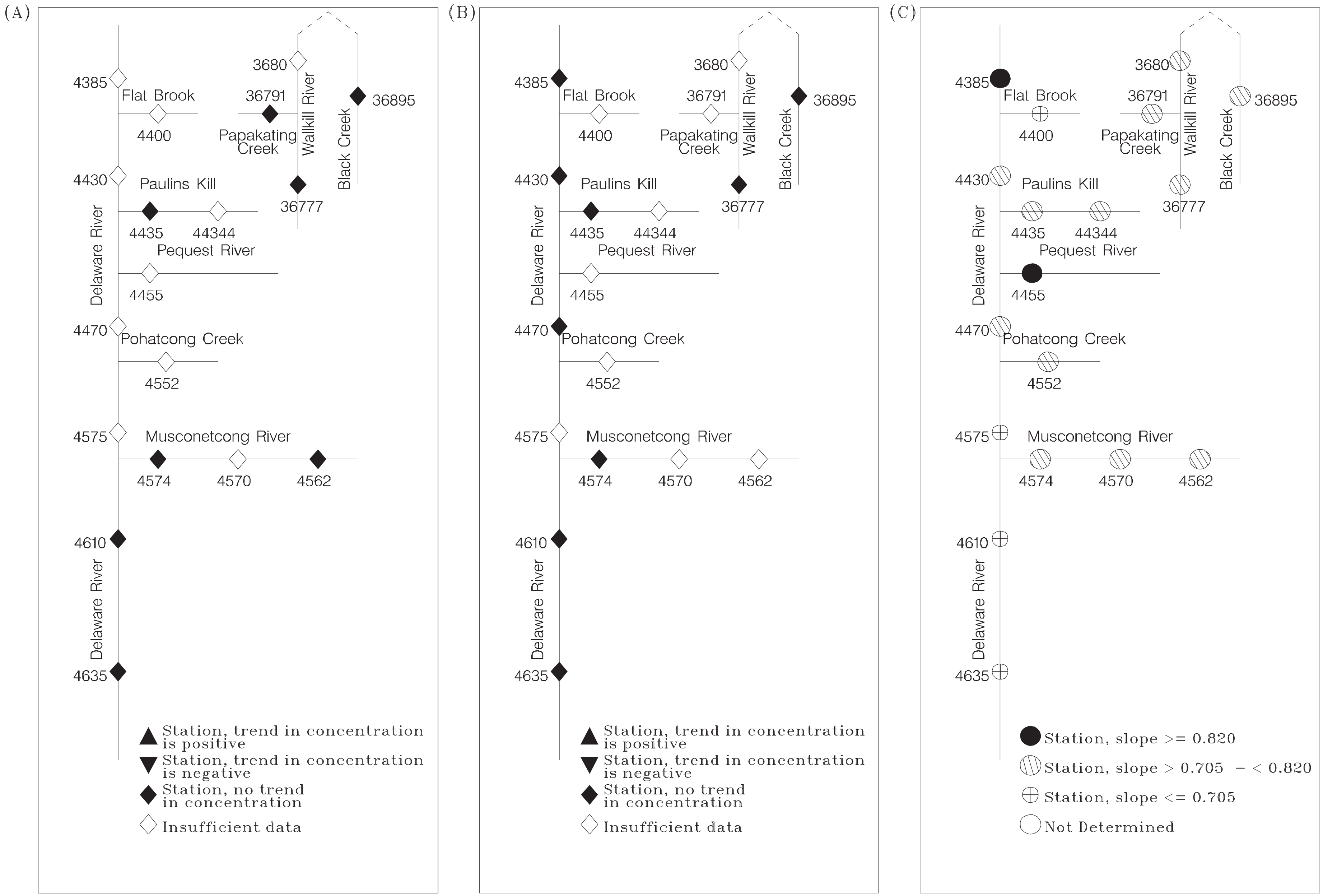


Figure 8. Trends in hardness concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total hardness load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

The methods used to measure TOC analyze fractions of total carbon. These fractions are defined as inorganic carbon, the carbonate, bicarbonate, and dissolved carbon dioxide removed from solution by gas stripping under specified conditions; TOC, all carbon atoms covalently bonded in organic molecules; dissolved organic carbon (DOC), the fraction of TOC that passes through a 0.45 µm-pore-diameter filter; particulate organic carbon (POC), the fraction of TOC that is retained by a 0.45 µm-pore-diameter filter; volatile organic carbon (VOC), the fraction of TOC removed from an aqueous solution by gas stripping under specified conditions; and non-purgeable organic carbon, the fraction of TOC not removed by gas stripping. In most surface water, the VOC contribution to TOC is negligible. When not measured directly, TOC concentration is calculated as the sum of the DOC and POC concentrations.

Relation of trends in concentration to flow conditions

Concentrations of TOC during high flows show no trend at the upstream station on the Wallkill River (36777), the stations on the Papakating (36791) and Black (36895) Creeks, a downstream station on the Delaware River (4610), the downstream station on the Paulins Kill (4435), and the upstream (4562) and downstream (4574) stations on the Musconetcong River (fig. 9a). TOC concentrations during low flows show no trend at the upstream station on the Wallkill River (36777); the station on the Black Creek (36895); the second (4430), third (4470), and fifth (4610) downstream stations on the Delaware River; and the downstream stations on the Paulins Kill (4435) and the Musconetcong River (4574) (fig. 9b).

Relation of load to streamflow

The range categories of regression slopes of TOC load to streamflow are depicted in figure 9c. The slopes range from 0.926 at station 36791 on the Papakating Creek (table 7a) to 1.244 at the farthest upstream station on the Delaware River (4385) (table 9a). Slopes are in the high range at the upstream (4385), fourth downstream (4575), and farthest downstream (4635) stations on the Delaware River. At these sites, the contributions to instream TOC load from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. Slopes are in the low range at the stations on the Papakating (36791), Black (36895), and Pohatcong (4552) Creeks, the downstream station on the Wallkill River (36777), and all stations on the Musconetcong River (4562, 4570, and 4575). At these sites, however, the contributions to instream TOC loads from point sources and ground water probably are relatively insignificant because the load-to-streamflow slopes are large (greater than 0.8). Storm runoff most likely is a major contributor of TOC in the study area because the load-to-streamflow slopes at all stations are large. Slopes at stations on the Wallkill River decrease in the downstream direction, indicating a decrease in the contribution from storm runoff along the river.

Suspended Sediment

Suspended sediment, an aggregate property of water, is that part of total solids that is retained by a filter under specified conditions; its concentration is determined by the weight of the dry residue remaining after evaporation of the volatile part of a sample aliquot by heating to 105 °C (Eaton and others, 1995). Large concentrations of suspended sediments in surface water could inhibit light penetration to bottom-dwelling macrophytes and create esthetically

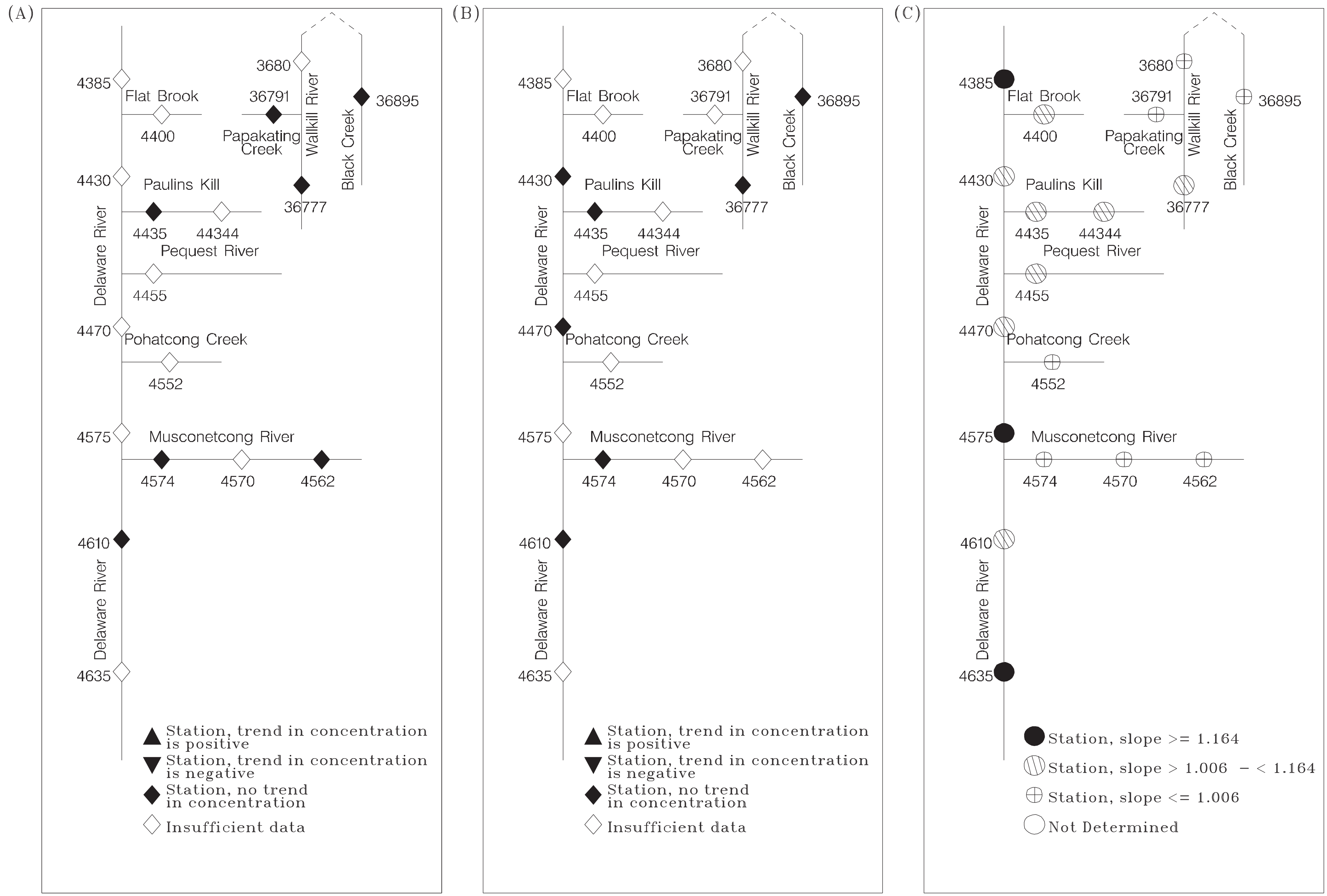


Figure 9. Trends in total organic carbon concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total organic carbon load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

unsatisfactory conditions for such purposes as swimming. Some metals, nutrients, and organic compounds can associate with the surface of suspended sediment and be transported with the suspended sediment in surface water. Suspended sediment concentration is the velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a constant approximately 0.3 feet above the bed) (Bauersfeld and others, 1994). Generally, the primary source of suspended sediment in a stream is from erosion, streambed scour, and overland runoff during storm events.

Relation of trends in concentration to flow conditions

Insufficient data are available to determine trends in suspended sediment concentrations during high and low flows at all stations in the study area (figs. 10a and 10b).

Relation of load to streamflow

The range categories of regression slopes of suspended sediment load to streamflow are depicted in figure 10c. The slopes range from 0.851 at the downstream station on the Wallkill River (3680) (table 6a) to 2.516 at station 4570 on the Musconetcong River (table 21a). The load-to-streamflow slopes are larger for suspended sediments than for any other constituent at all stations. During high flows, the stream velocity can become sufficient to scour the streambed, thereby, making the streambed an additional source of measured instream load. The influence of streamflow velocity on the magnitude of the load-to-streamflow slope should be considered when evaluating the influence of point sources and storm runoff.

Slopes are in the high range at the five upstream stations on the Delaware River (4385, 4430, 4470, 4575, and 4610), the one station on the Pequest River (4455), and station 4570 on the Musconetcong River. At these stations, the relative contributions to instream suspended sediment loads from storm runoff are larger than at other sites and less influenced by point sources and ground water. Slopes are in the low range at both stations on the Wallkill River (36777 and 3680) and the stations on the Papakating (36791) and Black (36895) Creeks. At these sites, however, the contributions to suspended sediment loads from point sources and ground water probably are relatively insignificant because the load-to-streamflow slopes are large (greater than 0.8). Storm runoff most likely is the dominant contributor of suspended sediment in the study area because the load-to-streamflow slopes at all stations are large.

Dissolved Solids

Dissolved solids, an aggregate property of water, is that part of total solids that passes through a filter of 0.45-µm (or smaller) nominal pore size under specified conditions; its concentration is determined by the weight of the dry residue remaining after evaporation of the volatile part of a sample aliquot by heating to 180 °C, the residue-upon-evaporation method (Eaton and others, 1995). All carbonates and bicarbonates will break down when heated, but organic matter will be only partially volatilized and not completely removed. Water with large concentrations of dissolved solids generally has an inferior palatability and may induce diarrhea.

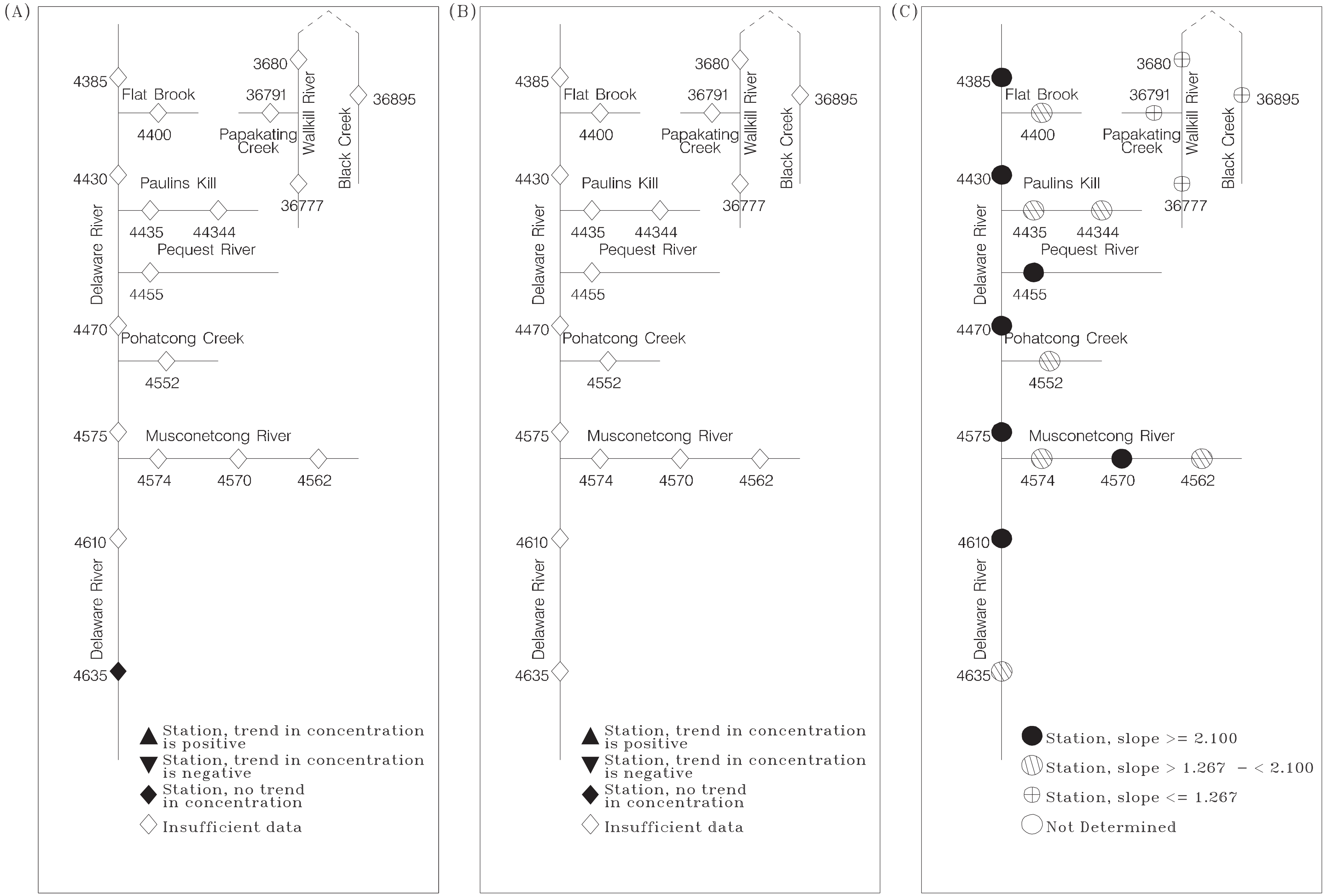


Figure 10. Trends in suspended sediment concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of suspended sediment load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Salts used for deicing highways can be carried to surface water by storm runoff and melting snow and can contribute to the dissolved solids load. The dissolved solids concentration can be compared to the computed ion balance when checking a water analysis.

Relation of trends in concentration to flow conditions

The trend in dissolved solids concentration during high flows is positive at the downstream station on the Delaware River (4635), indicating an increase in the contribution from storm runoff through time at this station (fig. 11a). Dissolved solids concentrations during high flows show no trends at the upstream station on the Wallkill River (36777), the one station on the Black Creek (36895), the fifth downstream station on the Delaware River (4610), the downstream station on the Paulins Kill (4435), and the upstream (4562) and downstream (4574) stations on the Musconetcong River.

The trend in dissolved solids concentrations during low flows is positive at the downstream station on the Musconetcong River (4574), indicating an increase in the contribution from point sources and ground water through time at this site (fig. 11b). The trend in dissolved solids concentrations during low flows is negative at the fifth downstream station on the Delaware River (4610), indicating a decrease in the contribution from point sources and ground water through time at this site. Concentrations of dissolved solids during low flows show no trends at the upstream station on the Wallkill River (36777); the one station on the Black Creek (36895); the second (4430), third (4470) and farthest downstream (4635) stations on the Delaware River; and the downstream station on the Paulins Kill (4435).

Relation of load to streamflow

The range categories of regression slopes of dissolved solids load to streamflow are depicted in figure 11c. The slopes range from 0.702 at the fifth downstream station on the Delaware River (4610) (table 13a) to 0.926 at the upstream station on the Delaware River (4385) (table 9a). Slopes are in the high range at the two upstream stations on the Delaware River (4385 and 4430) where the contributions to instream dissolved solids loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. Slopes are in the low range at the upstream station on the Wallkill River (36777), the three downstream stations on the Delaware River (4575, 4610, and 4635), and the one station on the Flat Brook (4400). At these sites, the contributions to instream dissolved solids loads from point sources and ground water are larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Delaware River decrease in the downstream direction, indicating a decrease in the contributions from storm runoff along the river. Slopes at stations on the Wallkill River increase in the downstream direction, indicating an increase in the contribution from storm runoff along the river.

Dissolved Sodium

Sodium is present in most surface water. The ratio of sodium to total cations is important in agriculture and human pathology. Sodium tends to remain in solution, when dissolved from rocks by weathering, and not form precipitates that can maintain low sodium concentrations.

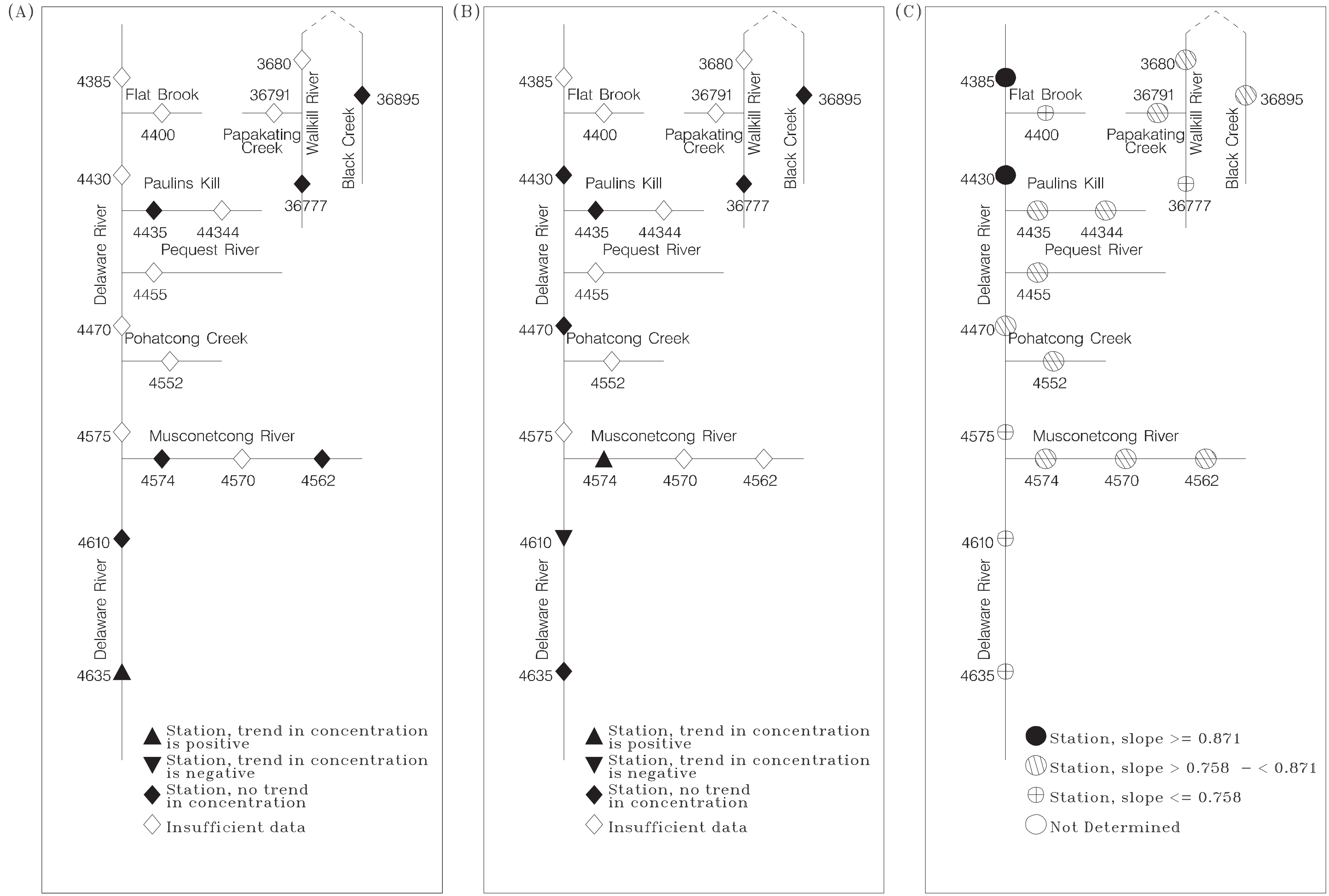


Figure 11. Trends in dissolved solids concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of dissolved solids load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Sodium is retained by adsorption on mineral surfaces, especially by minerals with high cation-exchange capacities, such as clays. Cation exchange processes in freshwater systems tend to extract divalent ions from solution and replace then with monovalent ions, especially sodium (Hem, 1985). Sodium salts used for deicing highways can be carried to surface water by storm runoff and melting snow. The reuse of water for irrigation commonly leaves a residual that is much higher in sodium concentration than was the original water.

Relation of trends in concentration to flow conditions

The trends in sodium concentrations during high flows are positive at the upstream station on the Wallkill River (36777), the one station on the Papakating Creek (36791), the two downstream stations on the Delaware River (4610 and 4635), the downstream station on the Paulins Kill (4435), and the upstream station on the Musconetcong River (4562) (fig. 12a). Contributions from storm runoff increased through time at these stations. Sodium concentrations during high flows show no trends at the one station on the Black Creek (36895) and the downstream station on the Musconetcong River (4574).

The trends in sodium concentrations during low flows are positive at the upstream station on the Wallkill River (36777), the three farthest upstream stations (4385, 4430, and 4470) and the farthest downstream (4635) station on the Delaware River, and the downstream stations on the Paulins Kill (4435) and the Musconetcong River (4574) (fig. 12b). Contributions from point sources and ground water increased through time at these sites. Sodium concentrations during low flows show no trends at the one station on the Black Creek (36895) and the fifth downstream station on the Delaware River (4610).

Relation of load to streamflow

The range categories of regression slopes of dissolved sodium load to streamflow are depicted in figure 12c. The slopes range from 0.634 at the fourth downstream station on the Delaware River (4575) (table 12a) to 1.051 at the downstream station on the Musconetcong River (4574) (table 22a). The slopes are in the high range at the two downstream stations on the Musconetcong River (4570 and 4574) where the contributions to instream sodium loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slopes are in the low range at the three farthest downstream stations on the Delaware River (4575, 4610, and 4635) where the contributions to instream sodium loads from point sources and ground water are larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Delaware River decrease in the downstream direction, indicating a decrease in the contributions from storm runoff along the river. Slopes at stations on the Musconetcong River increase in the downstream direction, indicating an increase in the contribution from storm runoff along the river.

Dissolved Chloride

Chloride is present in all surface water, but usually in low (<10 mg/L) concentrations. Chloride ions do not significantly enter into oxidation or reduction reactions, form no important solute complexes with other ions unless the chloride concentration is extremely high, do not form

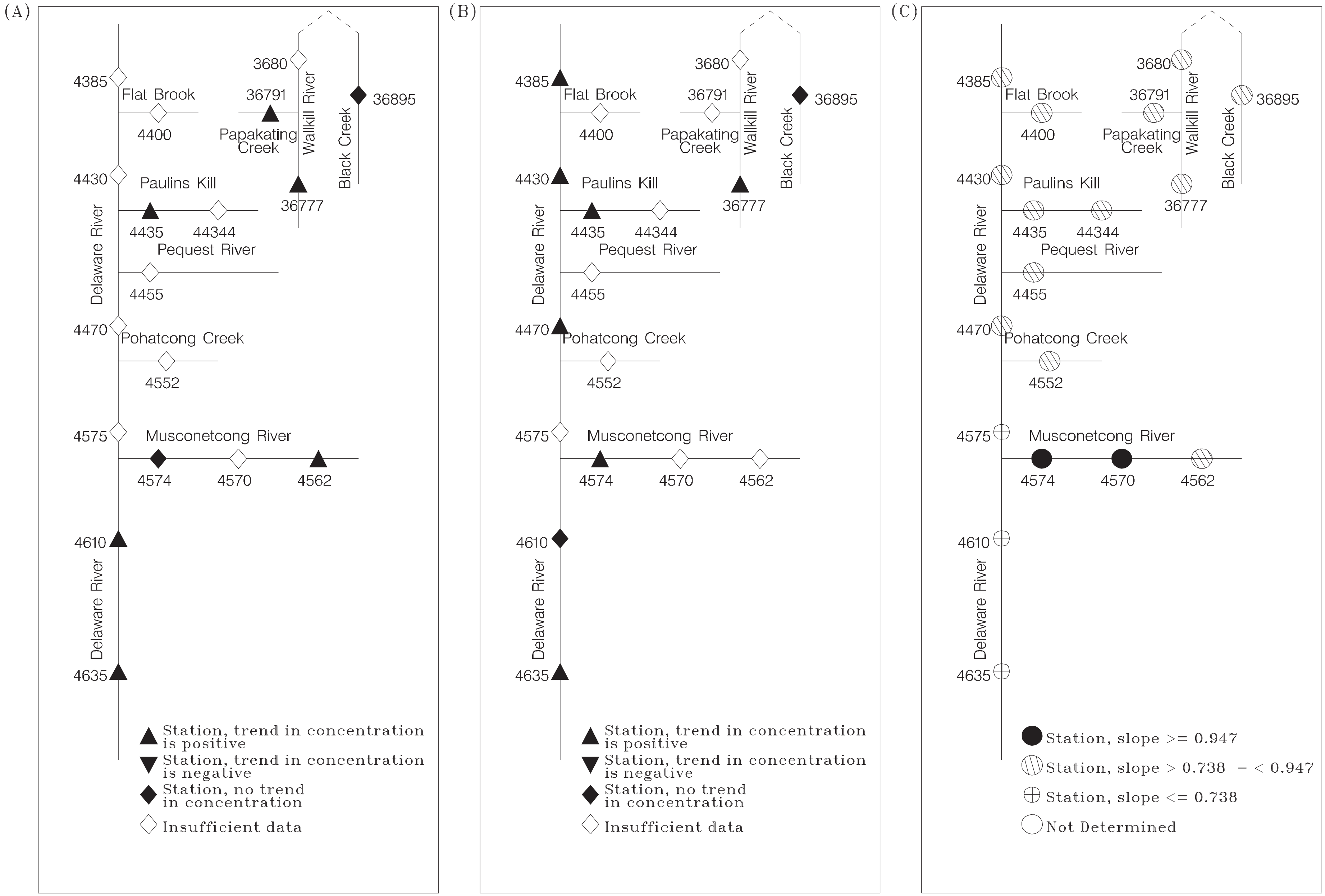


Figure 12. Trends in dissolved sodium concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of dissolved sodium load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

salts of low solubility, are not significantly adsorbed onto mineral surfaces, and play few vital biochemical roles (Hem, 1985). Conservative constituents such as chloride move through a stream system mainly by physical processes (water inputs and withdrawals). Chloride is present in various rock types in concentrations lower than that of any of the other major constituents of ambient water. In most streams, chloride concentrations are smaller than those of sulfate or bicarbonate. Exceptions occur where streams receive inflows of ground water or industrial wastewater containing large concentrations of chloride, or are affected by oceanic tides. Chloride salts used for deicing highways can be carried to surface water by storm runoff and melting snow.

Relation of trends in concentration to flow conditions

The trends in chloride concentrations during high flows are positive at the upstream station on the Wallkill River (36777), the one station on the Papakating Creek (36791), and the two farthest downstream stations on the Delaware River (4610 and 4635). Contributions from storm runoff increased through time at these sites (fig. 13a). Chloride concentrations during high flows show no trends at the one station on the Black Creek (36895), the downstream station on the Paulins Kill (4435), and the upstream (4562) and downstream (4574) stations on the Musconetcong River. The trends in chloride concentrations during low flows are positive at the upstream station on the Wallkill River (36777), the four downstream stations on the Delaware River (4430, 4470, 4610, and 4635), the downstream station on the Paulins Kill (4435), and the two downstream stations on the Musconetcong River (4570 and 4574). Contributions from point sources and ground water increased through time at these sites (fig. 13b). Chloride concentrations during low flows show no trends at the one station on the Black Creek (36895) and the farthest upstream station on the Delaware River (4385).

Relation of load to streamflow

The range categories of regression slopes of chloride load to streamflow are depicted in figure 13c. The slopes range from 0.686 at the fourth downstream station on the Delaware River (4575) (table 12a) to 1.069 at the downstream station on the Musconetcong River (4574) (table 22a). The slopes are in the high range at the downstream stations on the Musconetcong River (4570 and 4574) where the contributions to instream chloride loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slopes are in the low range at the upstream station on the Wallkill River (36777), the one station on the Black Creek (36895), the three downstream stations on the Delaware River (4575, 4610, and 4635), and the one station on the Flat Brook (4400). At these sites, the contributions to instream chloride loads from point sources and ground water are larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Delaware River decrease in the downstream direction, indicating a decrease in the contributions from storm runoff along the river. Slopes at stations on the Wallkill and Musconetcong Rivers increase in the downstream direction, indicating an increase in the contributions from storm runoff along the river.

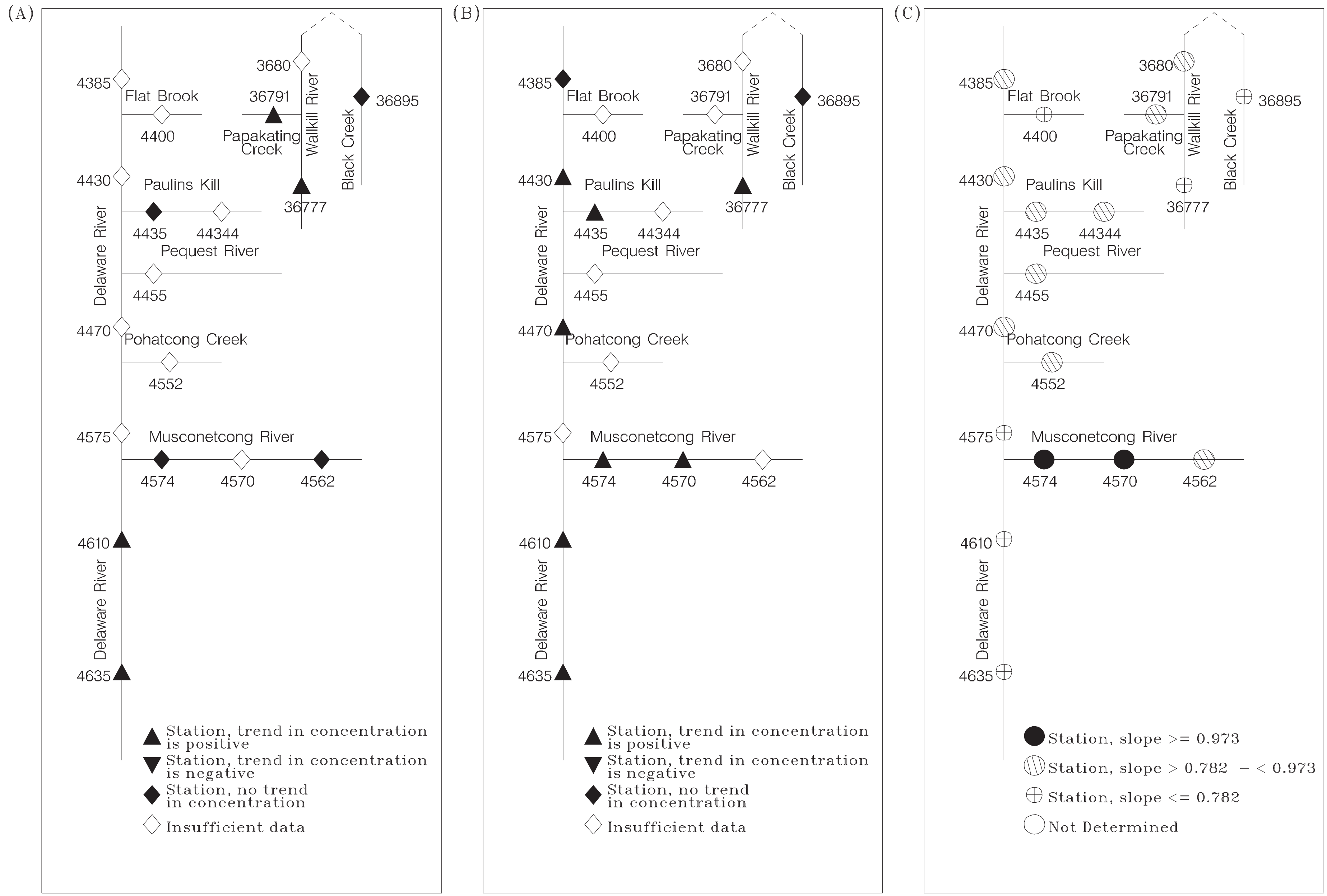


Figure 13. Trends in dissolved chloride concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of dissolved chloride load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations in surface water depend on the physical, chemical, and biochemical activities occurring in the water body and are a function of water temperature, atmospheric pressure, and concentrations of other solutes. The higher forms of aquatic life require oxygen for survival, and the measurement of DO is used widely to evaluate the biochemistry of surface water (Hem, 1985). Photosynthesis and water turbulence are important mechanisms that replenish DO consumed by organic matter. Oxygen supersaturation can occur in slow moving systems in winter and when photosynthesizing biota are abundant during the summer. The presence of organic compounds in surface water can cause oxygen demand. Positive trends and steeper slopes of load to streamflow can indicate improved water quality.

Relation of trends in concentration to flow conditions

The trend in dissolved oxygen concentrations during high flows is positive at the one station on the Flat Brook (4400) (fig. 14a). Dissolved oxygen concentrations during high flows show no trends at the upstream station on the Wallkill River (36777), the stations on the Papakating (36791) and Black (36895) Creeks, the two farthest downstream stations on the Delaware River (4610 and 4635), the one station on the Pequest River (4455), the downstream station on the Paulins Kill (4435), and the upstream (4562) and downstream (4574) stations on the Musconetcong River. Dissolved oxygen concentrations during low flows show no trends at the downstream station on the Wallkill River (3680), the one station on the Black Creek (36895), the three upstream (4385, 4430, and 4470) and two farthest downstream (4610 and 4635) stations on the Delaware River, and the downstream stations on the Paulins Kill (4435) and Musconetcong River (4570 and 4574) (fig. 14b).

Relation of load to streamflow

The range categories of regression slopes of dissolved oxygen load to streamflow are depicted in figure 14c. The range of slopes is narrow, from 0.996 at station 4570 on the Musconetcong River (table 21a) to 1.226 at station 36791 on the Papakating Creek (table 7a), the only station with a slope in the high range. The slopes are in the low range at the downstream station on the Delaware River (4635); the one station on each of the Flat Brook (4400), Pequest River (4455), and Pohatcong Creek (4552); and the upstream stations on the Musconetcong River (4562 and 4570).

Fraction of Dissolved Oxygen at Saturation

The fraction of dissolved oxygen at saturation is the ratio of the measured DO concentration to the maximum DO concentration possible in the water. The maximum DO concentration possible is a function of atmospheric pressure, water temperature, and specific conductance of the water sample. Values are determined from published equations. The calculation of the fraction of dissolved oxygen at saturation removes the effect of temperature on oxygen solubility so that the effects of photosynthesis on DO concentration are easier to evaluate. Loads of percent dissolved oxygen saturation were not calculated.

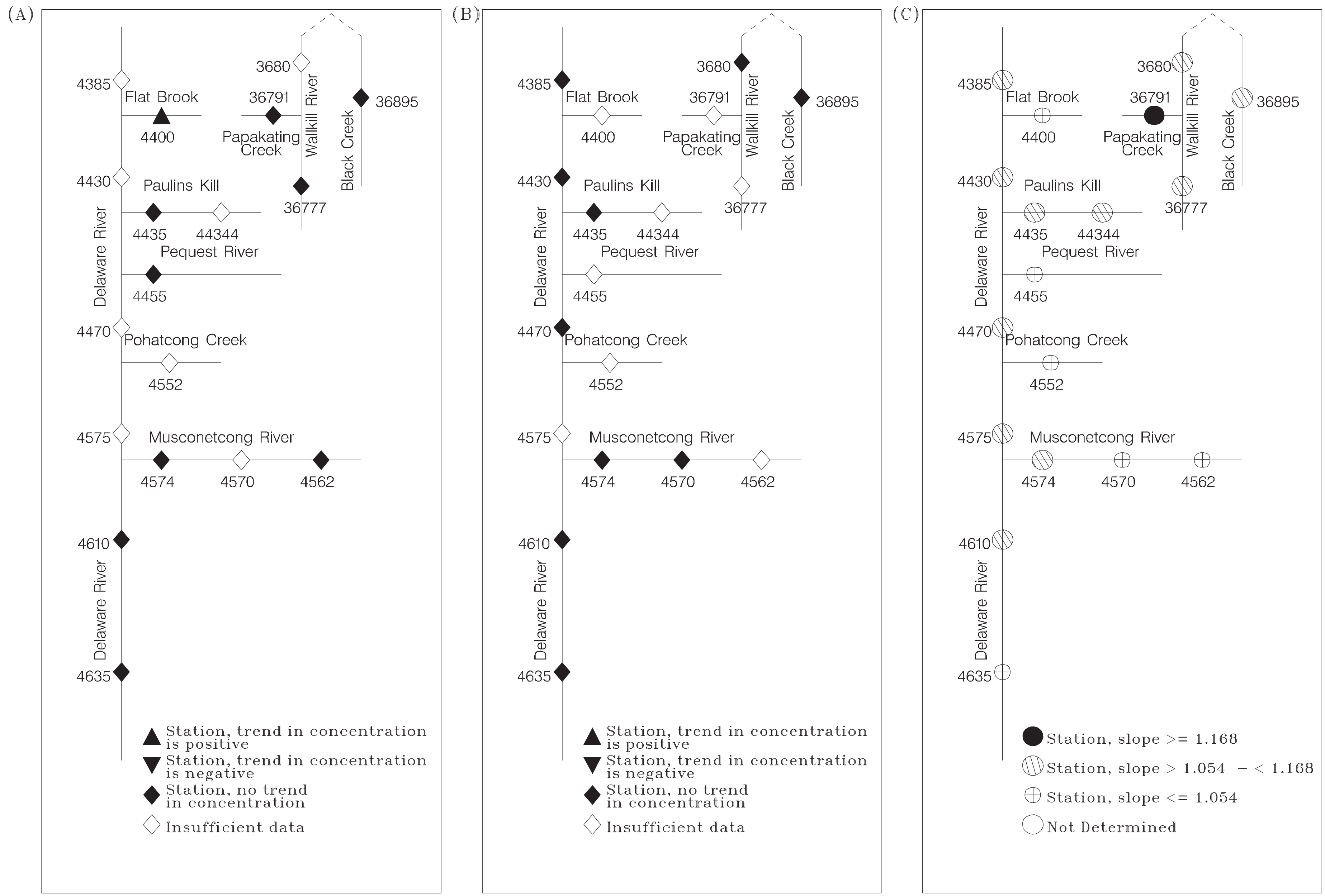


Figure 14. Trends in dissolved oxygen concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of dissolved oxygen load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Relation of trends in concentration to flow conditions

The trends in the fraction of dissolved oxygen at saturation during high flows are positive at the one station on the Flat Brook (4400) and the downstream station on the Paulins Kill (4435). No trends are apparent at the upstream station on the Wallkill River (36777), the one station on each of the Papakating (36791) and Black (36895) Creeks, the two farthest downstream stations on the Delaware River (4610 and 4635), the one station on the Pequest River (4455), and the upstream (4562) and downstream (4574) stations on the Musconetcong River (fig. 15a). The trend in the fraction of dissolved oxygen at saturation during low flows is positive at the one station on the Black Creek (36895). No trends are apparent at the downstream station on the Wallkill River (3680), the three upstream (4385, 4430, and 4470) and two downstream (4610 and 4635) stations on the Delaware River, and the downstream stations on the Paulins Kill (4435) and Musconetcong River (4570 and 4574) (fig. 15b).

Total Phosphorus

Phosphorus is present in surface water as orthophosphates, condensed phosphates (pyro-, meta-, and other polyphosphates), and organically bound phosphates (Sawyer and McCarty, 1978). Phosphates are found in solution, associated with particles, and in detritus and the bodies of aquatic organisms. They are derived from a variety of sources and are relatively immobile in soils or sediments (Hem, 1985). Phosphorus is a common element in igneous rock and is fairly abundant in sediment. Orthophosphates applied to agricultural or residential land as fertilizers can be carried into surface water by storm runoff. Phosphorus is an essential nutrient and can limit the primary productivity of a water body. Primary productivity is a measure of the rate at which new organic matter is formed and accumulated through the photosynthetic and chemosynthetic activity of producer organisms (chiefly green plants) (Bauersfeld and others, 1994). The addition of phosphorus to surface water from storm runoff and the discharge of treated wastewater, agricultural drainage, or certain industrial wastes to the water can stimulate the growth of photosynthetic aquatic micro- and macro-organisms in nuisance quantities.

Relation of trends in concentration to flow conditions

The concentrations of total phosphorus show no trends during high flows at the upstream stations on the Wallkill (36777) and Musconetcong (3915) Rivers and the downstream stations on the Paulins Kill (4435) and Delaware River (4635) (fig. 16a). The concentration of total phosphorus shows no trends during low flows at one downstream station on the Delaware River (4635) (fig. 16b).

Relation of load to streamflow

The range categories of regression slopes of total phosphorus load to streamflow are depicted in figure 16c. The slopes range from 0.511 at station 4575 on the Delaware River (table 12a) to 1.130 at station 4385 on the Delaware River (table 9a). The slopes are in the high range at the farthest upstream station on the Delaware River (4385) and the one station on the Pequest River (4455) where the contributions to instream total phosphorus loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area.

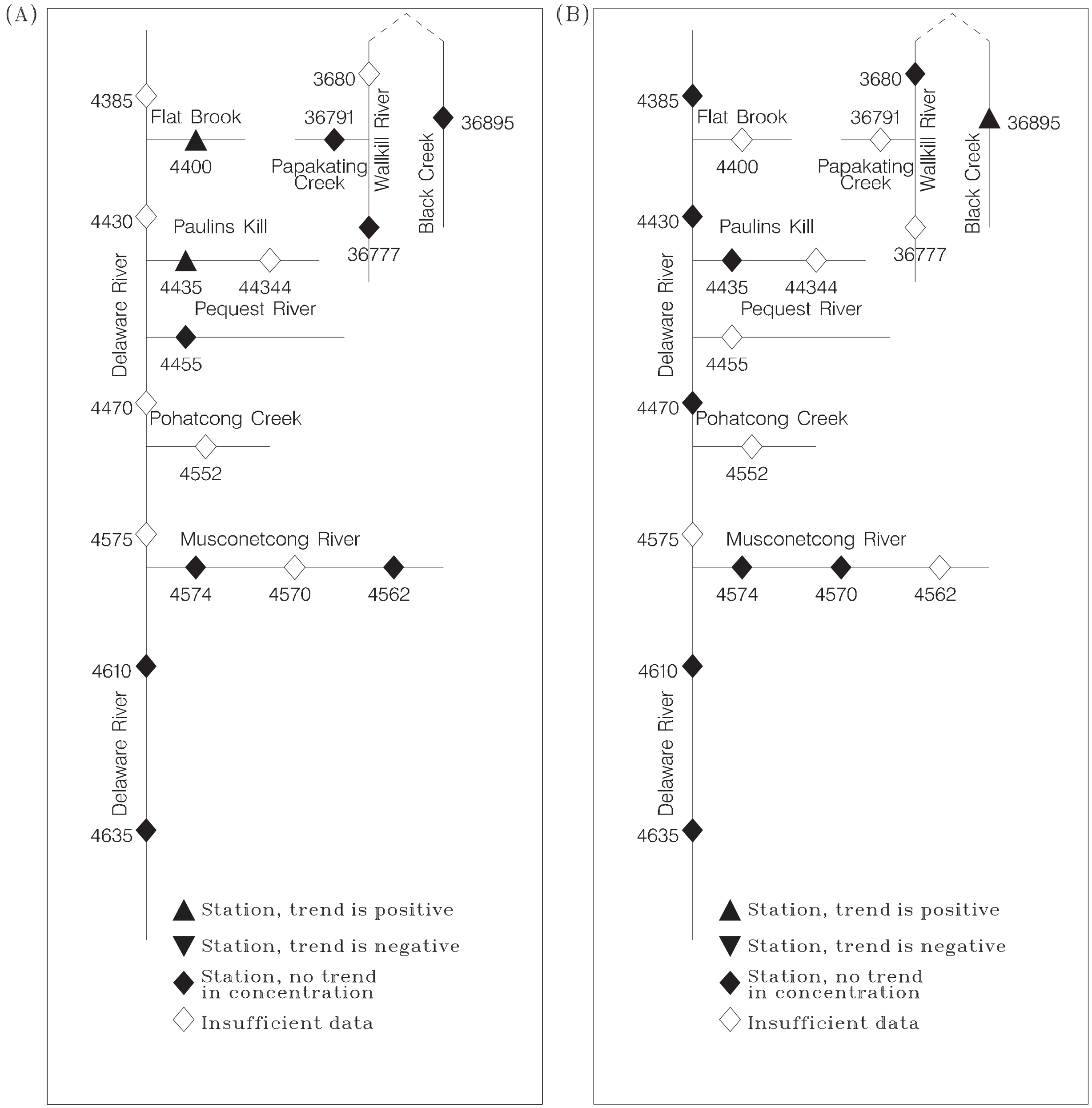


Figure 15. Trends in fraction of dissolved oxygen at saturation during (A) high- and (B) low-flow conditions at surface-water-quality stations in the Wallkill and Upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

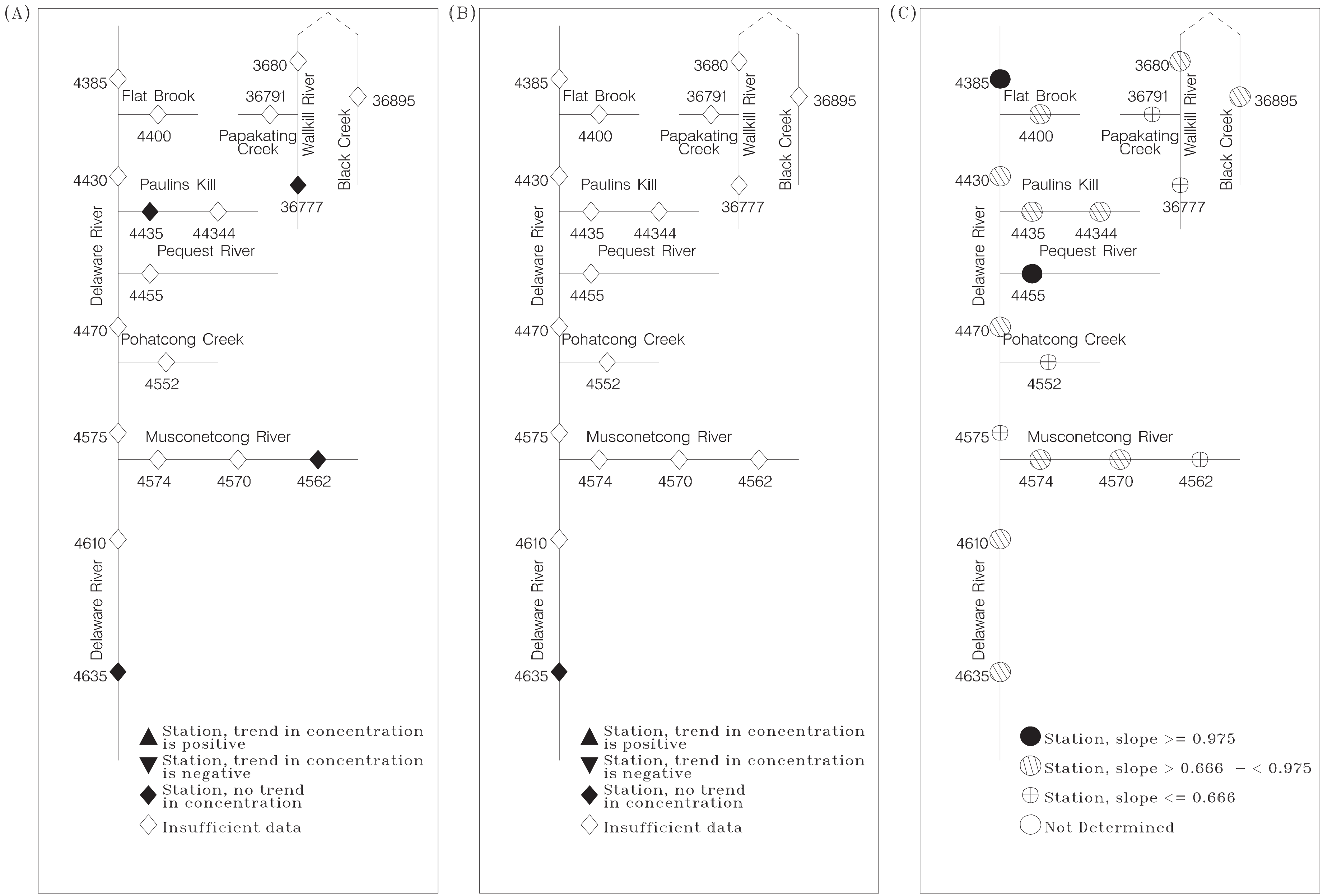


Figure 16. Trends in total phosphorus concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total phosphorus load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Slopes are in the low range at the upstream station on the Wallkill River (3677), one downstream station on the Delaware River (4575), the stations on the Papakating (36791) and Pohatcong (4552) Creeks, and the upstream station on the Musconetcong (4562) River. At these sites, the contributions to instream total phosphorus loads from point sources and ground water are larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Wallkill and Musconetcong Rivers increase in the downstream direction, indicating an increase in the contributions from storm runoff along the rivers.

Total Nitrogen

Nitrogen is an essential element for plant and animal growth; however, sufficiently large concentrations of certain nitrogen species can adversely affect the quality of surface water by causing excess algal growth (eutrophication) or toxicity to aquatic and terrestrial animals. Important forms of nitrogen in surface water are, in order of decreasing oxidation state, nitrate, nitrite, ammonia, and organic nitrogen. The cycling of nitrogen is controlled mainly by biological processes. Nitrogen enters aquatic environments from fertilizers, agricultural wastes, decomposition of organic matter, atmospheric deposition, biotic fixation, and ambient soils and rocks. Ground water and storm runoff are important sources of nitrate and ammonia to surface water. High concentrations of nitrate and nitrite can reduce the oxygen-carrying capacity of hemoglobin in warm-blooded animals. Un-ionized ammonia can be toxic to aquatic organisms.

Relation of trends in concentration to flow conditions

The trend in total nitrogen concentrations during high flows is positive at the farthest downstream station on the Delaware River (4635), indicating an increase in the contribution from storm runoff through time at this station (fig. 17a). The concentrations of total nitrogen show no trends during high flows at the upstream station on the Wallkill River (36777). During low flows, the trend in total nitrogen concentrations is positive at the upstream station on the Wallkill River (36777), indicating an increase in the contributions from point sources and ground water through time at this station (fig. 17b). The trend is negative at one downstream station on the Delaware River (4610) and the downstream station on the Paulins Kill (4435). Contributions from point sources and ground water through time decreased at these stations. Total nitrogen concentrations during low flows show no trend at the downstream station on the Wallkill (3680) River, the three upstream (4385, 4430, and 4470) and the farthest downstream (4635) stations on the Delaware River, and the downstream station on the Musconetcong (4574) River.

Relation of load to streamflow

The range categories of regression slopes of total nitrogen load to streamflow are shown in figure 17c. The slopes range from 0.613 at the upstream station on the Wallkill River (36777) (table5a) to 1.125 at the downstream station on the Paulins Kill (4435) (table 17a). Slopes are in the high range at two upstream stations on the Delaware River (4385 and 4430), the one station on the Flat Brook (4400), and the downstream station on the Paulins Kill (4435). At these sites, the contributions to instream total nitrogen loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slope is in the low range at the upstream station on the Wallkill River (36777) where the contribution to the instream total

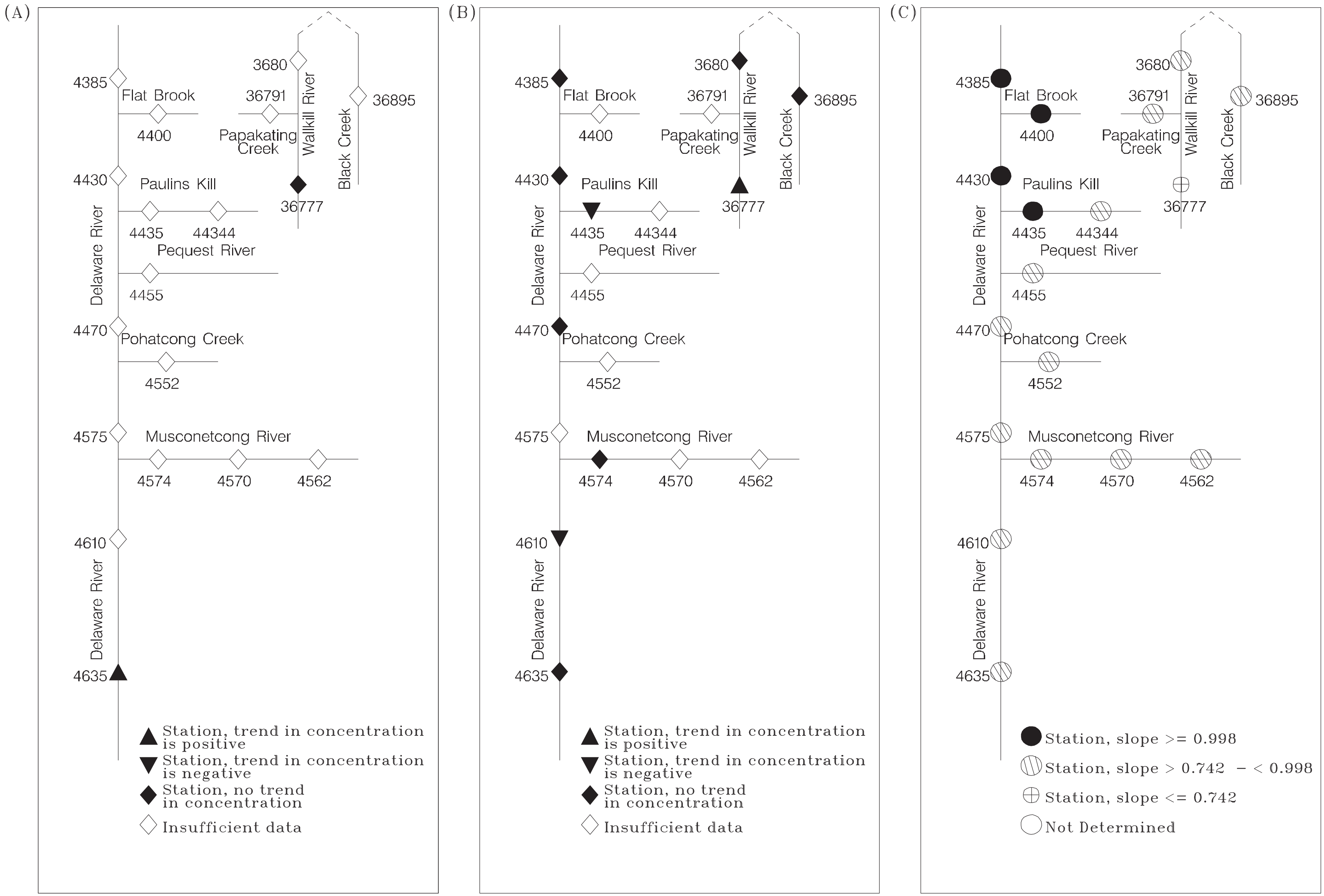


Figure 17. Trends in total nitrogen concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total nitrogen load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

nitrogen load from point sources and ground water is larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Wallkill River and Paulins Kill increase in the downstream direction, indicating an increase in the contributions from storm runoff.

Total Nitrate Plus Nitrite

The total oxidized nitrogen concentration is the sum of the nitrate and nitrite concentrations. Nitrite is an intermediate oxidation state of nitrogen. Nitrite is usually present in trace amounts in surface water because it is rapidly oxidized to nitrate and is generally considered to be an indicator of the presence of sewage or organic waste (low DO conditions). Nitrite can enter surface water in discharge from wastewater-treatment plants and water-reuse systems in fish culture facilities where the nitrification process to reduce ammonia concentrations is impaired (Rand and Petrocelli, 1985). Nitrite is the etiologic agent of methemoglobinemia in humans and fish. Under specific conditions, nitrite is involved in the formation of some carcinogenic nitrosamines. Nitrate is an essential nutrient for many photosynthetic autotrophs and, in some cases, has been identified as the growth-limiting nutrient. It is present generally in trace amounts in surface water, but can attain high levels in some ground-water systems (Hem, 1985). Nitrate fertilizers applied to agricultural and residential land, then carried into surface water by storm runoff and ground water, can stimulate the growth of photosynthetic aquatic micro- and macro-organisms. Nitrate is considerably less toxic to aquatic organisms than are ammonia and nitrite; however, in excess amounts (>10 mg/L), nitrate contributes to methemoglobinemia in small children and fish.

Relation of trends in concentration to flow conditions

The trend in total nitrate plus nitrite concentrations during high flows is positive at the upstream station on the Wallkill River (36777), indicating an increase in the contribution from storm runoff through time at this station (fig. 18a). The concentrations of total nitrate plus nitrite show no trend during high flows at the farthest downstream station on the Delaware River (4635). The trend in total nitrate plus nitrite concentrations during low flows is positive at both stations on the Wallkill River (36777 and 3680), indicating an increase in the contributions from point sources and ground water through time at these sites (fig. 18b). Discharge from wastewater-treatment plants in which the organic nitrogen is almost entirely oxidized can result in increased nitrate plus nitrite concentrations in the receiving streams. Also during low flows, the concentrations of total nitrogen show no trends at the one station on the Black Creek (36895), five stations on the Delaware River (4385, 4430, 4470, 4610 and 4635), and the downstream stations on the Paulins Kill (4435) and Musconetcong River (4570 and 4574).

Relation of load to streamflow

The range categories of regression slopes of total nitrate plus nitrite load to streamflow are depicted in figure 18c. The slopes range from 0.452 at the upstream station on the Wallkill River (36777) (table 5a) to 1.393 at the downstream station on the Paulins Kill (4435) (table 17a). Slopes are in the high range at one downstream station on the Delaware River (4430), the station on the Flat Brook (4400), and the downstream station on the Paulins Kill (4435). At these sites,

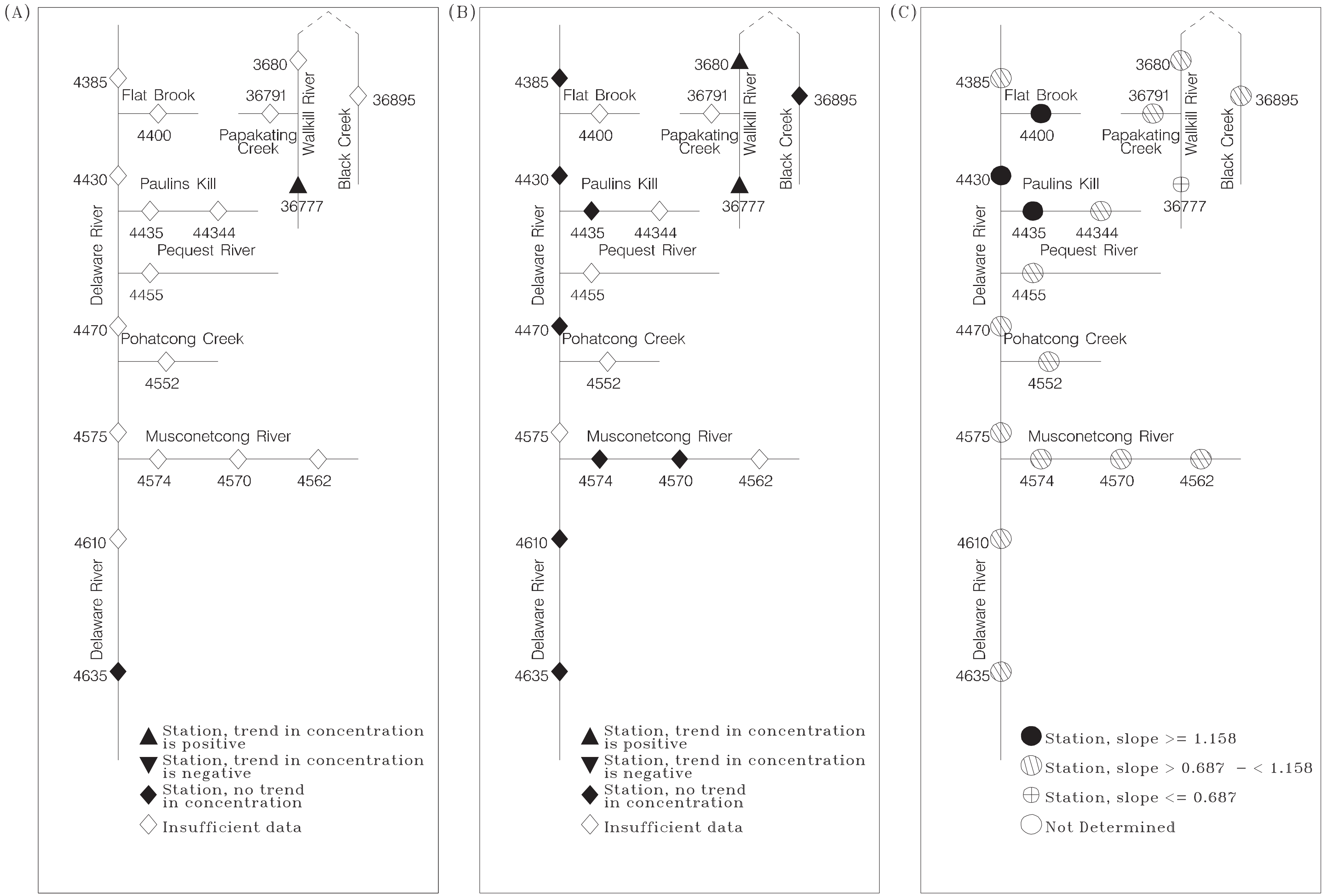


Figure 18. Trends in total nitrate plus nitrite concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total nitrate plus nitrite load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

the contributions to instream total nitrate plus nitrite loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slope is in the low range at the upstream station on the Wallkill River (36777), where the contribution to instream total nitrate plus nitrite loads from point sources and ground water is larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Wallkill and Musconetcong Rivers and Paulins Kill increase in the downstream direction, indicating an increase in the contributions from storm runoff along the rivers, whereas slopes at stations on the Delaware River decrease in the downstream direction, indicating a decrease in the contributions from storm runoff along the river.

Total Nitrite

Nitrite is an intermediate oxidation state of nitrogen, both in the oxidation of ammonia to nitrate and in the reduction of nitrate. Nitrite species are unstable in aerated water and are generally considered to be indicators of the presence of sewage or organic waste (low DO conditions). Nitrite is the etiologic agent of methemoglobinemia.

Relation of trends in concentration to flow conditions

Insufficient data are available to determine trends in total nitrite concentrations during high flows at all stations in the study area (fig. 19a). During low flows, no trends were determined at the downstream station on the Wallkill River (3680) or at station 4570 on the Musconetcong River (fig. 19b).

Relation of load to streamflow

The range categories of regression slopes of total nitrite load to streamflow are depicted in figure 19c. The slopes range from 0.313 at station 36791 on the Papakating Creek (table 7a) to 1.140 at station 4435 on the Paulins Kill (table 17a). The slopes are in the high range at the farthest upstream station on the Delaware River (4385), the one station on the Flat Brook (4400), the downstream station on the Paulins Kill (4435), and station 4570 on the Musconetcong River. At these sites, the contributions to instream total nitrite loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slopes are in the low range at two downstream stations on the Delaware River (4575 and 4610), the stations on the Papakating (36791) and Black (36895) Creeks, and the upstream station on the Musconetcong River (4562). At these sites, the contributions to instream total nitrite loads from point sources and ground water are larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Paulins Kill increase in the downstream direction, indicating an increase in the contribution from storm runoff along the river.

Total Ammonia Plus Organic Nitrogen

Organic nitrogen is defined as organically bound nitrogen in the tri-negative oxidation state. It includes natural materials such as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials, but does not include all organic nitrogen compounds. Ammonia is produced by the deamination of organic nitrogen-containing compounds. Ammonia

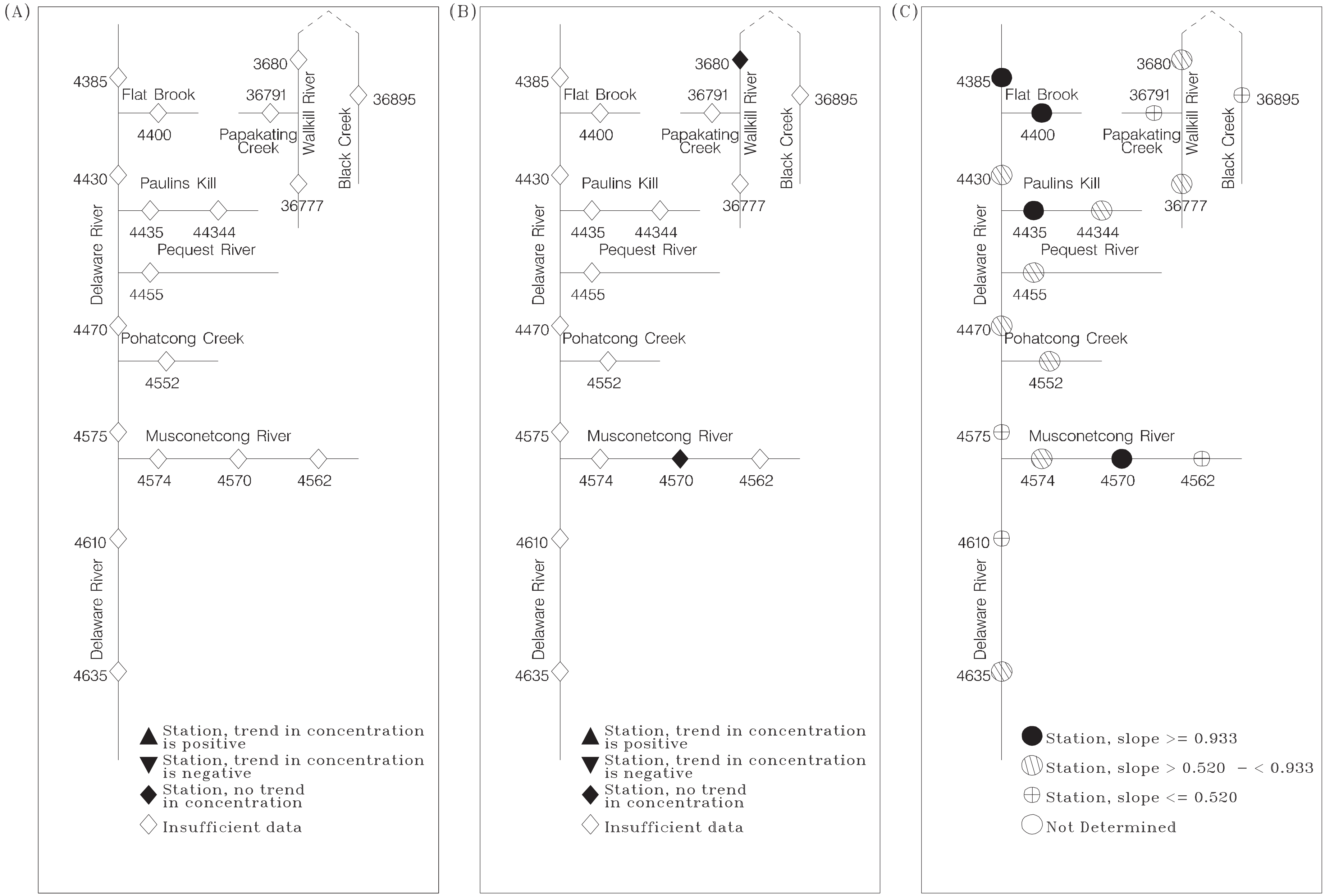


Figure 19. Trends in total nitrite concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total nitrite load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

can enter surface water dissolved in wastewater effluent, storm runoff, and rain. Temperature, pH, and ionic strength control the speciation of ammonia in surface water. The un-ionized form of ammonia is toxic to fish. The total ammonia plus organic nitrogen concentrations are determined together by the kjeldahl method (Eaton and others, 1995).

Relation of trends in concentration to flow conditions

The trends in total ammonia plus organic nitrogen concentrations during high flows are negative at the one station on the Black Creek (36895) and the downstream station on the Paulins Kill (4435), indicating a decrease in the contribution from storm runoff through time at these stations (fig. 20a). The trend in total ammonia plus organic nitrogen concentrations during high flows is positive at the farthest downstream station on the Delaware River (4635), indicating an increase in the contributions from storm runoff through time at this station. The concentrations of total ammonia plus organic nitrogen during high flows show no trends at the upstream station on the Wallkill River (36777), the one station on the Papakating Creek (36791), one downstream station on the Delaware River (4610), the one station on the Pequest River (4455), the downstream station on the Paulins Kill (4435), and the upstream (4562) and downstream (4574) stations on the Musconetcong River. The trends in total ammonia plus organic nitrogen concentrations during low flows are negative at the farthest upstream (4385) and fifth downstream (4610) stations on the Delaware River, indicating a decrease in the contribution from point sources and ground water through time at these stations (fig. 20b). The concentrations of total ammonia plus organic nitrogen during low flows show no trends at both stations on the Wallkill River (36777 and 3680); the one station on Black Creek (36895); the second (4430), third (4470), and farthest downstream (4635) stations on the Delaware River; and the downstream stations on the Paulins Kill (4435) and Musconetcong River (4574).

Relation of load to streamflow

The range categories of regression slopes of total ammonia plus total organic nitrogen load to streamflow are depicted in figure 20c. The slopes range from 0.798 at station 36791 on the Papakating Creek (table 7a) to 1.209 at station 4385 on the Delaware River (table 9a). The slopes are in the high range at the farthest upstream (4385) and downstream (4635) stations on the Delaware River, the upstream station on the Paulins Kill (44344), the one station on the Pohatcong Creek (4552), and station 4570 on the Musconetcong River. At these sites, the contributions to instream loads from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slopes are in the low range at the one station on each of the Papakating (36791) and Black (36895) Creeks, and the downstream station on the Musconetcong River (4574). At these sites, however, the contributions to instream TAON loads from point sources and ground water probably are relatively insignificant because the load-to-streamflow slopes are large (greater than 0.8). Storm runoff most likely is a major contributor of TAON in the study area because the load-to-streamflow slopes at all stations are large.

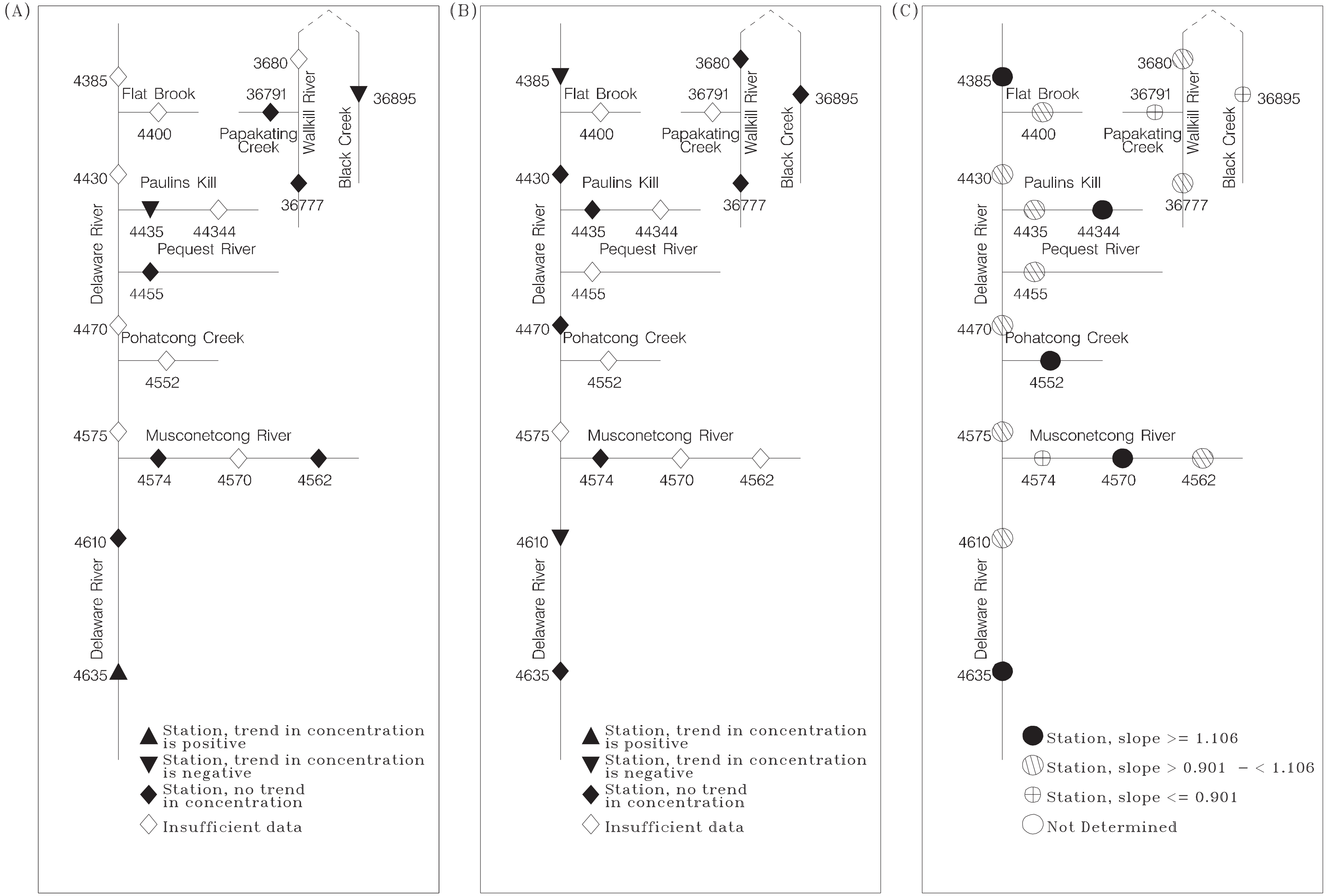


Figure 20. Trends in total ammonia plus organic nitrogen concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total ammonia plus organic nitrogen load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Total Ammonia

Ammonia is produced largely by deamination of organic nitrogen-containing compounds and by hydrolysis of urea. Ammonia can enter surface water by wet deposition with industrial, municipal, and agricultural wastewater and runoff, especially from areas treated with ammonia fertilizers. At some water-treatment plants, ammonia is added to react with chlorine to form a combined chlorine residual. Contributions of ammonia to surface water from ground water are usually small because ammonia can adsorb to soil particles and clays and does not leach from soils (Hem, 1985).

The toxicity of ammonia to fish is dependent on its speciation. Un-ionized ammonia is considered to be the toxic form to aquatic organisms (Rand and Petrocelli, 1985). The relative concentrations of ionized (NH_4^+) and un-ionized (NH_3) ammonia are a function of the pH, temperature, and ionic strength of the aqueous solution. When the pH, temperature, and total-ammonia concentration are measured in a solution, the relative concentrations of NH_3 and NH_4^+ can be calculated. Decreased dissolved oxygen concentrations can cause an increase in ammonia toxicity.

Relation of trends in concentration to flow conditions

The total ammonia concentrations during high flows show no trends at the upstream stations on the Wallkill (36777) and Musconetcong (4562) Rivers (fig. 21a). The trends in total ammonia concentrations during low flows are negative at the downstream station on the Wallkill River (3680), indicating a decrease in the contribution from point sources and ground water through time at this station (fig. 21b). Total ammonia concentrations during low flows show no trends at the one station on the Black Creek (36895), the three farthest upstream stations on the Delaware River (4385, 4430, and 4470), and the downstream stations on the Paulins Kill (4435) and Musconetcong River (4570 and 4574).

Relation of load to streamflow

The range categories of regression slopes of total ammonia load are depicted in figure 21c. The slopes range from 0.767 at station 36895 on the Black Creek (table 8a) to 1.445 at the farthest downstream station on the Delaware River (4635) (table 14a). The slopes are in the high range at the farthest downstream station on the Delaware River (4635), the station on the Pohatcong Creek (4552) and one station on the Musconetcong River (4570). At these sites, the contributions to instream total ammonia load from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slopes are in the low range at both stations on the Wallkill River (36777 and 3680), one station on the Papakating Creek (36791), the only station on Black (36895) Creek, the two farthest upstream stations (4385 and 4430) and the fourth downstream (4575) station on the Delaware River, and the only station on the Flat Brook (4400). At these sites, the contributions to instream total ammonia loads from point sources and ground water are larger and less influenced by storm runoff than at other sites in the study area. Slopes at stations on the Delaware River increase in the downstream direction, indicating an increase in the contributions from storm runoff along the river.

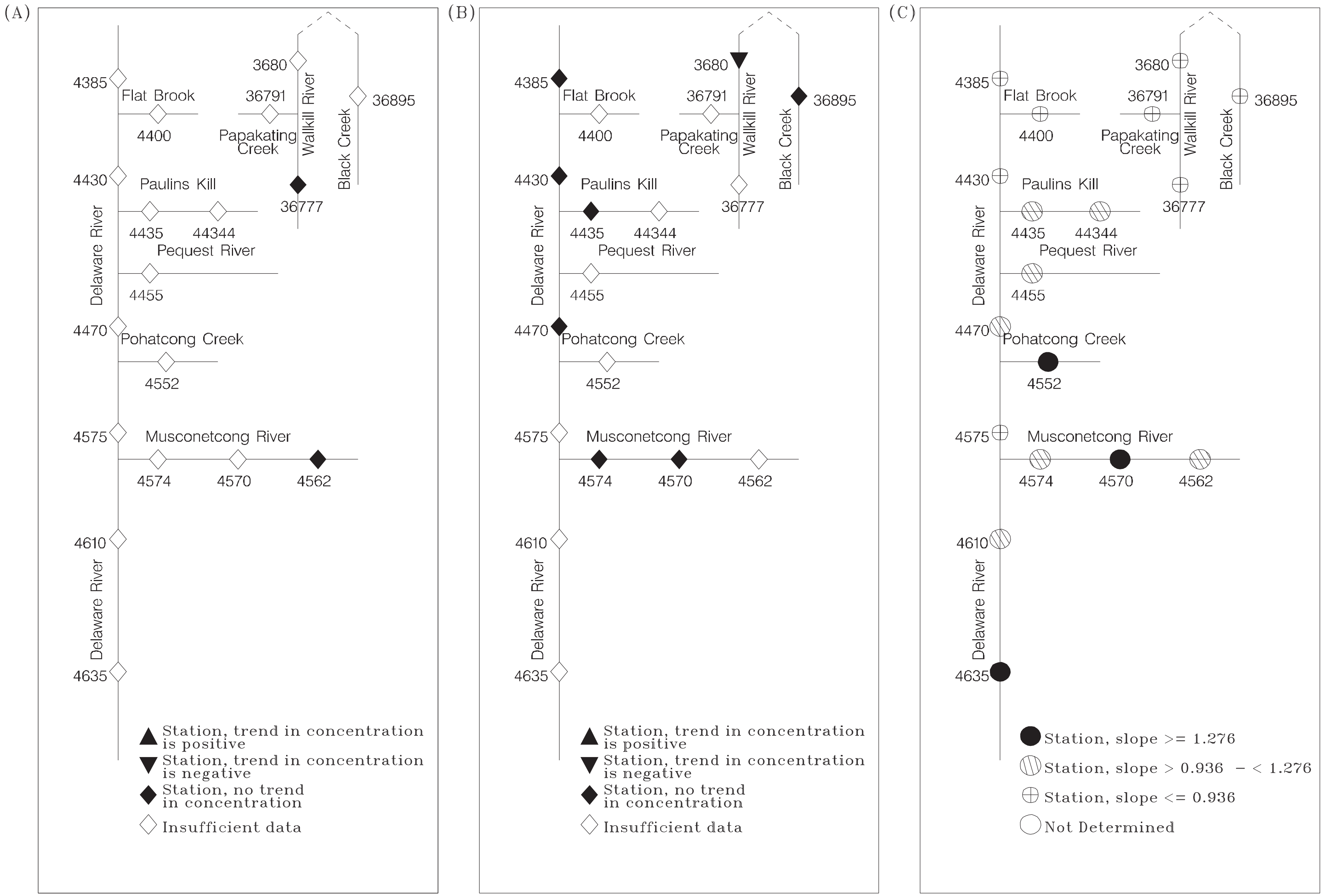


Figure 21. Trends in total ammonia concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total ammonia load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Total Boron

Boron is a minor constituent in most surface water. Small amounts of boron are essential for plant growth. Boron minerals are present in some igneous rocks; water in volcanic areas and thermal springs may contain considerable concentrations of boron (Hem, 1985). Boron from the cleaning agent, sodium tetraborate (borax), can be present in surface water as a result of the release of treated sewage and industrial-use water.

<u>Relation of trends in concentration to flow conditions</u>

Insufficient data are available to determine trends in boron concentrations during high and low flows at all stations in the study area (figs. 22a and b).

<u>Relation of load to streamflow</u>

The range categories of regression slopes of total boron to streamflow are depicted in figure 22c. Insufficient data are available to determine slopes at nine of the stations. The slopes range from zero at station 36791 on the Papakating Creek (table 7a) to 1.153 at the downstream station on the Musconetcong River (4574) (table 22a). The slopes are in the high range at the fifth downstream station on the Delaware River (4610) and the downstream station on the Musconetcong River (4574), indicating that contributions to instream boron load from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The slope is in the low range at the only station on the Pohatcong Creek (36791), indicating that the contributions to instream total boron loads from point sources and ground water are larger and less influenced by storm runoff at this site than at other sites in the study area.

Total Lead

Lead is occasionally present in surface water in trace amounts, which can be toxic to aquatic organisms. Lead is widely dispersed in sedimentary rocks; however, its mobility is low (Hem, 1985). The many uses of lead have dispersed the element throughout the environment. Dry fallout and rain-out of particulate lead is probably a factor of major importance in the circulation of the element. Concentrations of lead in rain and snow are greater in areas subject to substantial air pollution than in more remote areas. Storm runoff is a potential source of lead in surface water.

<u>Relation of trends in concentration to flow conditions</u>

Insufficient data are available to determine trends in lead concentrations during high and low flows at all stations in the study area (figs. 23a and b).

<u>Relation of load to streamflow</u>

The range categories of regression slopes of total lead to streamflow are depicted in figure 23c. Insufficient data are available to determine the slope at station 4435 on the Paulins Kill. The slopes range from zero at stations on the Papakating (36791) and Black (36895) Creeks and Flat

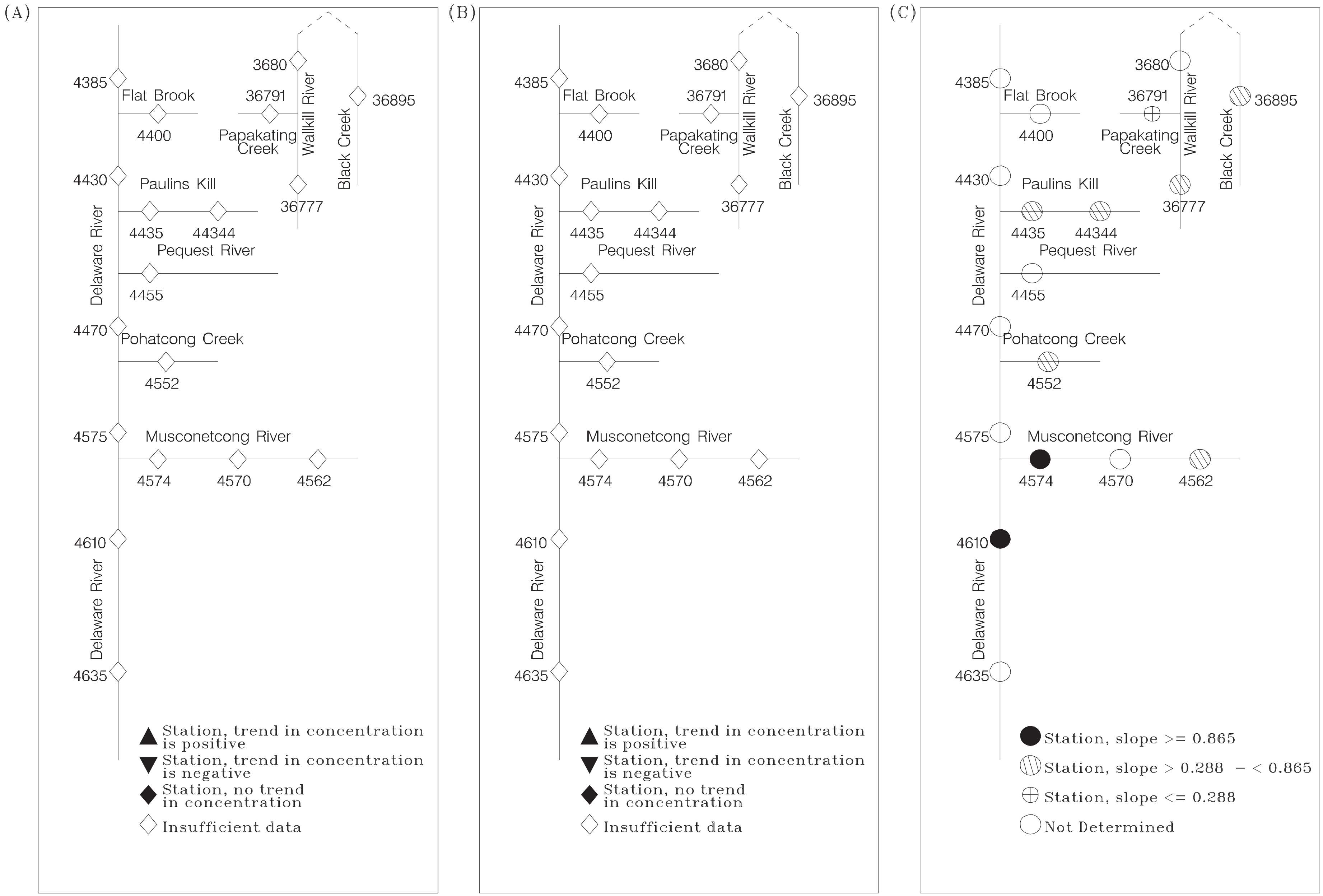


Figure 22. Trends in total boron concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total boron load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

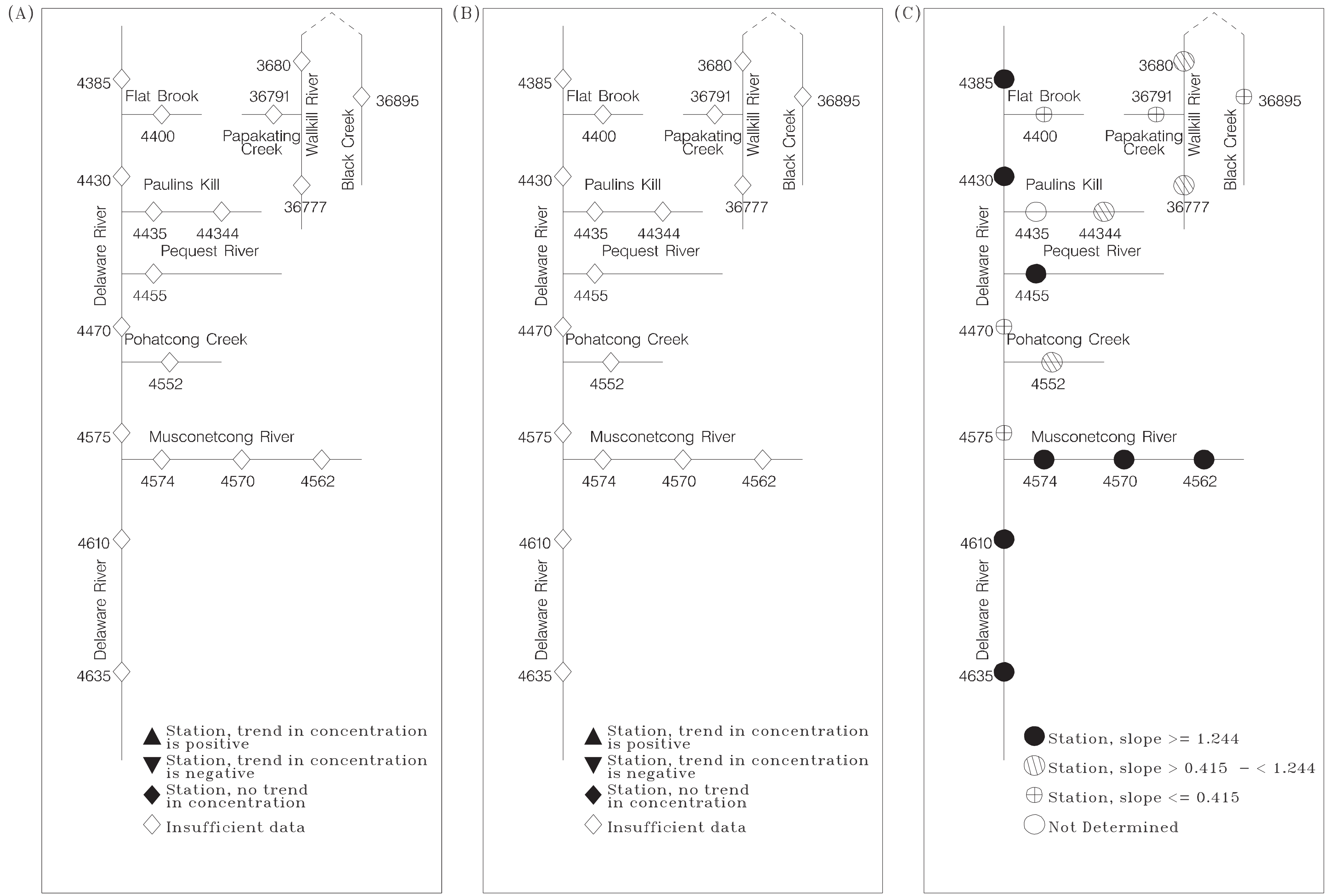


Figure 23. Trends in total lead concentrations during (A) high- and (B) low-flow conditions, and (C) relative slope of total lead load to streamflow at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

Brook (4400) (tables 7a, 8a, and 15a, respectively), and the third (4470) and fourth (4575) downstream stations on the Delaware River (tables 11a and 12a) to 1.659 at station 4570 on the Musconetcong River (table 21a). The slopes are in the high range at the two farthest upstream (4385 and 4430) and two farthest downstream (4610 and 4635) stations on the Delaware River, the only station on the Pequest River (4455), and all stations on the Musconetcong River (4562, 4562, and 4574). At these sites, contributions to instream total lead load from storm runoff are larger and less influenced by point sources and ground water than at other sites in the study area. The five stations with zero slope values are the only stations with slopes in the low range.

Fecal Coliform Bacteria

Fecal coliform bacteria are present in the intestine and feces of warm-blooded animals. The presence of high numbers of fecal coliform bacteria in surface water can indicate the recent release of untreated wastewater or the presence of animal feces, or both. These organisms also can indicate the presence of pathogens that are harmful to humans. High numbers of fecal coliform bacteria can render surface water unfit for some uses, such as swimming and fishing. Fecal coliform bacteria are often used as indicators of the sanitary quality of the water (Eaton and others, 1995). For laboratory purposes, fecal coliform bacteria are defined as all organisms that produce blue colonies within 24 hours when incubated at 44.5 °C ± 0.2 °C on M-FC medium (nutrient medium for bacterial growth) (Bauersfeld and others, 1994).

Relation of trends in concentration to flow conditions

The trend in fecal coliform bacteria concentrations during high flows is negative at the downstream station on the Paulins Kill (4435), indicating a decrease in the contribution from storm runoff through time at this station (fig. 24a). The fecal coliform bacteria concentrations during high flows show no trends at the upstream station on the Wallkill River (36777), the one station on each of the Papakating (36791) and Black (36895) Creeks, the fifth downstream station on the Delaware River (4610), one station each on the Flat Brook (4400) and the Pequest River (4455), and the upstream (4562) and downstream (4574) stations on the Musconetcong River. The trend in fecal coliform bacteria concentrations during low flows is positive at the downstream station on the Wallkill River (3680), indicating an increase in the contribution from point sources and ground water through time at this station (fig. 24b). The fecal coliform bacteria concentrations during low flows show no trends at the upstream station on the Wallkill River (36777), the one station on the Black Creek (36895), the three farthest upstream (4385, 4430, and 4470) and fifth downstream (4610) stations on the Delaware River, and the downstream stations on the Paulins Kill (4435) and Musconetcong River (4570 and 4574).

COMPARISON OF RESULTS

Positive trends in constituent concentrations through time during low flows indicate increasing constant-rate source contributions for DS at one station on the Musconetcong River (4574); for NA at stations on the Wallkill River (36777), the Paulins Kill (4435), and the Musconetcong River (4574); for CL at stations on the Wallkill River (36777), the Delaware River (4430, 4470, 4610, and 4635), the Paulins Kill (4435), and the Musconetcong River (4570 and 4574); for FDO at station 36895 on the Black Creek; for TN at station 36777 on the Wallkill

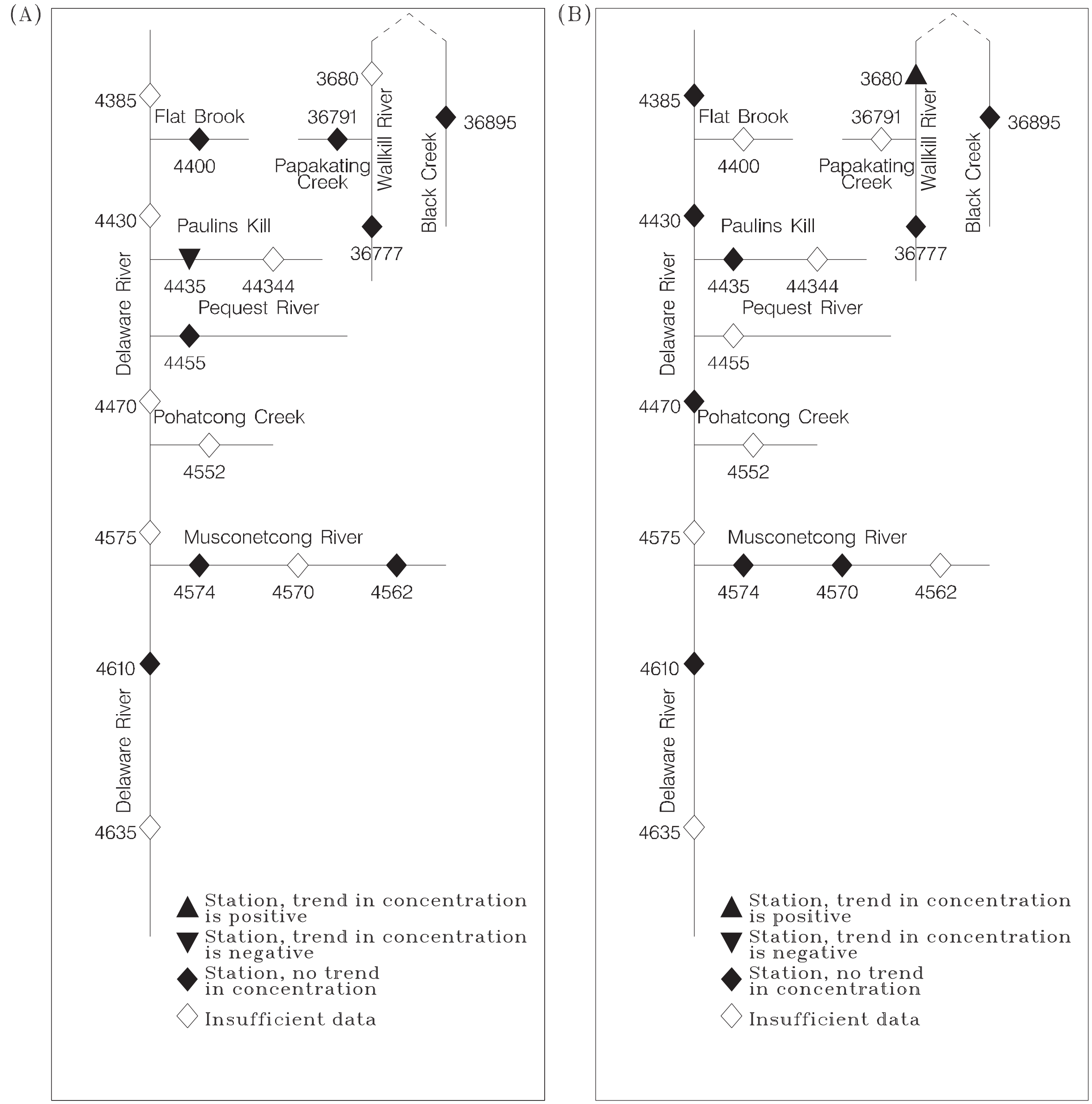


Figure 24. Trends in fecal coliform bacteria concentrations during (A) high- and (B) low-flow conditions at surface-water-quality stations in the Wallkill and upper Delaware River Basins, N.J. and vicinity, water years 1976-93.

River; for NO32 at both stations on the Wallkill River (36777 and 3680); and for BACT at station 3680 on the Wallkill River (table 23). Negative trends during low flows indicate decreasing constant-rate source contributions for DS at one station on the Delaware River (4610); for TN at stations on the Paulins Kill (4435) and the Delaware River (4610); for TAON at stations 4385 and 4610 on the Delaware River; and for NH4 at station 3680 on the Wallkill River (table 23).

Positive trends during high flows indicate increasing intermittent source contributions for DS at one station on the Delaware River (4635); for NA at stations on the Wallkill River (36777), the Papakating Creek (36791), the Delaware River (4610 and 4635), the Paulins Kill (4435), and the Musconetcong River (4562); for CL at stations on the Wallkill River (36777), the Papakating Creek (36791), and the Delaware River (4610 and 4635); for DO and FDO at station 4400 on the Flat Brook; for TN at station 4635 on the Delaware River; for NO32 at station 36777 on the Wallkill River; and for TAON at station 4635 on the Delaware River (table 24). Negative trends during high flows indicate decreasing intermittent source contributions for TAON at stations on the Black Creek (36895) and Paulins Kill (4435), and for BACT at station 4435 on the Paulins Kill (table 24).

Insufficient data are available for 3 of the 18 water-quality stations—44344 on the Paulins Kill, 4552 on the Pohatcong Creek, and 4575 on the Delaware River—to determine trends in concentrations during both high and low flows. Only high-flow trends are evident for stations on the Papakating Creek (36791), the Flat Brook (4400), the Pequest Creek (4455), and the Musconetcong (4562). Only low-flow trends are evident for stations on the Wallkill (3680), the Delaware River (4385, 4430, and 4470), and the Musconetcong River (4570). The lack of water-quality data during low and high flows at many of the stations is due, in part, to the conservative method used in this study. This method ensured that only data collected during base flow and storm flow were used to determine trends. If additional data were collected or the data-collection schedule were changed to accommodate sampling during a full range of flow conditions, and if different flow durations were used to group the data so that more of the data were included, a greater number of significant trends might be identified. (All figures generated in this study are available in appendixes on CD-ROM for further site-by-site comparisons of visual trends.)

Relations of concentration to streamflow show that concentrations decrease with increasing flows (dilution); therefore, negative slopes predominate. A significant seasonal dependency (a total of 10 more stations per constituent) is evident for NA, CL, DO, NO32, and BACT (table 25). Seasonal dependency is not evident at any station for B or PB. DO shows seasonal dependency at all stations, possibly because of its relation to bioactivity and temperature in surface water. NA and CL most likely show seasonal dependency because of road salting; however, they do not have an effect on the seasonality of DS.

A change in the slopes of load-to-streamflow relations along a river reach in a downstream direction indicates changes in the relative importance of constant and intermittent sources along the river. Slopes increase in the downstream direction, indicating an increased relative importance of storm runoff, for DS and CL on the Wallkill River; for NA and CL on the Musconetcong River; for NO32 on the Wallkill River, the Paulins Kill, and the Musconetcong River; for TP on the Wallkill and Musconetcong Rivers; and for TN on the Wallkill River and the Paulins Kill. Slopes decrease in the downstream direction, indicating a decreased relative importance of storm runoff, for TOC on the Wallkill River and DS, NA, CL, and NO32 on the Delaware River.

Table 23. Concentration trends during low flows at surface-water-quality stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity, water years 1976-93

[USGS, U.S. Geological Survey; No., number; ALK, alkalinity; HARD; hardness; TOC, total organic carbon; SS, suspended sediment; DS, dissolved solids; NA, sodium; CL, chloride; DO, dissolved oxygen; FDO, fraction of dissolved oxygen at saturation; TP, total phosphorus; TN, total nitrogen; NO32, nitrate plus nitrite; NO2, nitrite; TAON, total ammonia plus organic nitrogen; NH4, ammonia; B, boron, PB, lead; BACT, fecal-coliform bacteria; ↑, positive trend; ↓, negative trend; ↔, no trend (slope is not significant at the 0.05 level); -, insufficient data for analysis; --, no total]

River basin	USGS station number	ALK	HARD	TOC	SS	DS	NA	CL	DO	FDO	TP	TN	NO32	NO2	TAON	NH4	B	PB	BACT	No. of constituents with a positive trend	No. of constituents with a negative trend	No. of constituents with no trend
Wallkill	01367770	-	↔	↔	-	↔	↑	↑	-	-	-	↑	↑	-	↔	-	-	-	↔	4	0	5
Papakating	01367910	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Wallkill	01368000	-	-	-	-	-	-	-	↔	↔	-	↔	↑	↔	↔	↓	-	-	↑	2	1	5
Black Creek	01368950	-	↔	↔	-	↔	↔	↔	↔	↑	-	↔	↔	-	↔	↔	-	-	↔	1	0	11
Delaware	01438500	-	↔	-	-	-	↑	↔	↔	↔	-	↔	↔	-	↓	↔	-	-	↔	1	1	8
Flat Brook	01440000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Delaware	01443000	-	↔	↔	-	↔	↑	↑	↔	↔	-	↔	↔	-	↔	↔	-	-	↔	2	0	10
Paulins Kill	01443440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	01443500	-	↔	↔	-	↔	↑	↑	↔	↔	-	↓	↔	-	↔	↔	-	-	↔	2	1	9
Pequest	01445500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Delaware	01447000	-	↔	↔	-	↔	↑	↑	↔	↔	-	↔	↔	-	↔	↔	-	-	↔	2	0	10
Pohatcong	01455200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Musconetcong	01456200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	01457000	-	-	-	-	-	-	↑	↔	↔	-	-	↔	↔	-	↔	-	-	↔	1	0	6
	01457400	-	↔	↔	-	↑	↑	↑	↔	↔	-	↔	↔	-	↔	↔	-	-	↔	3	0	9
Delaware	01457500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	01461000	-	↔	↔	-	↓	↔	↑	↔	↔	-	↓	↔	-	↓	-	-	-	↔	1	3	7
	01463500	-	↔	-	-	↔	↑	↑	↔	↔	↔	↔	↔	-	↔	-	-	-	-	2	0	8
No. of stations with a positive trend		0	0	0	0	1	7	8	0	1	0	1	2	0	0	0	0	0	1	--	--	--
No. of stations with a negative trend		0	0	0	0	1	0	0	0	0	0	2	0	0	2	1	0	0	0	--	--	--
No. of stations with no trend		0	9	7	0	6	2	2	10	9	1	7	9	2	8	7	0	0	9	--	--	--

Table 24. Concentration trends during high flows at surface-water-quality stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity, water years 1976-93

[USGS, U.S. Geological Survey; No., number; ALK, alkalinity; HARD; hardness; TOC, total organic carbon; SS, suspended sediment; DS, dissolved solids; NA, sodium; CL, chloride; DO, dissolved oxygen; FDO, fraction of dissolved oxygen at saturation; TP, total phosphorus; TN, total nitrogen; NO32, nitrate plus nitrite; NO2, nitrite; TAON, total ammonia plus organic nitrogen; NH4, ammonia; B, boron, PB, lead; BACT, fecal-coliform bacteria; ↑, positive trend; ↓, negative trend; ↔, no trend (slope is not significant at the 0.05 level); -, insufficient data for analysis; --, no total]

River basin	USGS station number	ALK	HARD	TOC	SS	DS	NA	CL	DO	FDO	TP	TN	NO32	NO2	TAON	NH4	B	PB	BACT	No. of constituents with a positive trend	No. of constituents with a negative trend	No. of constituents with no trend
Wallkill	01367770	-	↔	↔	-	↔	↑	↑	↔	↔	↔	↔	↑	-	↔	↔	-	-	↔	3	0	10
Papakating	01367910	-	↔	↔	-	-	↑	↑	↔	↔	-	-	-	-	↔	-	-	-	↔	2	0	6
Wallkill	01368000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Black Creek	01368950	-	↔	↔	-	↔	↔	↔	↔	↔	-	-	-	-	↓	-	-	-	↔	0	1	8
Delaware	01438500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Flat Brook	01440000	-	-	-	-	-	-	-	↑	↑	-	-	-	-	-	-	-	-	↔	2	0	1
Delaware	01443000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Paulins Kill	01443440	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	01443500	-	↔	↔	-	↔	↑	↔	↔	↑	↔	-	-	-	↓	-	-	-	↓	2	2	6
Pequest	01445500	-	-	-	-	-	-	-	↔	↔	-	-	-	-	↔	-	-	-	↔	0	0	4
Delaware	01447000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Pohatcong	01455200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
Musconetcong	01456200	-	↔	↔	-	↔	↑	↔	↔	↔	↔	-	-	-	↔	↔	-	-	↔	1	0	10
	01457000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	01457400	-	↔	↔	-	↔	↔	↔	↔	↔	-	-	-	-	↔	-	-	-	↔	0	0	9
Delaware	01457500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0
	01461000	-	↔	↔	-	↔	↑	↑	↔	↔	-	-	-	-	↔	-	-	-	↔	2	0	7
	01463500	-	↔	-	↔	↑	↑	↑	↔	↔	↔	↑	↔	-	↑	-	-	-	-	5	0	6
No. of stations with a positive trend		0	0	0	0	1	6	4	1	2	0	1	1	0	1	0	0	0	0	--	--	--
No. of stations with a negative trend		0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	--	--	--
No. of stations with no trend		0	8	7	1	6	2	4	9	8	4	0	1	0	6	2	0	0	8	--	--	--

Table 25. Seasonal dependency at surface-water-quality stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity, water years 1976-93

[USGS, U.S. Geological Survey; No., number; ALK, alkalinity; HARD, hardness; TOC, total organic carbon; SS, suspended sediment; DS, dissolved solids; NA, sodium; CL, chloride; DO, dissolved oxygen; FDO, fraction of dissolved oxygen at saturation; TP, total phosphorus; TN, total nitrogen; NO32, nitrate plus nitrite; NO2, nitrite; TAON, total ammonia plus organic nitrogen; NH4, ammonia; B, boron; PB, lead; BACT, fecal-coliform bacteria; S indicates seasonal dependency (the slope and (or) intercept of growing (April through October) and non-growing (November through March) season data were different at the 0.05 significance level; -, no seasonal dependency or insufficient data for analysis; --, no total]

River basin	USGS station number	ALK	HARD	TOC	SS	DS	NA	CL	DO	FDO	TP	TN	NO32	NO2	TAON	NH4	B	PB	BACT	No. of constituents with seasonal dependency
Wallkill	01367770	S	-	S	-	-	S	S	S	S	-	-	S	-	-	-	-	-	S	8
Papakating	01367910	S	S	S	-	S	-	S	S	S	S	S	S	S	-	-	-	-	S	12
Wallkill	01368000	-	-	-	-	-	-	-	S	S	-	-	S	-	-	S	-	-	S	5
Black Creek	01368950	S	S	S	-	S	S	-	S	-	-	-	S	S	-	-	-	-	S	9
Delaware	01438500	-	-	-	-	-	-	-	S	-	-	S	S	-	-	-	-	-	S	4
Flat Brook	01440000	-	-	-	-	-	-	S	S	-	-	-	S	-	-	-	-	-	S	4
Delaware	01443000	-	S	S	-	S	S	S	S	-	-	-	S	-	S	-	-	-	-	8
Paulins Kill	01443440	-	-	S	-	-	S	S	S	S	-	-	S	S	S	S	-	-	S	10
	01443500	S	S	S	S	-	-	-	S	-	-	S	S	-	-	-	-	-	S	8
Pequest	01445500	-	S	-	-	-	-	-	S	-	-	-	-	S	S	-	-	-	S	5
Delaware	01447000	-	-	S	-	-	S	S	S	S	-	-	S	-	-	-	-	-	-	6
Pohatcong	01455200	S	S	-	-	S	S	S	S	-	-	-	-	S	-	S	-	-	S	9
Musconetcong	01456200	S	S	S	-	S	S	S	S	-	-	-	-	S	S	S	-	-	S	11
	01457000	-	S	-	-	-	-	-	S	-	-	-	-	-	-	S	-	-	S	4
	01457400	S	S	-	-	-	S	S	S	-	-	-	-	-	-	-	-	-	S	6
Delaware	01457500	-	-	-	-	-	-	-	S	-	S	-	S	S	-	S	-	-	-	5
	01461000	-	-	-	-	-	S	S	S	-	-	-	S	-	-	-	-	-	-	4
	01463500	S	-	-	S	-	S	S	S	-	S	-	S	-	-	S	-	-	-	8
No. of stations with seasonal dependency		8	9	8	2	5	10	11	18	5	3	3	13	7	4	7	0	0	13	--

Table 26. Maximum, minimum, and spread of load-to-streamflow slopes for selected constituents at surface-water-quality stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity, water years 1976-93

[USGS, U.S. Geological Survey; ALK, alkalinity; HARD, hardness; TOC, total organic carbon; SS, suspended sediment; DS, dissolved solids; NA, sodium; CL, chloride; H, high-slope category; L, low-slope category; -, moderate-slope category; ND, not determined; --, no total]

River basin	USGS station number	ALK	HARD	TOC	SS	DS	NA	CL	Number of constituents with high slopes	Number of constituents with low slopes
Wallkill	01367770	-	-	-	L	L	-	L	0	3
Papakating	01367910	-	-	L	L	-	-	-	0	2
Wallkill	01368000	-	-	L	L	-	-	-	0	2
Black Creek	01368950	H	-	L	L	-	-	L	1	3
Delaware	01438500	L	H	H	H	H	-	-	4	1
Flat Brook	01440000	ND	L	-	-	L	-	L	0	3
Delaware	01443000	-	-	-	H	H	-	-	2	0
Paulins Kill	01443440	-	-	-	-	-	-	-	0	0
	01443500	H	-	-	-	-	-	-	1	0
Pequest	01445500	H	H	-	H	-	-	-	3	0
Delaware	01447000	-	-	-	H	-	-	-	1	0
Pohatcong	01455200	-	-	L	-	-	-	-	0	1
Musconetcong	01456200	-	-	L	-	-	-	-	0	1
	01457000	L	-	L	H	-	H	H	3	2
	01457400	-	-	L	-	-	H	H	2	1
Delaware	01457500	H	L	H	H	L	L	L	3	4
	01461000	L	L	-	H	L	L	L	1	5
	01463500	-	L	H	-	L	L	L	1	4
Number of stations with high slopes		4	2	3	7	2	2	2	--	--
Number of stations with low slopes		3	4	7	4	5	3	6	--	--
Maximum slope		.69	.88	1.24	2.52	.93	1.05	1.07	--	--
Minimum slope		.50	.65	.93	.85	.70	.63	.69	--	--
Spread between maximum and minimum slopes		.19	.23	.31	1.67	.23	.42	.38	--	--

Table 27. Maximum, minimum, and spread of load-to-streamflow slopes for selected nutrients at surface-water-quality stations in the Wallkill and upper Delaware River Basins, New Jersey and vicinity, water years 1976-93

[USGS, U.S. Geological Survey; TP, total phosphorus; TN, total nitrogen; NO32, nitrate plus nitrite; NO2, nitrite; TAON, total ammonia plus organic nitrogen; NH4, ammonia; H, high-slope category; L, low-slope category; -, moderate-slope category; --no total]

River basin	USGS station number	TP	TN	NO32	NO2	TAON	NH4	Number of constituents with high slopes	Number of constituents with low slopes
Wallkill	01367770	L	L	L	-	-	L	0	4
Papakating	01367910	L	-	-	L	L	L	0	4
Wallkill	01368000	-	-	-	-	-	L	0	1
Black Creek	01368950	-	-	-	L	L	L	0	3
Delaware	01438500	H	H	-	H	H	L	4	1
Flat Brook	01440000	-	H	H	H	-	L	3	1
Delaware	01443000	-	H	H	-	-	L	2	1
Paulins Kill	01443440	-	-	-	-	H	-	1	0
	01443500	-	H	H	H	-	-	3	0
Pequest	01445500	H	-	-	-	-	-	1	0
Delaware	01447000	-	-	-	-	-	-	0	0
Pohatcong	01455200	L	-	-	-	H	H	2	1
Musconetcong	01456200	L	-	-	L	-	-	0	2
	01457000	-	-	-	H	H	H	3	0
	01457400	-	-	-	-	L	-	0	1
Delaware	01457500	L	-	-	L	-	L	0	3
	01461000	-	-	-	L	-	-	0	1
	01463500	-	-	-	-	H	H	2	0
Number of stations with high slopes		2	4	3	4	5	3	--	--
Number of stations with low slopes		5	1	1	5	3	8	--	--
Maximum slope		1.13	1.12	1.39	1.14	1.21	1.45	--	--
Minimum slope		.51	.61	.45	.31	.80	.77	--	--
Spread of maximum and minimum slopes		.62	.51	.94	.83	.41	.68	--	--

Overall, for HARD, TOC, DS, NA, and CL, more slopes are in the low range than the high range (table 26). Slopes are generally in the low range at stations on the Wallkill River and the Papakating and Black Creeks. Slopes are in the high range at stations on the Paulins Kill, the Pequest River, and the Delaware River. In general, a similar number of slopes of nutrient load to streamflow are in the high and low ranges (table 27); however more slopes for nutrients are in the high range than in the low range on the Flat Brook, the Paulins Kill, and the Delaware River. For stations on the Wallkill River and the Papakating and Black Creeks, most nutrient slopes are in the low range. The load-to-streamflow slopes are greater than 0.8 for SS, TOC, and TAON at all stations.

SUMMARY

The U.S. Geological Survey, in cooperation with the New Jersey Department of Environmental Protection, investigated the quality of surface water in the Wallkill and upper Delaware River Basins during water years 1976-93. After selection of the appropriate surface-water-quality stations, constituents, and period of record, the water-quality data, instantaneous streamflow data, and flow durations were compiled and checked for accuracy. A project data base was maintained, and statistical parameters, such as median constituent concentrations, slopes of regression for load to streamflow and concentration to streamflow, and trends in constituent concentrations through time, were determined. Eighteen water-quality constituents at 18 surface-water-quality stations were investigated. The relative contributions of constant and intermittent sources of water-quality constituents were evaluated by testing for trends in concentrations during low and high flows, and qualitative values of source contributions were estimated by statistically defining the relations between concentration and streamflow, and load and streamflow.

Results of trend analysis can indicate the relative contributions of constant and intermittent sources to stream-water quality through time within a basin. A trend in concentrations during high-flow conditions can indicate increasing or decreasing intermittent source contributions through time, and a trend in concentrations during low-flow conditions can indicate increasing or decreasing constant source contributions through time. A conservative method was used to determine trends during low and high flows. The use of flow duration values covering a greater range would possibly allow additional significant trends to be determined.

The slopes of regression lines of load to streamflow were grouped into low (less than or equal to 25 percent of the interval between the minimum and maximum slopes of each constituent), medium (greater than 25 percent to less than 75 percent of the slope interval), and high (greater than 75 percent of the slope interval) ranges in order to compare sites by constituent. At sites with slopes in the high range, contributions to instream loads from storm runoff probably are larger than at other sites in the study area, indicating an increased relative importance of intermittent (nonpoint storm runoff) source contributions. At sites with slopes in the low range, contributions to instream loads from intermittent sources probably are smaller than at other sites in the study area, indicating an increased relative importance of constant (point sources and ground water) source contributions. For constituents with large slopes of load to streamflow (for example, total organic carbon, suspended sediment, and total ammonia plus organic nitrogen), storm runoff is most likely the significant contributor to instream loads, even for stations with load slopes in the low range. Constituent concentrations cannot be related to streamflow in the same way as load because contributions from storm runoff are flow dependent.

Trends in concentrations during low flows are positive (increasing constant-rate source contributions) at one station for dissolved solids, fraction of dissolved oxygen at saturation, total nitrogen, and bacteria; at two stations for nitrate plus nitrite; at seven stations for dissolved sodium; and at eight stations for dissolved chloride. Trends during low flows are negative (decreasing constant-rate source contributions) at one station for dissolved solids and ammonia and at two stations for total nitrogen and total ammonia plus organic nitrogen.

Trends in concentrations during high flows are positive (increasing intermittent source contributions) at one station for dissolved solids, dissolved oxygen, total nitrogen, nitrate plus nitrite, and total ammonia plus organic nitrogen; at two stations for fraction of dissolved oxygen at saturation; at four stations for dissolved chloride; and at six stations for dissolved sodium. Trends during high flows are negative (decreasing intermittent source contributions) at one station for fecal coliform bacteria and at two stations for total ammonia plus organic nitrogen.

Insufficient data are available to determine trends in concentrations during high- and low-flow conditions at 3 of the 18 water-quality stations. Trends tests were conducted only if there was at least one measurement in each period of not less than four of the six water years in each one-third of the period of study (18 years); a lack of data results in no trend.

Concentration-to-streamflow relations show seasonal dependency at one or more stations for 16 of the 18 constituents. Seasonal dependency is not indicated for total boron and lead. Slopes for hardness and dissolved solids are negative at all stations. At 16 stations, slopes are negative for alkalinity, dissolved sodium, and dissolved chloride, and at 12 stations, slopes are negative for total phosphorus. Slopes for total nitrogen, total nitrate plus nitrite, and total nitrite are almost equally divided between negative slopes and zero slopes (zero indicates the slope is not different from zero at the 0.05 significance level). Slopes for total organic carbon are positive at five stations and zero at all other stations. Slopes for suspended sediment are positive at 12 stations and zero at all other stations. Slopes for dissolved oxygen are positive at 16 stations; slopes for fraction of dissolved oxygen at saturation are zero at 13 stations. Slopes for total boron, total lead, and bacteria are zero at most stations.

Slopes of load-to-streamflow relations increase in the downstream direction along one river reach for dissolved solids and dissolved sodium, and along two river reaches for dissolved chloride, total phosphorus, total nitrogen, and total nitrate plus nitrite, indicating an increased relative importance of storm runoff. For one stream, slopes decrease in the downstream direction for dissolved solids, dissolved sodium, dissolved chloride, and nitrate plus nitrite, indicating a decreased relative importance of storm runoff.

The relation of load to streamflow provides a qualitative estimate of the relative contributions from nonpoint storm runoff and ground water, and point sources, to surface-water quality, and represents preliminary results of the total maximum daily load process for the State's watersheds. The results of this study, along with identification of constant-rate sources, additional water-quality data collected during low and high flows, and ground-water data (water-quality data, water levels, flow rates, and travel times) could facilitate a more detailed analysis of the overall hydrology of these river basins.

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