Water Resources of Monroe County, New York, Water Years 1994-96, with Emphasis on Water Quality in the Irondequoit Creek Basin

Atmospheric Deposition, Ground Water, Streamflow, Trends in Water Quality, and Chemical Loads to Irondequoit Bay

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 00-4201

Prepared in cooperation with the
Monroe County Department of Health

Water Resources of Monroe County, New York, Water Years 1994-96, with Emphasis on Water Quality in the Irondequoit Creek Basin

Atmospheric Deposition, Ground Water, Streamflow, Trends in Water Quality, and Chemical Loads to Irondequoit Bay

By DONALD A. SHERWOOD

U.S. GEOLOGICAL SURVEY
Water Resources Investigations Report 00-4201

Prepared in cooperation with the
MONROE COUNTY DEPARTMENT OF HEALTH

USGS
science for a changing world

U.S. DEPARTMENT OF THE INTERIOR
Gale A. Norton, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

Subdistrict Chief
U.S. Geological Survey
30 Brown Road
Ithaca, NY 14850

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225

CONTENTS

FIGURES

APPENDIX

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To Obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	2.59	square kilometer
acre	0.40483	hectare
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch per year (in/yr)	25.4	millimeter per year
million gallons per day (Mgal/d)	3.785	cubic meters per day
gallons per minute (gal/min)	0.06309	liter per second
gallons per second (gal/s)	0.0010515	liter per second
	Volume	
cubic feet (ft^3)	0.02832	cubic meters
	Temperature	
degrees Fahrenheit (˚F)	˚C = 5/9 (˚F-32)	degrees Celsius

Specific Conductance

microsiemens per centimeter at 25˚ Celsius (µS/cm)

Equivalent Concentration Terms

milligrams per liter (mg/L) = parts per million
micrograms per liter (µg/L) = parts per billion

Load

Tons per day (ton/d)907.1kilograms per day
Pounds per square mile (lb/mi^2)0.175kilograms per square kilometer

Vertical datum: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Water Resources of Monroe County, New York, Water Years 1994-96, with Emphasis on Water Quality in the Irondequoit Creek Basin

Atmospheric Deposition, Ground Water, Streamflow, Trends in Water Quality, and Chemical Loads to Irondequoit Bay

By Donald A. Sherwood

ABSTRACT

Irondequoit Creek drains 169 square miles in the eastern part of Monroe County. Nutrients transported by Irondequoit Creek to Irondequoit Bay on Lake Ontario have contributed to the eutrophication of the Bay. Sewage-treatment-plant effluent, a major source of nutrients to the creek and its tributaries, was eliminated from the basin in 1979 by diversion to a regional wastewater-treatment facility, but sediment and contaminants from nonpoint sources continue to enter the creek and Irondequoit Bay.

This report analyzes data from five surface-water-monitoring sites in the Irondequoit Creek basin—Irondequoit Creek at Railroad Mills, East Branch Allen Creek at Pittsford, Allen Creek near Rochester, Irondequoit Creek at Blossom Road, and Irondequoit Creek at Empire Boulevard. It is the third in a series of reports that present interpretive analyses of the hydrologic data collected in Monroe County since 1984. Also included are data from a site on Northrup Creek, which drains a 23.5-square-mile basin west of the Genesee River in western Monroe County, to provide information on surface-water quality in a stream west of the Genesee River and on loads of nutrients delivered to Long Pond, a small eutrophic embayment of Lake Ontario, and data from the Genesee River for comparison of historical water-quality conditions with 1994-96 conditions. Water-level and water-quality data from nine observation wells in Ellison Park, and atmospheric-deposition data from Mendon Ponds, also are included.

Average annual yields of chemical constituents from atmospheric deposition for 1994-96 were generally similar to those for the previous 10 years (1984-93), except for dissolved sodium, dissolved potassium, total phosphorus, and orthophosphate, which ranged from 42 percent (dissolved sodium) to 275 percent (dissolved potassium) greater than during 1984-93, and dissolved sulfate and ammonia, which were about 30 percent less than in 1984-93.

Loads of all nutrients deposited in the Irondequoit Creek basin from atmospheric sources during water years 1994-96 exceeded those removed by Irondequoit Creek at Blossom Road—ammonia by 5,600 percent, orthophosphate by 2,500 percent, ammonia + organic nitrogen by 350 percent, total phosphorus by 300 percent and nitrite + nitrate by 140 percent. Average yields of dissolved chloride and dissolved sulfate from atmospheric deposition were much less than those transported in streamflow—yields of dissolved chloride from atmospheric sources were only 1.9 percent, and yields of sulfate were only 9.2 percent, of those transported in streamflow at Blossom Road.

Concentrations of several chemical constituents in streams of the Irondequoit Creek basin showed statistically significant trends from

the beginning of their period of record through 1996. The constituents that showed the greatest number of statistically significant trends were dissolved chloride, ammonia, and ammonia + organic nitrogen. Dissolved chloride showed an upward trend at Blossom Road, Allen Creek, and Empire Boulevard and a downward trend at Railroad Mills. Ammonia showed downward trends at Allen Creek, Blossom Road and Railroad Mills. Ammonia + organic nitrogen showed a downward trend at Allen Creek, Blossom Road, and Empire Boulevard. Nitrite + nitrate showed a downward trend at Allen Creek, and orthophosphate showed an upward trend at that site. Turbidity and total suspended solids showed a downward trend at Empire Boulevard. Neither total phosphorus nor volatile suspended solids showed statistically significant trends in concentration at any of the Irondequoit basin sites.

Northrup Creek showed a downward trend in total suspended solids and ammonia + organic nitrogen, and an upward trend in dissolved chloride. The Genesee River showed a downward trend in ammonia + organic nitrogen and chloride, and an upward trend in orthophosphate.

Most constituents for the 1994-96 water years showed lower average yields at Blossom Road than for the 1989-93 water years, but dissolved chloride showed higher yields for the 1994-96 water years at all sites except Blossom Road. Ammonia + organic nitrogen and total phosphorus showed a decrease in yield at all sites after 1993, and nitrite + nitrate showed slightly higher yields for 1994-96 at the upstream, predominantly rural sites, and lower yields at the downstream, more urban sites, than during 1989-93.

The trends and changes in surface-water quality after 1993 can be attributed to several factors within the basin, including land-use changes, annual and seasonal variations in streamflow, and year-to-year variations in the application of deicing salts on area roads. Statistical analyses of long-term (9 years or more) streamflow records of three unregulated streams in Monroe County indicate that annual mean flows for water years 1994-96 were in the normal range (75th to 25th percentile), although Allen Creek showed a statistically significant downward trend in monthly mean streamflow over the 1984-96 water years.

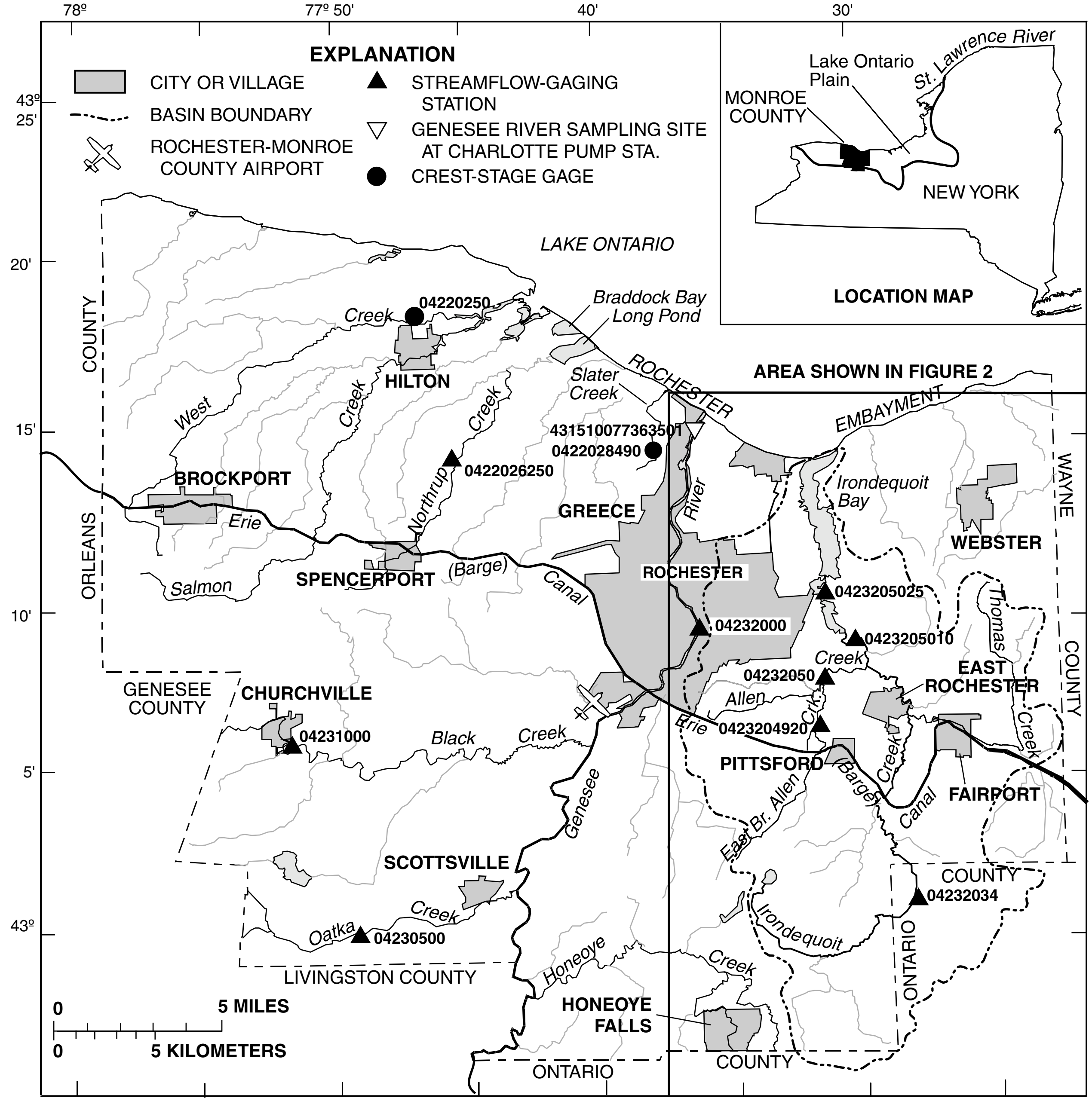
INTRODUCTION

Irondequoit Bay, near the city of Rochester, N.Y., (fig 1) has been eutrophic (overly enriched with nutrients) for several decades largely as a result of sewage, sediment, and nutrients that enter the bay from Irondequoit Creek. The discharge of sewage to Irondequoit Creek was eliminated in 1979, when the Monroe County wastewater treatment facility along the shore of Lake Ontario began operation.

Since 1980, the U.S. Geological Survey (USGS) has conducted a program in cooperation with the Monroe County Health Department (MCHD) and the Monroe County Environmental Health Laboratory (MCEHL) to collect and analyze water-resources data from several sites in Monroe County, particularly the Irondequoit Creek basin (fig. 1), to identify sources of contamination, quantify the annual loads of selected constituents, and define trends in concentration of these constituents in the county's streams and rivers. Although the discharge of sewage to Irondequoit Creek was eliminated in 1979, data collection has been continued in an effort to monitor the chemical quality of the creek and its tributaries and to assess the effectiveness of current resource management practices. A similar monitoring effort began in 1990 on Northrup Creek near North Greece (fig. 1), the main tributary to Long Pond, a small, highly eutrophic (Makarewicz and others, 1990) embayment in western Monroe County along the southern edge of Lake Ontario.

During water years[1] 1980-81, the USGS National Urban Runoff Program (NURP) study of the Irondequoit Creek basin investigated nonpoint-source contamination from selected areas representing specific land uses. Results of that study provided a basis from which changes in the nutrient and chemical loads of Irondequoit Creek could be identified. In 1993, the USGS, in cooperation with the Monroe County Health Department, began a program to

[1]Water year: the 12-month period from October 1 through September 30 of the following year. Thus, the water year ending on September 30, 1996, is the 1996 water year. All years referenced in this report are water years.



Base from U.S. Geological Survey
Digital Line Graph, 1:100,000

Streamflow-gaging stations

0422026250	Northrup Creek at North Greece	**04230500**	Oatka Creek at Garbutt
04231000	Black Creek at Churchville	**04232000**	Genesee River at Rochester
04232006	Genesee River at Charlotte Docks	**04232034**	Irondequoit Creek at Railroad Mills
04232050	Allen Creek near Rochester	**0423204920**	East Branch Allen Creek at Pittsford
0423205025	Irondequoit Creek at Empire Boulevard	**0423205010**	Irondequoit Creek at Blossom Road

Water quality site

431510077363501	Genessee River at Charlotte Pump Station

Crest stage gages

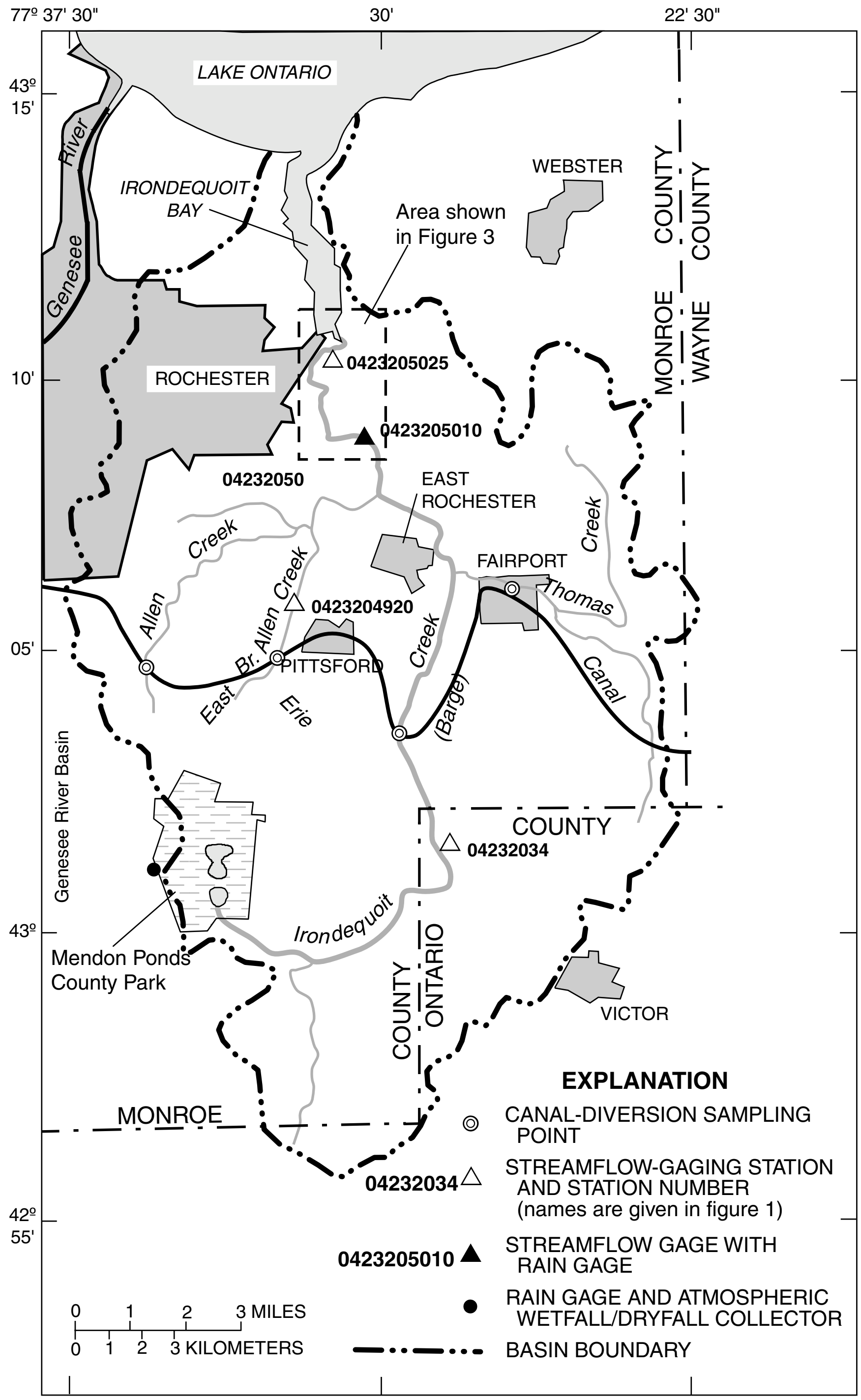
04220250	West Creek at Hilton, N.Y.	**0422028490**	Slater Creek near Greece, N.Y.

Figure 1. Principal geographic features of Monroe County, N.Y. and locations of streamflow-gaging stations in study area (From Sherwood, 1999, fig. 1.)

analyze hydrologic data collected in Monroe County to detect significant temporal trends in the concentrations of selected chemical constituents in streamflow and ground water. Statistical analyses of hydrologic data collected during water years 1984-88 are given in Johnston and Sherwood (1996); those for water years 1989-93 are given in Sherwood (1999). Data collection has continued since then to detect changes in water quality since 1993 and to help identify the causes of water-quality improvement or deterioration.

Purpose and Scope

This report describes the hydrologic conditions within Monroe County and the Irondequoit Creek basin during water-years 1994-96 and explains the methods of data analysis and the statistical methods used for trend analyses and estimation of constituent loads. It also (1) presents data on precipitation volume and chemical quality of bulk atmospheric deposition during 1994-96, for comparison with data from the two previous periods (1984-88, 1989-93), (2) analyzes fluctuations in ground-water levels in northern Ellison Park (fig. 2) and examines the vertical distribution of chemical concentrations in ground water at paired wells; (3) relates streamflow in Monroe County during 1994-96 to historical streamflow and to streamflow during 1989-93; (4) examines water-quality trends in Monroe County and relates chemical concentrations in 1994-96 to those of the previous two study periods and (5) presents loads and yields of selected constituents transported by Irondequoit Creek to Irondequoit Bay and by Northrup Creek to Long Pond and the Genesee River to Lake Ontario. Monthly and annual loads of selected constituents at the Irondequoit basin sites and Northrup Creek are presented in the appendix of this report.



Base from U.S. Geological Survey
State base map 1:500,000, 1974

Figure 2. Locations of streamflow-gaging stations, canal-diversion sites, and atmospheric deposition collection sites within the Irondequoit Creek basin, Monroe County, N.Y. (Locations shown in fig. 1. Modified from Sherwood, 1999, fig. 2.)

Description of the study area

Monroe County encompasses 673 mi^2 in the Lake Ontario Plain region of western New York (fig. 1) (Heffner and Goodman, 1973). Rochester, the county seat and largest city, is in the northern part of the county. The Genesee River, which flows northward through Rochester into Lake Ontario is the largest in Monroe County, and has a drainage area of 2,480 mi^2 at its mouth (Wagner and Dixson, 1985). Streams in the several smaller drainage basins (ranging from less than 5 mi^2 to about 88 mi^2) west of the Genesee River flow northeastward into Lake Ontario or to one of the several bays of the western part of the Rochester Embayment. Streams in several small drainage basins (ranging from less than 0.2 mi^2 to nearly 24 mi^2) east of the Genesee River flow north or northwestward into Lake Ontario and the Irondequoit Creek basin (169 mi^2).

Irondequoit Creek drains into Lake Ontario through Irondequoit Bay (fig. 2). Its drainage basin is mostly in eastern Monroe County and includes drainage from the east side of the city of Rochester and from neighboring Ontario and Wayne Counties. Northrup Creek, in western Monroe County, drains 23.5 mi^2 in the towns of Ogden, Parma, and Greece, and flows into Long Pond, a small embayment on the southern edge of Lake Ontario. A more complete description of the Irondequoit Creek basin, by Kappel and others (1986) describes stormwater and sanitary-sewer systems, drinking-water supplies, surficial geology, and climate. The glacial history and geohydrology of the Irondequoit Creek valley are discussed in Kappel and Young (1989).

The Erie (Barge) Canal flows southeastward through the middle of the county and receives flow from the headwater areas of several of these streams. Diversion structures at several points along the canal allow water from the canal to augment the flow of several small streams during low-flow conditions. The canal intersects the Genesee River 11.8 mi upstream from the river's mouth. Water diverted by the canal from Lake Erie is discharged into the Genesee River from the west; a smaller amount is then diverted from the Genesee River easterward into the canal.

Acknowledgments

Special thanks are extended to the personnel of MCEHL for assistance in the collection, analysis, and verification of the data presented herein. Richard Burton, MCEHL laboratory administrator, provided guidance and suggestions throughout the data-collection period. Charles Knauf of MCEHL organized and prepared the chemical-quality data for entry into the USGS data base.

ATMOSPHERIC DEPOSITION

Records of precipitation volume collected at the Rochester-Monroe County Airport (fig. 1) and published by the National Oceanic and Atmospheric Administration (NOAA) (1983, 1994-96) were used with chemical data from Mendon Ponds Park near the southwestern edge of the Irondequoit basin (fig. 2) for computation of constituent loads from atmospheric deposition within the Irondequoit Creek basin. The Mendon Ponds site was selected to represent deposition that is unaffected by urban emissions. Data from Mendon Ponds Park included wetfall (liquid deposition), dustfall (dry deposition, the fraction that settles out of the atmosphere as dust), and bulk (composite) deposition, which consists of the two previous forms. The three forms of deposition were analyzed for common ions, nutrients, and lead, and for physical characteristics such as pH and specific conductance. Only the bulk deposition analyses were used to estimate the contribution of atmospheric loads to the basin.

Precipitation Volume

The National Weather Service at the Rochester-Monroe County airport has collected precipitation data since May 1, 1929. Monthly total, annual total, and average monthly precipitation values for water years 1994-96 are shown in table 1; which includes "normal" values (mean values calculated from 1961-90 records). The 3-year average annual rainfall for 1994-96 was 1.44 in. (5 percent) above normal. Large rainstorms in October, November, April, June, and September 1996 pushed precipitation totals for the 1996 water year to 12 in. (38 percent) above normal. A deficiency in precipitation from February through June caused precipitation totals for the 1995 water year to be 6.5 in. (20 percent) below normal.

Table 1. Monthly and annual total precipitation, with 3-year average monthly and normal monthly values, at Rochester-Monroe County Airport, N.Y., water years 1994-96.

[All values are in inches. Location is shown in fig.1.]

Water year	Month												Annual total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	
1994	3.21	3.27	1.60	2.68	1.63	1.70	4.08	2.56	2.43	0.61	4.27	2.68	30.72
1995	1.34	3.24	2.32	2.46	1.58	1.15	1.18	1.75	2.07	3.85	3.05	1.50	25.49
1996	5.70	4.21	1.50	3.18	1.72	2.07	4.84	3.51	6.65	2.18	3.33	5.09	43.98
3-year average	3.42	3.57	1.81	2.77	1.64	1.64	3.37	2.61	3.72	2.21	3.55	3.09	33.40
Normal*	2.44	2.92	2.73	2.08	2.10	2.28	2.61	2.72	3.00	2.71	3.40	2.97	31.96

*Normal values are based on the average monthly or annual totals for 1961-90.

Chemical Loads

Loads of nitrogen species deposited on the Irondequoit Creek basin from atmospheric sources exceeded those removed by Irondequoit Creek by a substantial amount—ammonia by 5,600 percent, ammonia + organic nitrogen by 350 percent, and nitrite + nitrate by 140 percent. Annual yield (load per unit area) from atmospheric sources was calculated from the following formula:

$$\text{Yield} = CP \times \text{conversion factor},$$

where: C = concentration, in milligrams per liter; and

P = precipitation (annual), in inches.

The concentration C is obtained from the analysis of monthly bulk samples. The conversion factor transforms the results to the desired units of yield, in mass per unit area. The yield is then multiplied by drainage area to obtain load. This computation assumes that the precipitation recorded at the rain gage fell uniformly over the entire area represented by that particular gage, which is not usually the case and, therefore, may be subject to some degree of error.

Annual loads of selected constituents from atmospheric sources to the Irondequoit Creek basin are given in table 2. The most abundant constituents derived from atmospheric deposition during 1994-96 were sulfate and ammonia + organic nitrogen, with average annual yields of 19,500 lb/mi^2 and 4,400 lb/mi^2, respectively. The least abundant was lead, with an average annual yield of 28.5 lb/mi^2.

Annual loads deposited on the Irondequoit Creek basin from atmospheric sources during 1994-96 were similar to those during 1984-93 (table 2). Loads of total phosphorus, orthophosphorus, and potassium for 1994-96 ranged from 148 percent to 275 percent greater than for 1984-93, whereas loads of chloride, ammonia, and sulfate ranged from 15 to 34 percent lower.

Table 2. Annual yields of selected constituents in bulk atmospheric deposition at Mendon Ponds park, Monroe County, N. Y., water years 1994-96.

[Yields are in pounds per square mile. Location is snown in fig. 2.]

Water year	Calcium, dis-solved	Magnes-ium, dis-solved	Sodium, dis-solved	Potas-sium, dis-solved	Sulfate, dis-solved	Chloride, dissolved	Ammonia + organic nitrogen	Nitrite + nitrate	Ammonia	Total phos-phorus	Ortho-phos-phate	Lead, total recov-erable	Zinc, total recov-erable
1994	3,200	756	1,240	2,962	20,726	3,608	3,216	2,504	1,388	514	312	36.0	180
1995	2,159	676	636	2,784	12,318	2,948	4,418	1,361	797	700	501	17.6	168
1996	4,041	1,070	2,343	2,848	25,317	6,244	5,642	3,729	2,220	1,266	855	31.8	223
1994-96 avg.	3,133	834	1,406	2,865	19,454	4,267	4,425	2,531	1,468	827	556	28.5	190
1984-93 avg.	3,115	816	989	763	29,341	5,016	4,746*	2,682*	2,128	334*	189	30.9	196*
Percent difference	+0.6	+2.2	+42	+275	-34	-15	-6.8	-5.6	-31	+148	+194	-7.8	-3.1

* Averages are for less than 10 years of data.

GROUND WATER

Ground-water-level and water-quality data used in this report were obtained from nine wells in Ellison Park (fig. 3). Water levels were measured monthly and recorded to the nearest 0.01 ft. Water samples were collected once during 1994 and twice each year during 1995-96 from all wells and analyzed by MCEHL for specific conductance, pH, and concentrations of common ions, nutrients, metals, dissolved solids, alkalinity, and hardness. All wells except Mo 659 are finished in the upper (unconfined) part of the aquifer (table 3). Water levels and chemical quality at differing depths in the aquifer were compared through data from three sets of paired wells—Mo 663 and Mo 664 on the upper south slope of the buried Pinnacle Hills moraine (fig. 3), Mo 665 and Mo 666 on top of the moraine, and Mo 667 and Mo 668 upper north slope of the moraine.

Water Levels

Water-level data indicate local seasonal fluctuations in the water table, as well as changes in gradient of the water table in relation to other parts of the aquifer or to the water surface in nearby streams. Sand and gravel aquifers in the glaciated northeastern United States are recharged by snowmelt and precipitation, either by direct infiltration or by underflow from the upgradient aquifer system; they also are recharged by infiltration of surface water. Normally, the recharge and ground-water levels are highest during the spring snowmelt period and are lowest during midsummer, when evapotranspiration is greatest (fig. 4). Substantial recharge also can occur during fall, when evapotranspiration decreases.

All wells except Mo 2 and Mo 659 are within the flood plain of Irondequoit Creek (fig. 3) and, thus, respond to stage fluctuations in the creek. Annual mean water levels in well Mo 3, which is on the east bank of Irondequoit Creek (fig. 3), averaged 2.24 ft lower than in Mo 2, which is near the east wall of the valley and upgradient from Mo 3. Water levels in Mo 2 during 1984-96 ranged from 1.24 ft above land surface to 1.77 ft below, and those in Mo 3 ranged from 2.03 ft above land surface to 4.17 ft below. Mean monthly water levels at Mo 2 and Mo 3 (the Ellison Park wells with the longest period of record) during 1994-96 were within the monthly extremes for the period of record (fig. 5) and, except for January, were reasonably close to the mean monthly values for the period of record (1985-93). All wells including Mo 659 (confined aquifer) showed similar seasonal water-level fluctuations and response to recharge.

Table 3. Completion data on wells in Ellison Park , Monroe County, N.Y.

[LS, land surface; ft, feet. Locations shown in fig. 3.]

Well no.	Installation date	LS datum (ft above sea level)	Depth (ft below LS)	Screen interval (ft below LS)	Aquifer type[1]	Principal aquifer[2]
Mo 2	9/84	252.60	45	41-45	U	S & G
Mo 3	9/84	253.20	16	13.5-16	U	A
Mo 659	12/86	266.58	215	80-90 160-170	C	S & G
Mo663	9/88	251.16	10	7.5-10	U	A
Mo 664	9/88	251.18	27	22-27	U	A
Mo 665	9/88	254.14	17	12-17	U	A
Mo 666	9/88	254.14	27	22-27	U	A
Mo 667	9/88	255.38	15	10-15	U	A
Mo 668	9/88	255.32	36	31-36	U	A

[1] U, unconfined; C, confined

[2] S &G, sand and gravel; A, alluvium

Water level records from the beginning of the period of record through 1996 were tested for trends through the seasonal Kendall test (Hirsch and others, 1982), described further on. The results (table 4) identified two wells with statistically significant ($\alpha = 0.05$) trends—well Mo 659 (confined aquifer) showed a downward trend for the period of record, in contrast to the upward trend noted during 1989-93, and well Mo 667, a shallow well (15 ft), showed a upward trend. The deep (36 ft) paired well to Mo 667, (Mo 668), showed no corresponding trend in water level.

Chemical Concentrations

Comparison of results of chemical analyses of water samples among wells can indicate local differences in water quality within a given aquifer, ground-water movement to or from a stream, and possible sources of contamination and the degree of mixing. Water-quality data also can be used to estimate temporal trends in ground-water chemistry at a given site. Differences in water quality among wells can result from several factors, including well depth and location, direction of ground-water flow (vertical as well as horizontal), type of aquifer material, and precipitation amount and intensity. These and other factors warrant consideration when local differences in ground-water quality are interpreted.

Mean concentrations of selected constituents in water samples from Ellison Park wells were compared through oneway analysis of variance (ANOVA) and Tukey's multiple comparison test to identify statistically significant areal differences in mean concentration among wells, as well as differences in concentration with depth at the paired wells. ANOVA is a statistical test used to determine the significance of overall differences in the means of groups of data, but it does not specify which groups are different from the others. Tukey's multiple comparison test is usually used in conjunction with ANOVA to indicate which of the groups are significantly different from the others, and whether the difference is positive or negative.

Spatial Variability

As during the 1989-93 study, the highest median concentrations of nutrients were in samples from well Mo 667, the shallower (15 ft) of a well pair finished in sediments of the historic Irondequoit Creek flood plain. Disturbance of this area during the construction of a local sewer project could be a contributing factor (Young, 1993). Relatively high median concentrations of ammonia and ammonia + organic nitrogen also were noted at nearby wells Mo 666 and Mo 668 (fig. 6). The highest median concentrations of nitrite + nitrate were at well Mo3, which is close to Irondequoit Creek and, thus, reflects the influence of the creek on this well. Median concentrations of nitrite + nitrate in all other wells were at or below the detection limit (0.05 mg/L). Median concentrations of total phosphorus at six of the nine wells for the 1994-96 period were higher than for the previous period of record; median concentrations of ammonia + organic nitrogen were higher at four of the wells and ammonia was higher at only two of the wells. Median concentrations of total phosphorus at Mo 667 were nearly three times the median concentration for the previous period.

The highest concentrations of common ions, by far, were at Mo 664, at the upstream edge of the buried Pinnacle Hills moraine (fig. 6). These high concentrations are the result a pool of dense brine collected at the base of the impermeable buried moraine being diluted and forced upward by ground-water flow from the south (Young, 1993). Median concentration of common ions at the nine wells for 1994-96 differed little from those of the pre-1996 period of record, although median concentrations of total phosphorus for 1994-96 at Mo 667, near Irondequoit Creek were considerably higher than for the previous period, and median concentraions of ammonia and ammonia + organic nitrogen were considerably lower. Median concentrations of nutrients at the other wells for 1994-96 were similar to the earlier values.

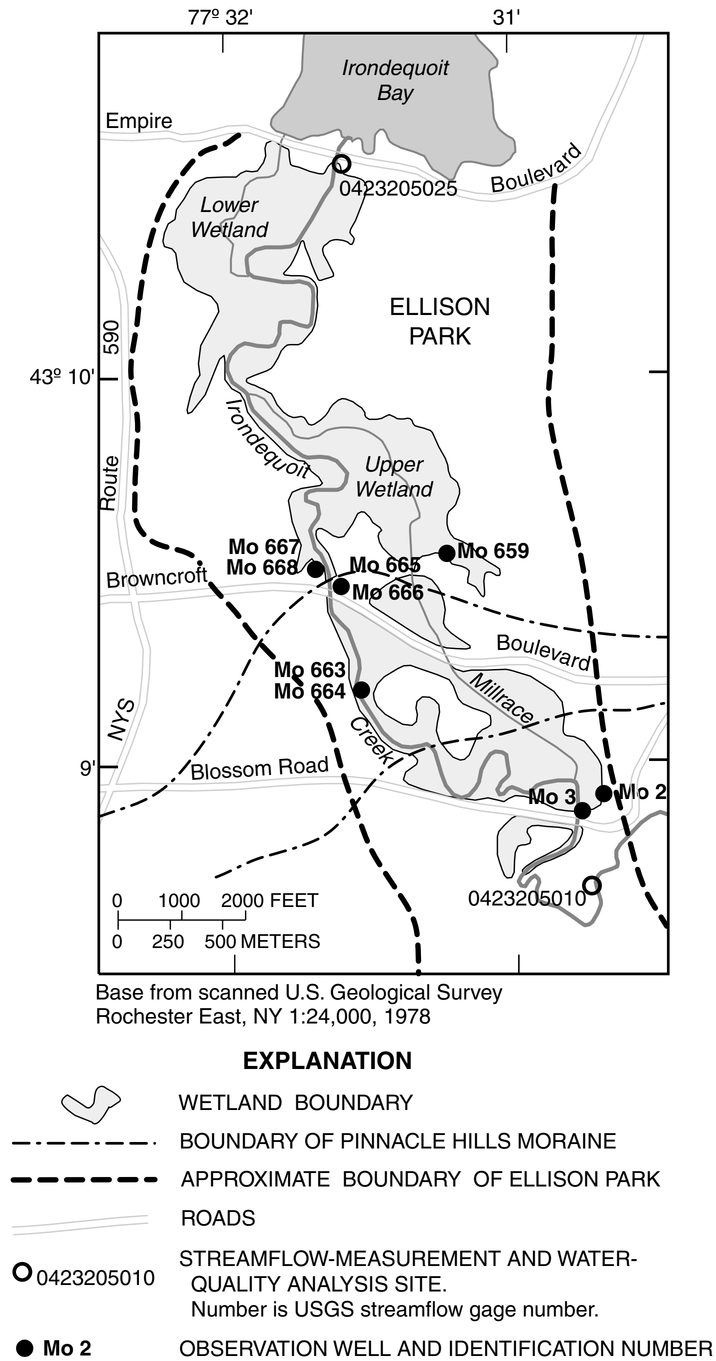


Figure 3. Locations of observation wells in Ellison Park, Monroe County, N.Y. (Modified from Coon, 1996, fig.2.)

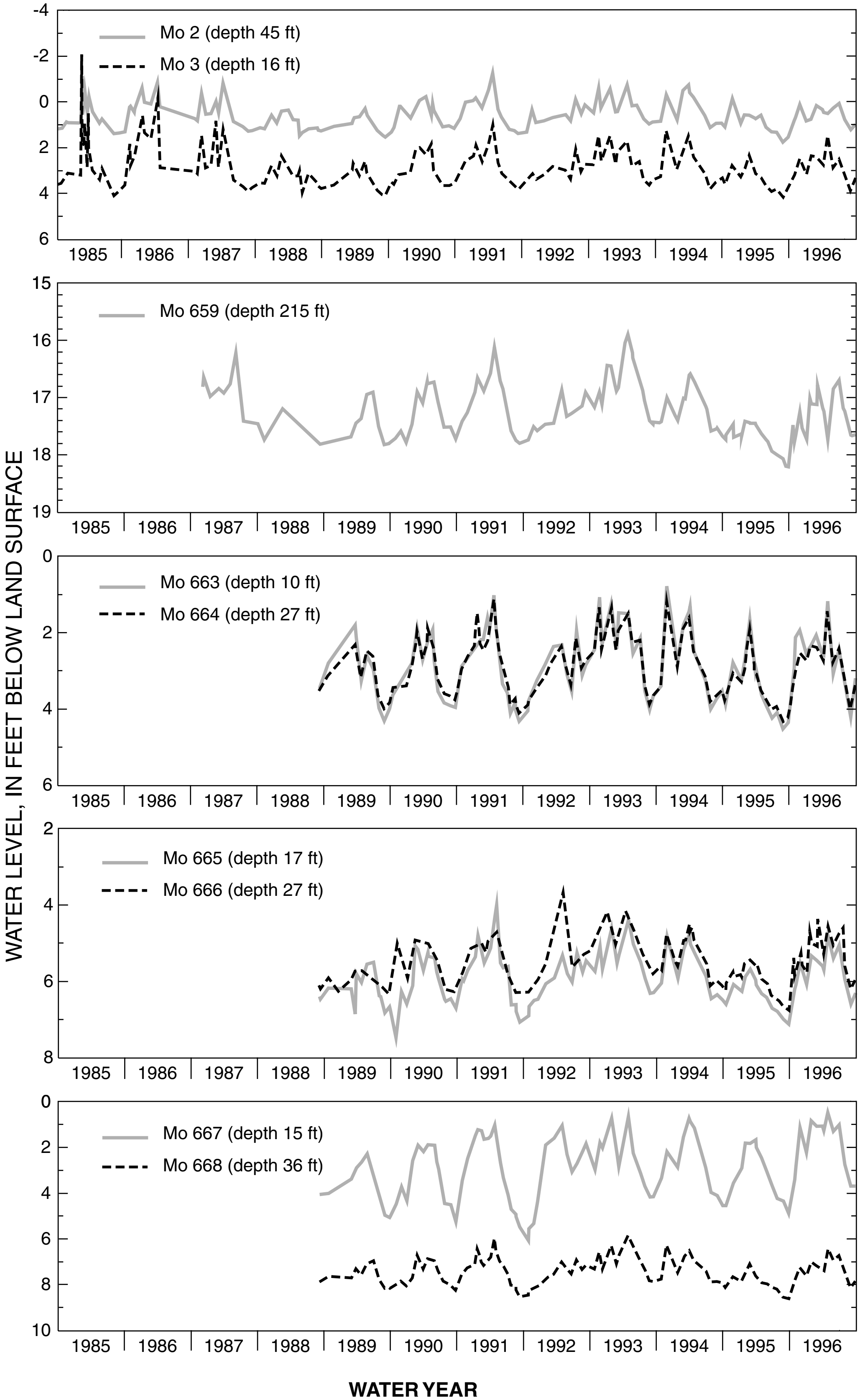


Figure 4. Water levels in Ellison Park wells, Monroe County, N.Y., period of record through 1996. (Locations are shown in fig. 3.)

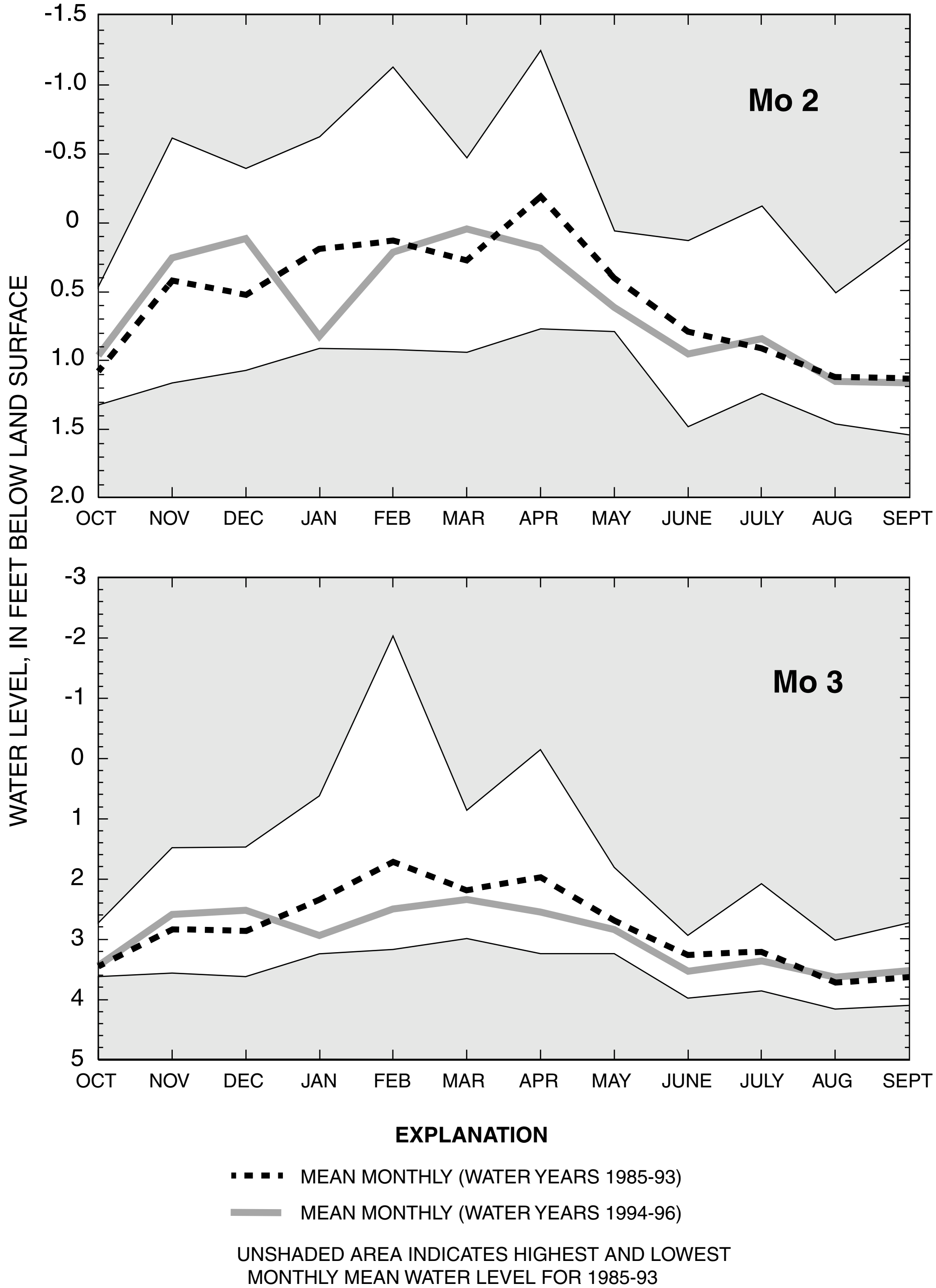


Figure 5. Mean monthly water levels at wells Mo2 and Mo3, Monroe County, N.Y., for 1994-96, with mean monthly, maximum, and minimum water levels for 1985-93. (Location is shown in fig. 3.)

Table 4. Descriptive statistics and trends of water levels in Ellison Park wells, Monroe County, N.Y., period of record through 1996.

[Values are in feet except as noted. **Bold type** indicates trend is statistically significant at $\alpha = 0.05$. *p*, significance of trend. Well locations are shown in fig. 3.]

Well no.	Period of Record	Descriptive statistics: Max	Min	Mean	25th percentile	50th percentile (median)	75th percentile	Trend: Units per year	Percent per year	*p*
Mo 2	1985-96	1.77	-1.24	0.57	0.20	0.69	1.08	--	--	0.934
Mo 3	1985-96	4.17	-2.03	2.81	2.41	3.03	3.42	--	--	.906
Mo 659	**1987-96**	**18.21**	**15.89**	**17.25**	**16.90**	**17.40**	**17.63**	**-.0001**		**.013**
Mo 663	1989-96	4.53	.78	2.87	2.19	2.84	3.64	--	--	.975
Mo 664	1989-96	4.35	1.10	2.88	2.36	2.93	3.52	--	--	.588
Mo 665	1989-96	7.48	4.00	5.89	5.41	5.93	6.42	--	--	.331
Mo 666	1989-96	6.75	3.66	5.54	5.02	5.63	6.01	--	--	.666
Mo 667	**1989-96**	**6.06**	**.47**	**2.86**	**1.80**	**2.74**	**4.05**	**+.0004**		**.023**
Mo 668	1989-96	8.65	5.83	7.54	7.00	7.49	7.90	--	--	.900

Median concentrations of iron in wells Mo 663 through Mo 668 were considerably higher than in upgradient wells Mo 2, Mo3, and Mo 659. The differences in median concentration of iron between 1994-96 and the preceding period of record varied among wells.

Median concentrations of constituents at some paired wells showed statistically significant differences with depth (table 5). Generally, the lower median concentrations were at the shallower wells. Concentrations of all the common ions at shallow well Mo 663 were lower than at deep well Mo 664 because the latter contains brine. Shallow well Mo 667 had higher turbidity and higher median concentrations of ammonia + organic nitrogen, total phosphorus, potassium, and iron, and lower concentrations of chloride, than its paired deep well (Mo 668).

Constituent Trends

Constituent concentrations in in water samples from Ellison Park wells were tested for trends through the Kendall slope estimator, a nonparametric test that does not account for seasonality in the data. The Kendall slope estimator incorporates the Mann-Kendall test to determine the statistical significance of the trend.

The constituents that showed significant trends were primarily common ions and associated constituents; the nutrients showed relatively few trends, except at Mo 2 (table 6). The largest numbers of statistically significant trends in constituent concentration were at wells Mo 2 and Mo 659 (13 and 11 constituents, respectively). The trends at Mo 2 were mostly downward, and those at Mo 659 were mostly upward. Of the constituents with the downward trends at well Mo 2, 12 were common ions and one was in ammonia, and of the two upward trends, one was for nitrite + nitrate, and one was total phosphorus. Of the upward trends at well Mo 659, most were also common ions and associated constituents; only potassium showed a downward trend. Wells Mo 3 and Mo 665 had nine and eight significant trends, respectively. All trends at Mo 3 were downward; those at Mo 665 were mixed. The only trend at Mo 663 was a downward trend in turbidity.

Table 5. Statistically significant differences in median concentrations of constituents in paired wells by depth in Ellison Park, Monroe County, N.Y., 1994-96.

[D, mean for deep well is significantly higher than for shallow well ; S, mean for shallow well is is significantly higher than for deep well; nd, no significant difference. Locations are shown in fig. 2.]

Constituent/Property	Well Pair: Mo 663 Mo 664	Mo 665 Mo 666	Mo 667 Mo 668
Turbidity	nd	nd	S
Specific conductance	D	nd	nd
Ammonia, as N	D	D	D
Ammonia + organic nitrogen, as N	D	D	S
Nitrite + nitrate, as N	nd	nd	nd
Phosphorus, total as P	nd	nd	S
Hardness, as $CaCO_3$	D	nd	nd
Magnesium, dissolved	D	nd	nd
Sodium, dissolved	D	nd	nd
Potassium, dissolved	D	D	S
Chloride, dissolved	D	nd	D
Sulfate, dissolved	D	nd	nd
Iron, dissolved	D	D	S
Total dissolved solids	D	nd	nd

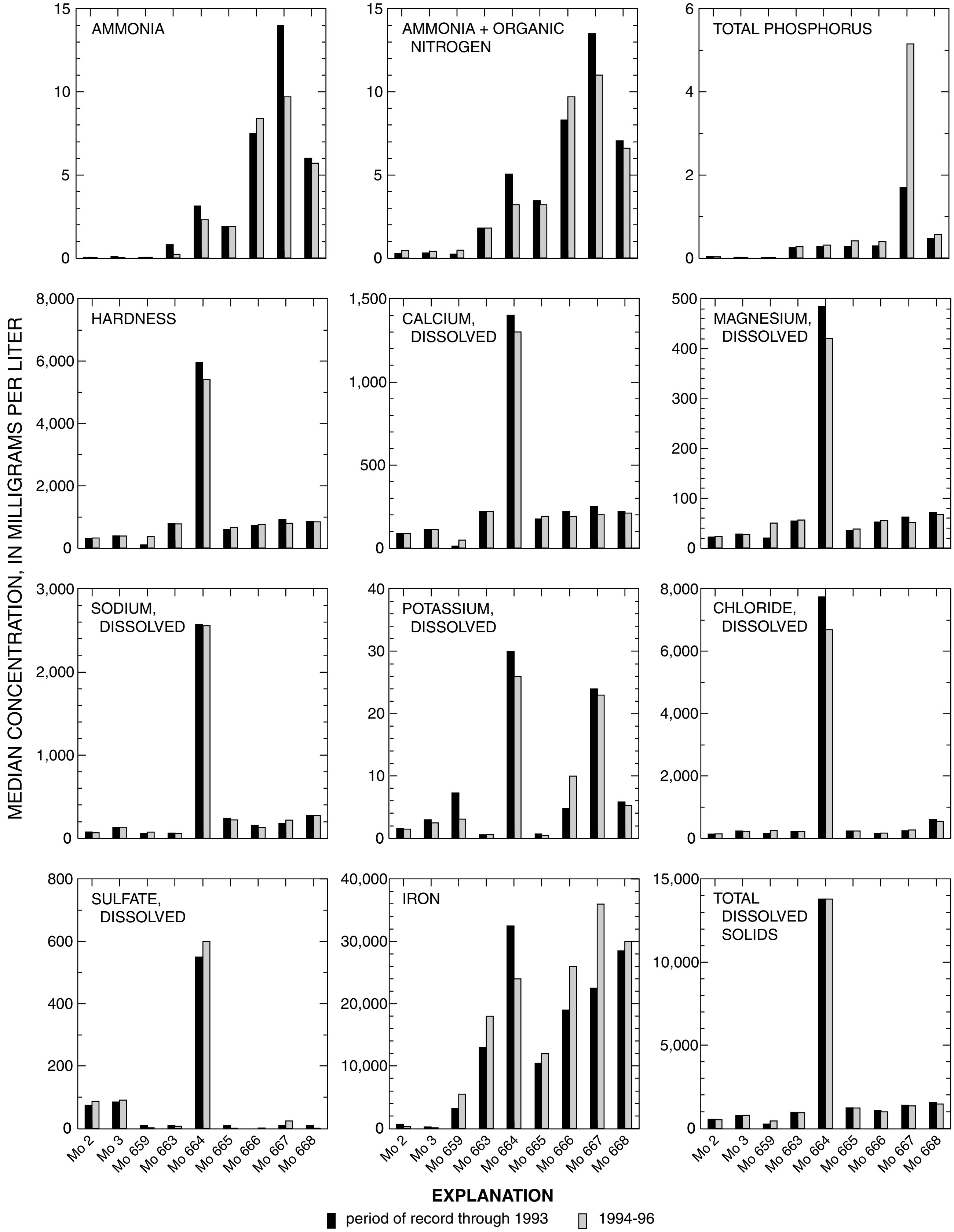


Figure 6. Median concentrations of selected constituents in Ellison Park wells, Monroe County, N.Y., for period of record through 1993 and for 1994-96. (Locations are shown in fig. 3.)

Table 6. Statistically significant (α = 0.05) trends in concentrations of selected ground-water constituents at Ellison Park wells, Monroe County, N.Y., period of record through 1996.

[-, downward trend; +, upward trend; o, no trend. Dashes indicate insufficient data for trend test. Well locations are shown in fig. 3]

Constituent or Property	Mo 2	Mo 3	Mo 659	Mo 663	Mo 664	Mo 665	Mo 666	Mo 667	Mo 668
Turbidity	-	-	+	-	-	o	--	+	-
Specific conductance	-	-	+	o	o	+	--	o	o
Oxygen, dissolved	-	-	+	o	o	+	--	o	o
Ammonia, ,as N, dissolved	-	o	+	o	o	o	--	o	o
Ammonia + organic nitrogen, as N, total	o	o	o	o	o	o	--	o	o
Nitrite + nitrate as N, total	+	o	o	o	o	o	--	o	o
Phosphorus, total as P	+	-	o	o	o	+	--	+	o
Orthophosphate as P, dissolved	o	o	o	o	o	-	--	o	o
Hardness	-	-	+	o	o	+	--	o	o
Calcium, dissolved	-	o	+	o	o	o	--	o	+
Magnesium, dissolved	o	-	+	o	o	+	--	o	o
Sodium, dissolved	-	o	+	o	o	o	--	+	o
Potassium, dissolved	-	o	-	o	-	-	--	o	-
Chloride, dissolved	-	-	+	o	o	o	--	o	-
Sulfate, dissolved	o	o	o	o	+	-	--	o	-
Iron, dissolved	-	-	o	o	o	o	--	+	o
Dissolved solids	-	-	+	o	o	o	--	o	-

SURFACE WATER

Stage and discharge data were collected at five sites in the Irondequoit Creek basin and at five sites in the Genesee River basin. One of the sites in the Irondequoit Creek basin—Irondequoit Creek at Empire Boulevard (0423205025)—is part of another USGS project, but some data from that site are incorporated in this report to provide additional insight into the hydrology of the Irondequoit Creek basin. Water-quality data were collected at the five gaging stations in the Irondequoit Creek basin as well as at the Charlotte pump station on the Genesee River (fig. 1.) and from a site on Northrup Creek in western Monroe County (fig 1.). Streamflow and chemical concentration data were used to test for trends in concentrations and to estimate annual loads of constituents transported by the streams.

Crest-Stage Sites

Two crest-stage gages are currently in operation on two small streams in the western part of Monroe County (fig. 1). These gages, at West Creek near Hilton and at Slater Creek near Greece have been active since 1989. West Creek near Hilton drains about 31 mi^2 of primarily agricultural land and is tributary to Salmon Creek, which drains into Braddock Bay on Lake Ontario. Slater Creek near Greece has a drainage area of only 1.5 mi^2 that is primarily urban and residential; it also is tributary to Lake Ontario.

Crest-stage gage sites record only peak stages that occurred between inspections and are used to provide information on flood crests (Rantz, 1982). Peak flows that correspond to peak stages are obtained from stage-discharge ratings defined by periodic measurements of flow at these sites. The peaks obtained by the crest-stage gages are then correlated with peaks recorded at continuously recording streamflow gages to determine the dates of their occurrence. Dates of peaks at West Creek and Slater Creek are obtained by comparison with records from Northrup Creek near North Greece. The differences in dates of peaks between these two sites (table 7) result from differences in drainage-area characteristics.

Water Temperature

Monroe County began collecting continuous records of water temperature at the five Irondequoit Creek basin surface-water-monitoring sites in 1994. The monthly range of temperatures, and the monthly mean temperatures, for all sites except Empire Boulevard are shown in figure 7 and table 8.

Table 7. Annual peak flows at West Creek near Hilton and Slater Creek near Greece, Monroe County, N.Y., water years 1989-96

[Flows are in cubic feet per second; gage heights are in feet above gage datum. Locations are shown in fig. 1].

West Creek near Hilton			Slater Creek near North Greece		
Date (d/mo/yr)	Flow CFS	Stage ft.	Date (d/mo/yr)	Flow CFS	Stage ft.
6/23/89	994	8.70	6/23/89	71.2	3.07
5/17/90	603	7.29	5/17/90	112	3.62
4/22/91	1030	8.82	3/4/91	61.9	2.93
3/27/92	785	8.00	3/27/92	76.6	3.15
4/1/93	821	8.13	11/2/92		3.40
4/13/94	636	7.43	6/24/94	171	4.30
1/20/95	591	7.23	8/3/95	93.0	3.38
1/19/96	975	8.64	6/12/96	145	4.02

Stream-water temperature is affected by several factors. As water moves down the stream channel, its temperature changes in response to the environment. In addition to being affected by seasonal cycles, water temperature is affected by ground-water contribution, precipitation, and, by the amount of solar radiation reaching the stream.

Temperature is one of the most important factors in water-quality control because it affects most physical properties of water as well as the rate of chemical reactions and the activity of all organisms in the aquatic environment. Some of the physical properties that are affected by temperature are density, specific heat, rate of vaporization, viscosity, and gas diffusibility; these properties in turn affect stratification, evaporation, velocity of settling particles, and dissolved oxygen saturation. Water temperature also affects the ionic strength and electrical conductivity of water, the solubility of constitutents; and the growth and death rates of microorganisms, which are important to the biological processes of waste stabilization. Temperature changes also can affect higher aquatic organisms such as fish, although the effects are more complex and differ among species.

The optimum temperature range for trout (10^{o} to 22^{o}C, fig. 7) is the range over which feeding occurs

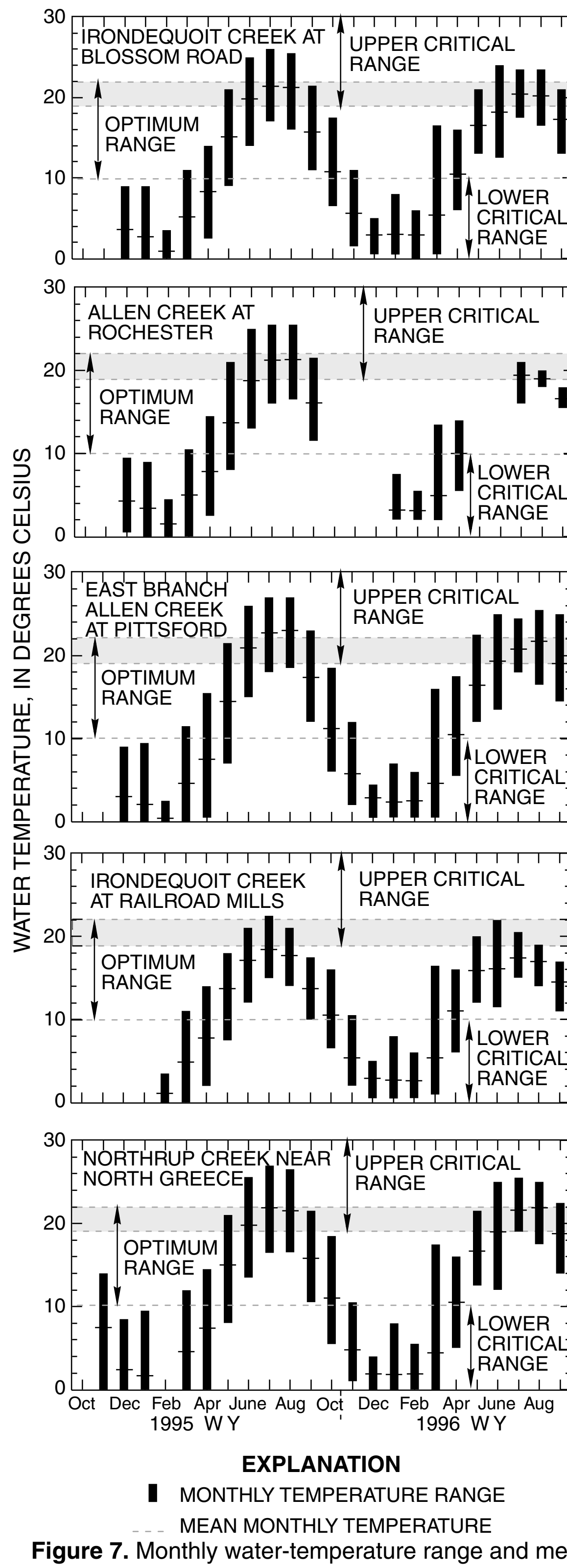


Figure 7. Monthly water-temperature range and mean monthly water temperature, with optimum, upper, and lower critical temperature ranges for rainbow trout at four Irondequoit basin sites and Northrup Creek, water years 1994-96. (Locations are shown in fig. 1, Trout data from Bidgood, and Berst, 1969)

and that produces no external signs of abnormal behavior. For most species, the optimum temperature range generally overlaps the upper and lower critical ranges. The critical temperature ranges (19^{o} to 30^{o} and 0^{o} to 10^{o}C) are the ranges over which a noticeable disturbance in the normal behavior of a fish may occur. These critical temperature ranges vary, depending on the species of fish.

Temperatures in Irondequoit Basin streams and Northrup Creek range from 0^{o} C during winter to 27^{o} C during summer. Mean temperatures for the period of record and annual mean temperatures (October 1995 through September 1996) were fairly consistent among sites, with the exception of Irondequoit Creek at Railroad Mills, where the mean temperature for the period of record was lower than at other sites.

Temporal Trends in Streamflow

The temporal variability in streamflow reflects climatic conditions and affects many water-quality properties. Concentration-to-discharge relations and trends in streamflow form an important basis for interpretation of trends in water quality. For example, increasing runoff (overland flow from rainfall) causes washoff of chemical constituents to streams, and thereby increases the concentrations of suspended constituents from nonpoint sources; at the same time it can decrease the concentration of some dissolved constituents through dilution. Therefore, any observed trend in constituent concentration could be at least partly due to a concurrent trend in streamflow. Thus variability in steamflow can produce a significant bias in the trends of constituent concentrations

Table 8. Monthly maximum, minimum, and mean water temperatures at four Irondequoit Creek basin sites and Northrup Creek, Monroe County, N.Y., water years 1995-96 and period of record

[All values are in degrees Celsius.; dashes indicate no data. Locations are shown in fig. 1.]

	Irondequoit Creek at Blossom road			Allen Creek			East Branch Allen Creek			Irondequoit creek at Railroad Mills			Northrup Creek		
Month	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
1995 Water Year															
Oct 94	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nov 94	--	--	--	--	--	--	--	--	--	--	--	--	14.0	0.0	7.5
Dec 94	9.0	0.0	3.5	9.5	0.5	4.5	9.0	0.0	3.0	--	--	--	8.5	0.0	2.5
Jan 95	9.0	0.0	2.5	9.0	0.0	3.5	9.5	0.0	2.0	--	--	--	9.5	0.0	1.5
Feb 95	3.5	0.0	1.0	4.5	0.0	1.5	2.5	0.0	0.5	3.5	0.0	1.0	--	--	--
Mar 95	11.0	0.0	5.0	10.5	0.0	5.0	11.5	0.0	4.5	11.0	0.0	5.0	12.0	0.0	4.5
Apr 95	14.0	2.5	8.5	14.5	2.5	8.0	15.5	0.5	7.5	14.0	2.0	8.0	14.5	0.0	7.5
May 95	21.0	9.0	15.0	21.0	8.0	13.5	21.5	7.0	14.5	18.0	7.5	13.5	21.0	8.0	15.0
Jun 95	25.0	14.0	20.0	25.0	13.0	19.0	26.0	15.0	21.0	21.0	12.0	17.0	25.5	13.5	20.0
Jul 95	26.0	17.0	21.5	25.5	16.0	21.0	27.0	18.0	22.5	22.5	15.0	18.5	27.0	16.5	22.0
Aug 95	25.5	16.0	21.0	25.5	16.5	21.5	27.0	18.5	23.0	21.0	14.0	17.5	26.5	16.5	21.5
Sept 95	21.5	11.0	15.5	21.5	11.5	16.0	23.0	12.0	17.5	17.5	10.0	13.5	21.5	10.5	16.0
1996 Water Year															
Oct 95	17.5	6.5	11.0	--	--	--	18.5	6.0	11.0	16.0	6.5	10.5	18.5	5.5	11.0
Nov 95	11.0	1.5	5.5	--	--	--	12.0	2.0	6.0	10.5	2.0	5.5	10.5	1.0	5.0
Dec 95	5.0	0.5	3.0	--	--	--	4.5	0.5	3.0	5.0	0.5	3.0	4.0	0.0	2.0
Jan 96	8.0	0.5	3.0	7.5	2.0	3.0	7.0	0.5	2.5	8.0	0.5	2.5	8.0	0.0	2.0
Feb 96	6.0	0.0	3.0	5.5	2.0	3.0	6.0	0.5	2.5	6.0	0.5	2.5	5.5	0.0	2.0
Mar 96	16.5	0.5	5.5	13.5	2.0	5.0	16.0	0.5	4.5	16.5	1.0	5.5	17.5	0.0	4.5
Apr 96	16.0	6.0	10.5	14.0	5.5	10.0	17.5	5.5	10.5	16.0	6.0	11.0	16.0	5.0	10.5
May 96	21.0	13.0	16.5	--	--	--	22.5	12.0	16.5	20.0	12.0	16.0	21.5	12.5	16.5
Jun 96	24.0	12.5	18.0	--	--	--	25.0	13.5	19.5	22.0	11.5	16.0	25.0	12.0	19.0
Jul 96	23.5	17.5	20.5	21.0	16.0	19.5	24.5	18.0	21.0	20.5	15.0	17.5	25.5	19.0	21.5
Aug 96	23.5	16.5	20.0	20.0	18.0	19.0	25.5	16.5	21.5	19.0	14.0	17.0	25.0	17.5	22.0
Sept 96	21.0	13.0	17.5	18.0	15.5	16.5	25.0	14.5	19.0	17.0	11.0	14.5	22.5	14.0	19.0
Period of record	26.0	0.0	11.0	25.5	0.0	--	27.0	0.0	11.5	22.5	0.0	11.0	27.0	0.0	--

Monthly mean streamflow data from the five Irondequoit Creek basin sites and Northrup Creek (table 9) were tested by the Seasonal Kendall trend test (Hirsch and others, 1982) to identify significant (α = 0.05) trends. Streamflow trends testing covered only the periods for which the water-quality trends were tested.

The only site to show a statistically significant trend in monthly mean streamflow was Allen Creek (table 9), which had a downward trend of 2.26 percent per year for 1984-96. Examination of the LOWESS (locally weighted scatterplot smooth) line (fig. 8) indicates that the overall downward trend for the 12-year period was affected primarily by a steep downward trend between 1984 and 1990; while the trend for the period from 1991 to 1996 was relatively flat (no trend).

Irondequoit Creek at Blossom Road

The Irondequoit Creek basin has two sites with at least 16 years of continuous streamflow record—Irondequoit Creek at Blossom Road (1981-96, 16 years), and Allen Creek near Rochester (1960-96, 37 years). The Blossom Road record for water years 1994-96 (fig. 9A) shows several monthly mean streamflows that were either above normal or below normal (fig. 9A). The normal range is defined as between the 25th percentile (flows exceeded 75 percent of the time) and the 75th percentile (flows exceeded 25 percent of the time). Monthly mean flow for water year 1994 was above normal for September and exceeded the 50th percentile (median) for February through May and for August and September, and was below normal for January and July. Those for water year 1995 were below the median for all months except July, and were below normal for February, April through June, August, and September. Monthly mean flows for 1996, in contrast, were above the median for October and November, January and February, from April through July, and September, and were above normal for January, May, June, and July. The mean monthly values for 1994-96 (fig. 10A) were close to the long-term average for 1981-96.

Allen Creek at Rochester

Allen Creek has a much longer period of record (37 years) than Blossom Road (16 years) and, thus, contains extremes that represent droughts as well as floods. The Allen Creek drainage basin is primarily moderate- to high-density residential land with some commercial areas and, therefore, is not representative of the rest of the Irondequoit Creek basin. Monthly mean flows of Allen Creek for water years 1994-96, like those of Irondequoit Creek at Blossom Road, were generally below the 75th percentile, and many were below the median (fig. 9B). Monthly mean flows for 1994 were within the normal range except those for October, June ,and July, which were below normal. The monthly means for water year 1995 were below the median for all months except January and July, and below normal for October, February through June, and September. The values for water year 1996 also were generally within the normal range except for October, January, May, and June, when they were above normal. Mean monthly flows for water years 1994-96 at Allen Creek (fig. 10B) were within the normal range except for September, which was slightly below normal, but were below the median for all months except January (fig. 10B).

Table 9. Statistical summary and results of trend tests for streamflow of Northrup Creek and five sites in Irondequoit Creek basin, Monroe County, N.Y., for period of record through water year 1996.

[n, number of samples for period of record. Q1, 25th percentile; Q3, 75th percentile; n(s), number of seasons used in trend test; n(t), number of samples used in trend analysis. *p*, significance of trend. Mean, median, Q1, Q3, and trend units are in cubic feet per second. **Bold type** indicates trend is statistically significant at α = 0.05.]

Site	Period of trend test	Descriptive statistics					Trend results				
		n	Mean	Q1	Median	Q3	n(s)	n(t)	Units per year	Percent per year	*p*
Northrup Creek	1989-96	84	12.7	4.01	8.34	17.9	12	84	0.000	0	0.860
Railroad Mills	1992-96	60	38.9	21.5	32.4	50.2	12	60	-.583	-1.50	.722
East Branch Allen	1991-96	72	8.91	3.94	6.54	12.1	12	72	.000	0	1.000
Allen Creek	**1984-96**	**156**	29.2	15.4	22.1	40.0	**12**	**156**	**-.660**	**-2.26**	**.011**
Blossom Road.	1984-96	156	135	71.7	104	186	12	156	-1.000	-.74	.378
Empire Boulevarvd	1990-96	75	137	66.9	109	185	12	75	-1.000	-.73	.415

Black Creek at Churchville

Black Creek at Churchville has a 50 year record, which was used to relate long-term flow conditions in western Monroe County (west of the Genesee River) to flow conditions in Northrup Creek during 1994-96. Many of the monthly mean flows for Black Creek, like those for the Irondequoit Creek basin during water years 1994-96, were outside the normal range (fig. 9C). All monthly mean values for 1994 were within the normal range except January, which was lower, and all except for December, January, and February were slightly higher than the long-term medians. The monthly means for 1995 were within or near the normal range until March, then fell below the 25th percentile for the rest of the water year, whereas monthly means for 1996 were in or near the normal range until April, when they exceeded the normal range for the remainder of the year. All mean monthly flows for 1994-96 but one (June) (fig. 10C) were within the normal range; this indicates that average mean monthly flows for Northrup Creek also were probably within the normal range.

Chemical Concentrations

Streamflow was measured at all sites at which water samples were collected, except the Genesee River at the Charlotte Pump station, to provide data needed for the interpretation of water-quality data; the streamflow values for the Charlotte Pump station site were derived from records for the Genesee River at Rochester (04232000), about 6 mi upstream. Each steamflow-gaging station was visited 2 or 3 times weekly, and water samples were collected hourly at each of these sites by automatic sampler; those collected during storms were combined into flow related composite samples. Additional samples were collected from Irondequoit Creek at Blossom Road and Empire Boulevard, and from the Genesee River at Charlotte Pump station, 2 or 3 times per week and combined into 2-to-4 day baseflow composite samples. Samples from all other sites were combined into baseflow composite samples at least monthly. These samples were analyzed for physical properties, nutrients, and common ions. For purposes of statistical

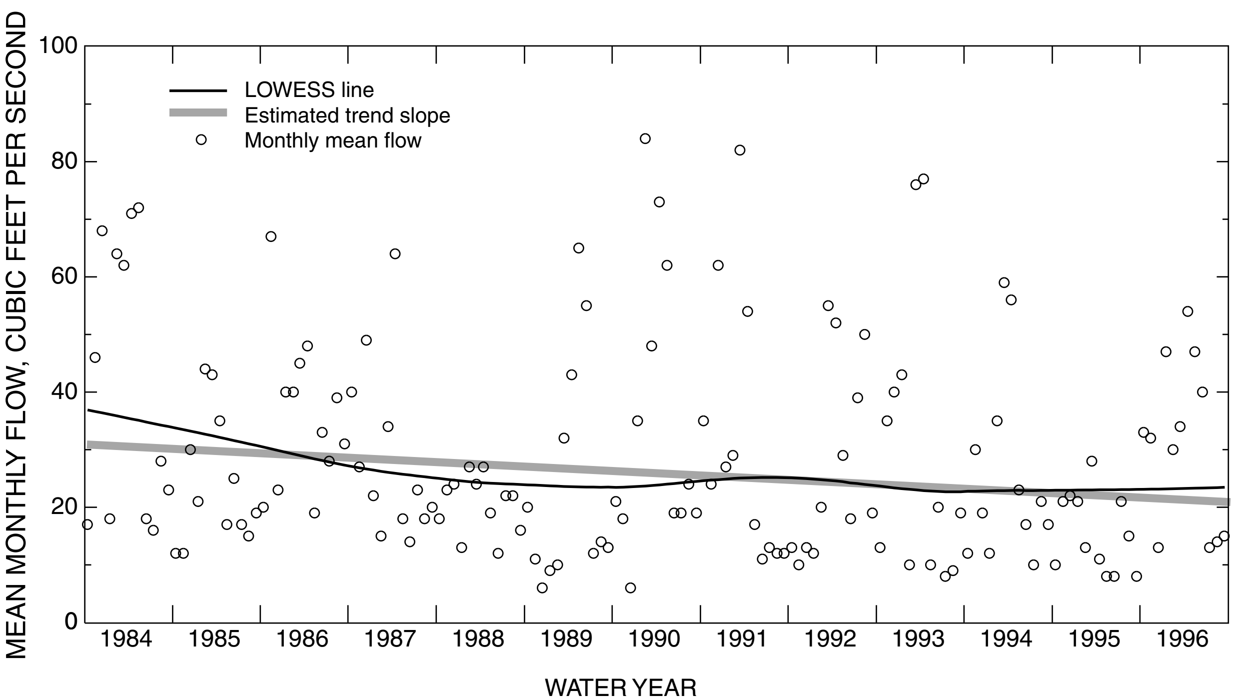


Figure 8. Monthly mean flows for Allen Creek, Monroe County, N.Y., with LOWESS (locally weighted scatterplot smooth) line and the estimated trend line. (Location is shown in fig. 1.)

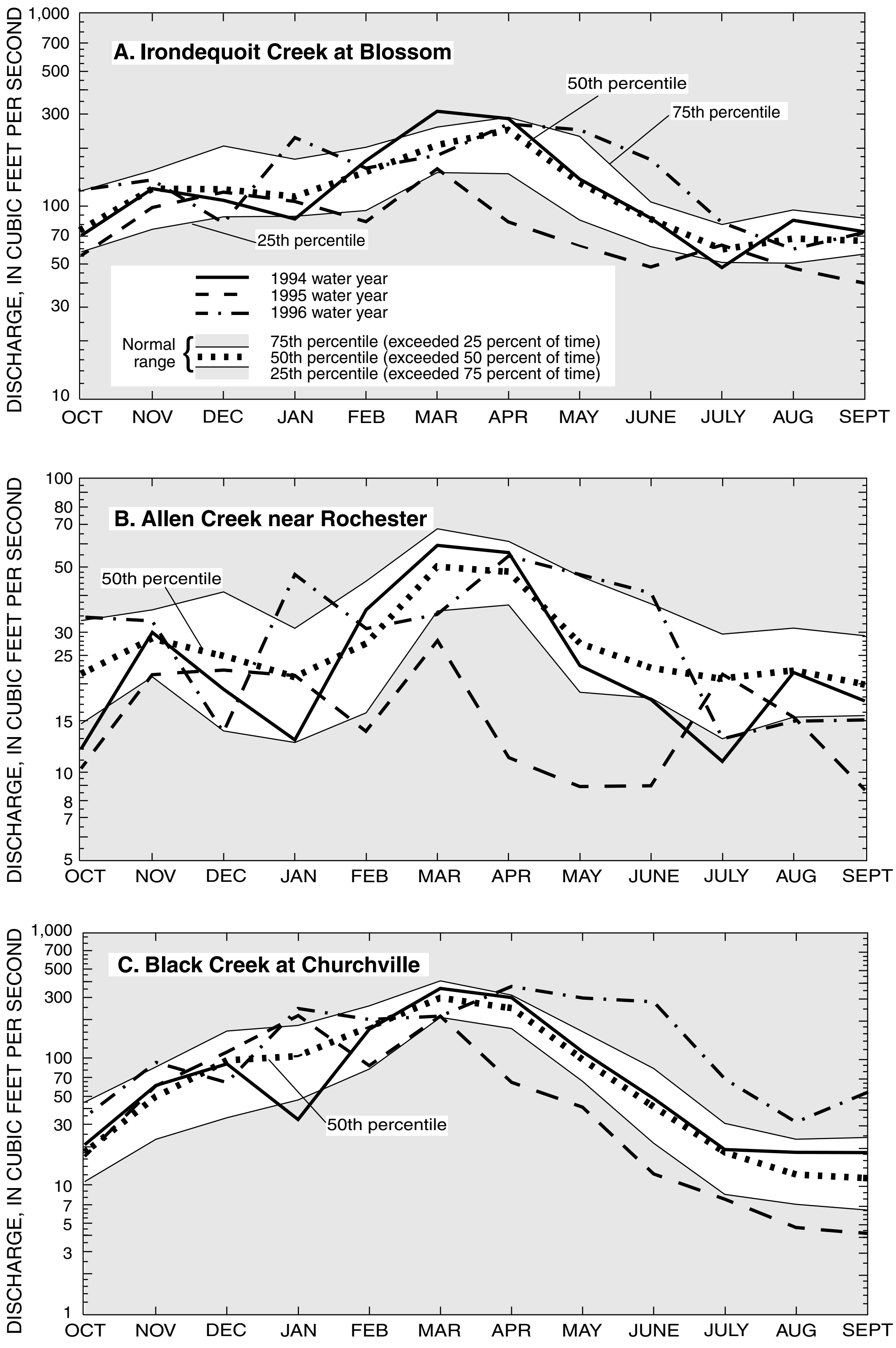


Figure 9. Monthly mean flow of three streams in Monroe County, N.Y., water years 1994, 1995, and 1996, in relation to normal range (flows exceeded 25 to 75 percent of time) for period of record: A. Irondequoit Creek at Blossom Road. B. Allen Creek near Rochester. C. Black Creek at Churchville.

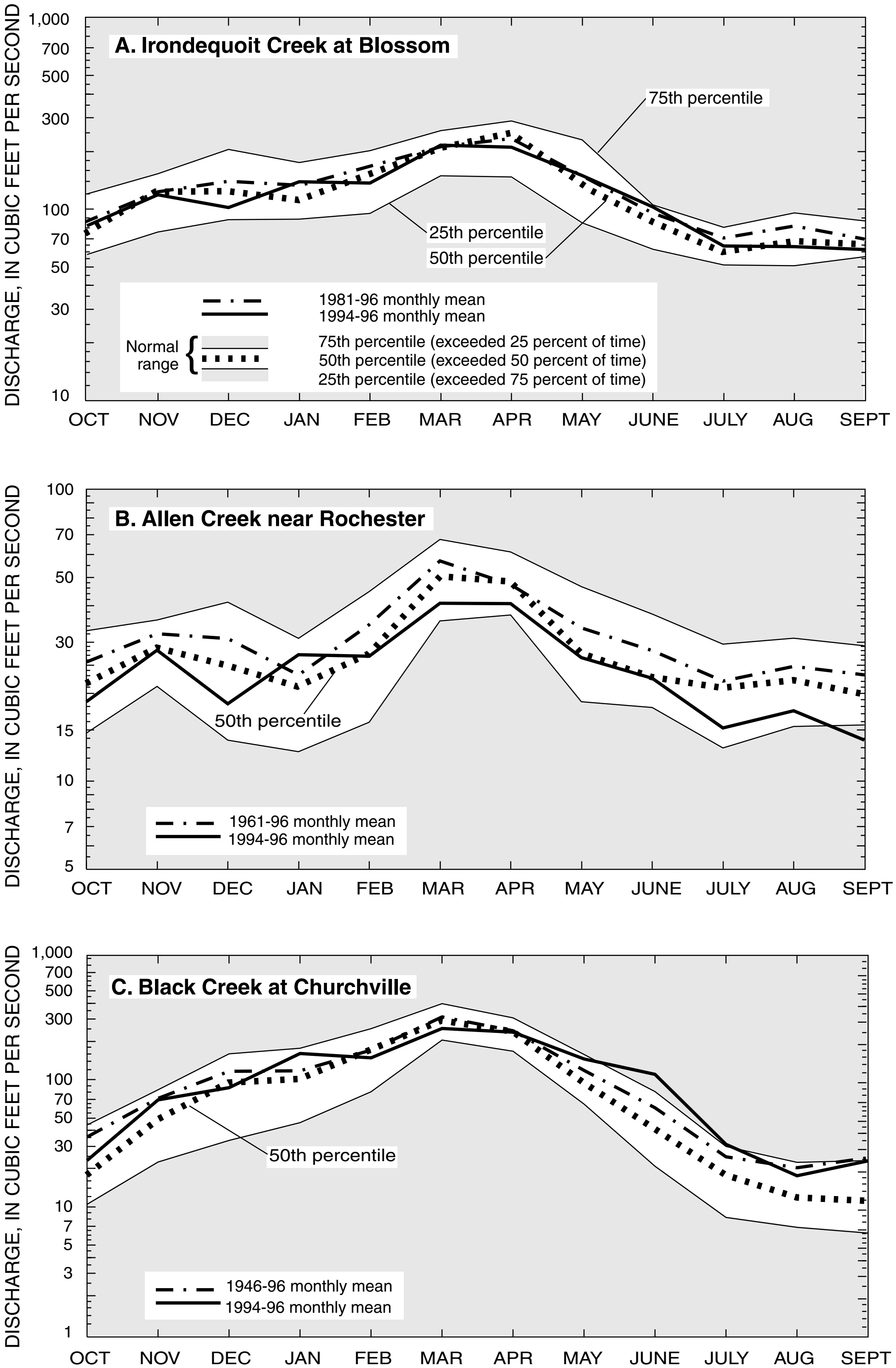


Figure 10. Mean monthly flows of three streams in Monroe County, N.Y., for period of record and water years 1994-96, in relation to normal range (flows exceeded 25 to 75 percent of time) for period of record: A. Irondequoit Creek at Blossom Road. B. Allen Creek near Rochester. C. Black Creek at Churchville. (Location shown in fig. 1)

Table 10. Median concentrations of selected constituents at five Irondequoit Creek basin sites and Northrup Creek, Monroe County, N.Y., water years 1994-96.
[Units are milligrams per liter unless otherwise noted. NTU, nephelometric turbidity units. Locations are shown in fig. 1.]

Site	Turbidity (NTU)	Total suspended solids	Volatile suspended solids	Ammonia as N, dissolved	Ammonia + organic nitrogen as N, total	Nitrite + nitrate as N, total	Total phosphorus as P	Orthophosphate as P, dissolved	Chloride, dissolved	Sulfate, dissolved
Irondequoit Creek basin sites										
Irondequoit Creek at Railroad Mills	18	153	21	0.01	0.54	1.1	0.080	0.006	69	180
East Branch Allen Creek at Pittsford	14	108	16	.02	.80	.92	.100	.023	110	84
Allen Creek near Rochester	12	129	19	.01	.74	.96	.095	.021	170	64
Irondequoit Creek at Blossom Road	12	140	20	.01	.68	.94	.090	.013	120	160
Irondequoit Creek at Empire Blvd	11	90	14	.03	.72	.82	.082	.015	130	150
Northrup Creek at North Greece	12	146	20	.03	.92	1.5	.280	.120	81	55

analysis, these composite samples are treated as discrete samples. Median constituent concentrations at the Irondequoit Creek sites and Northrup Creek are shown in table 10.

Spatial variability

The major cause of chemical variability among streams, oramong reaches of a given stream, in the Irondequoit Creek basin, is land use. For example, median concentrations of dissolved chloride were considerably lower at the two sites where the primary land use is agriculture (Northrup Creek and Irondequoit Creek at Railroad Mills) than at the other sites, which have predominantly urban drainage areas.

Flow in many of the Monroe County streams north of the Erie (Barge) Canal is supplemented by diversions from the canal during navigation season (about April 15 to November 15). Water is diverted from the canal to maintain minimum flows in the streams during low-flow periods for dilution of sewage-treatment-plant discharges and for irrigation. The Monroe County Environmental Health Laboratory (MCEHL) has been sampling these diversions (by siphons) at Allen Creek, East Branch Allen Creek, the Cartersville waste channel, which diverts water from the canal to Irondequoit Creek, and at the Fairport waste channel, which diverts water from the canal to Irondequoit Creek through Thomas Creek, since 1986 (fig. 2). Samples are collected at Allen Creek and East Branch Allen Creek, immediately upstream from the siphon, at the siphon, and immediately downstream of the siphon. Samples at Cartersville and Fairport are collected directly from the waste channels. Median concentrations of constituents at the Allen Creek diversion sites and East Branch Allen Creek for the period of record through 1996, and those at the downstream gages for the navigation period, are plotted in figure 11; those for the Irondequoit sites are plotted in figure 12.

Median concentrations of all constituents in the canal-water samples from the diversion (at siphon) were higher than those upstream at the Allen Creek and East Branch Allen Creek sites, except for chloride, ammonia + organic nitrogen, and orthophosphate at the East Branch sites and the median values for turbidity, suspended solids, sulfate, ammonia, nitrite + nitrate, and total phosphorus, and orthophosphate were lower downstream from the diversion than those above it. Median concentrations of suspended constituents, or those constituents associated with suspended sediment, were higher the East Branch Allen Creek and Allen Creek gages than at the diversions. Median concentrations of suspended constituents were generally lower in the waste channels than at the upstream site (Irondequoit Creek at Railroad Mills) or the downstream site (Irondequoit Creek at Blossom Road). Comparison of median concentrations of constituents indicates that the constituents whose concentrations are most likely to be affected by the diversion of canal water are ammonia nitrogen and orthophosphate.

Local differences in median and range of concentration of selected constituents in samples from Northrup Creek and the five Irondequoit Creek basin

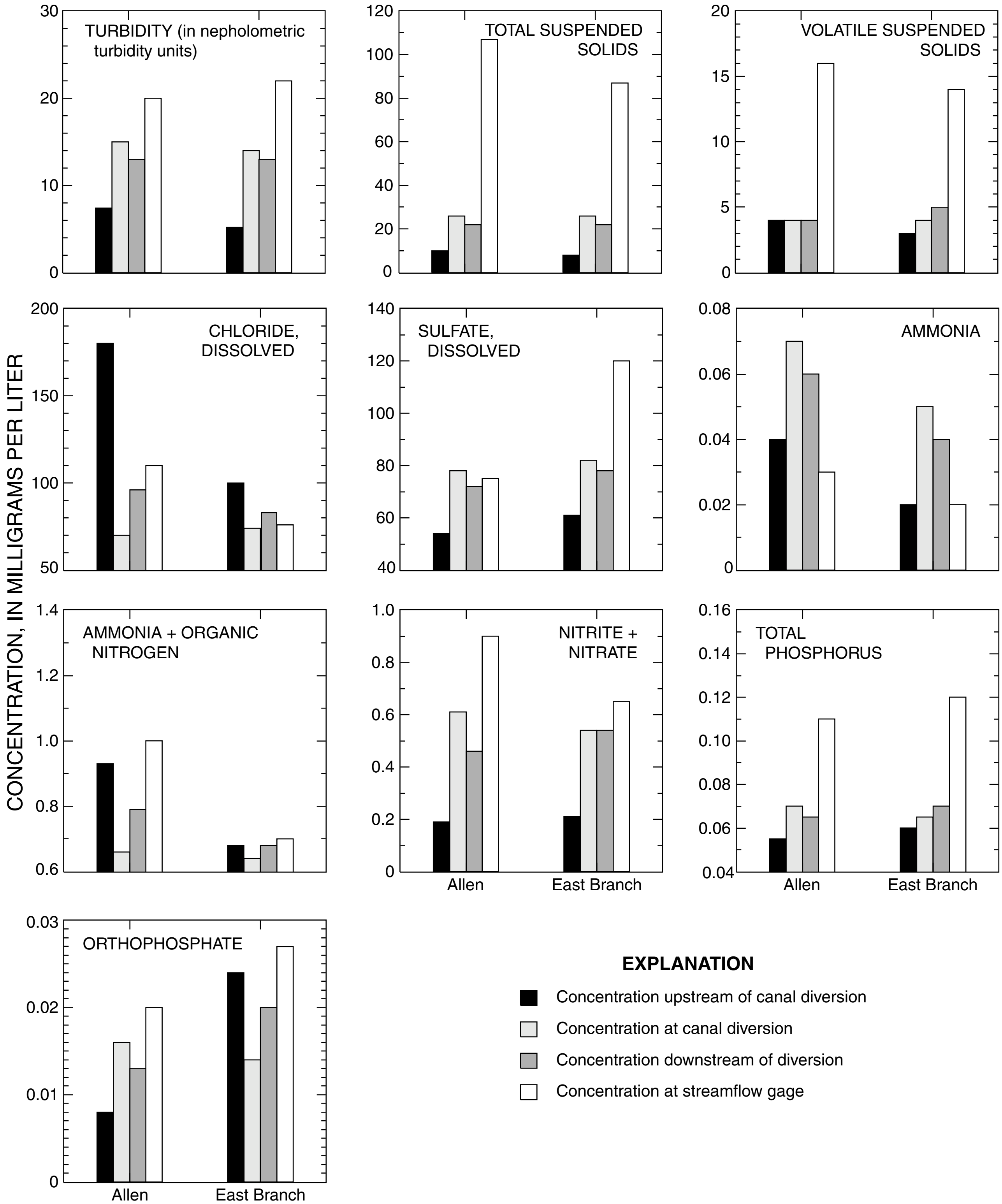


Figure 11. Median concentrations of selected constituents at Erie (Barge) Canal diversions at Allen Creek and East Branch Allen Creek, Monroe County, N.Y., and median concentrations at downstream gages during the navigation season, for period of record through 1996. (locations are shown in fig. 2)

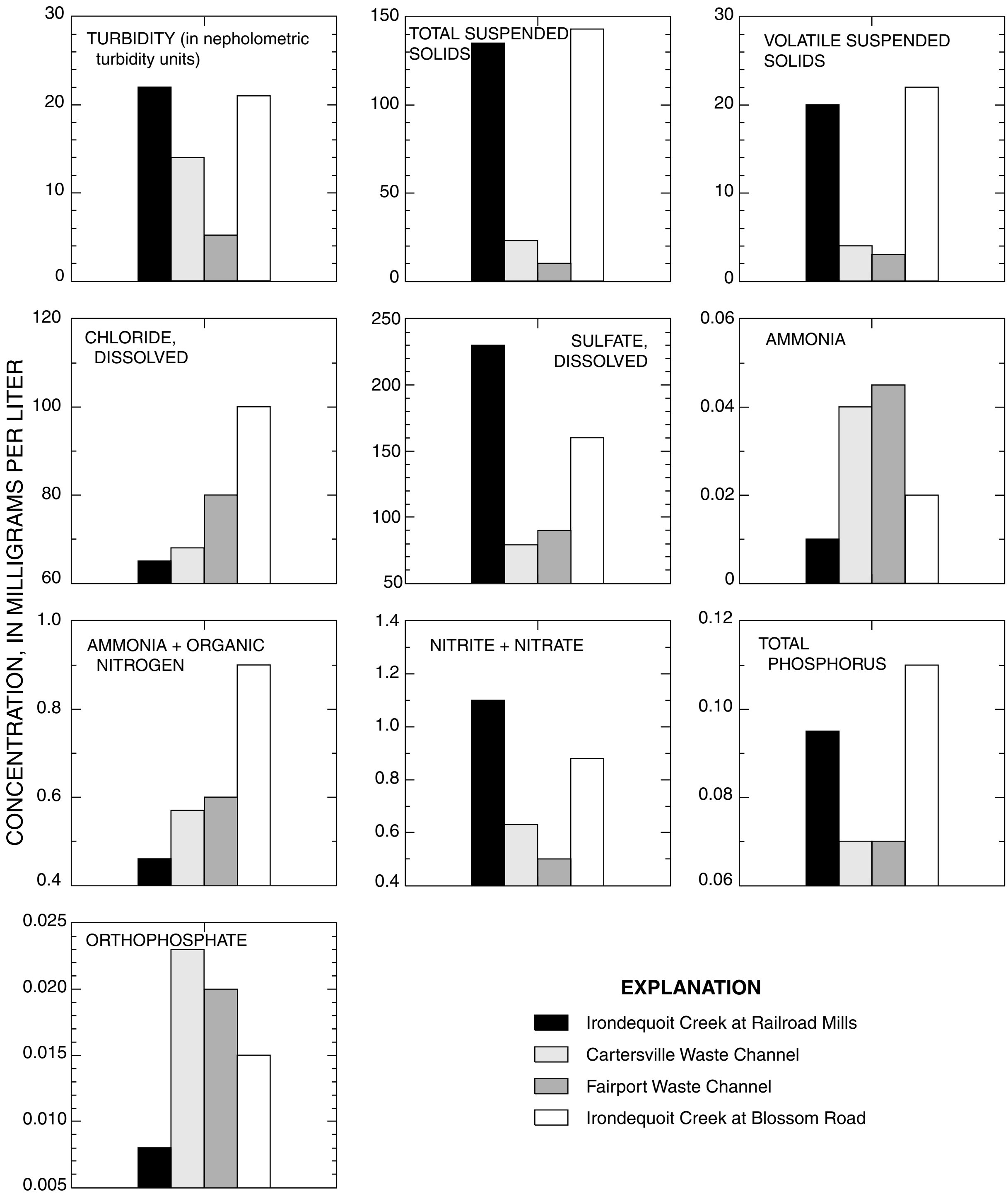


Figure 12. Median concentrations of selected constituents at Erie (Barge) Canal diversions at Cartersville and Fairport on Irondequoit Creek and at upstream site (Irondequoit Creek at Railroad Mills) and a downstream site (Blossom Road) during the navigation, season for period of record through 1996. (Locations are shown in fig. 2)

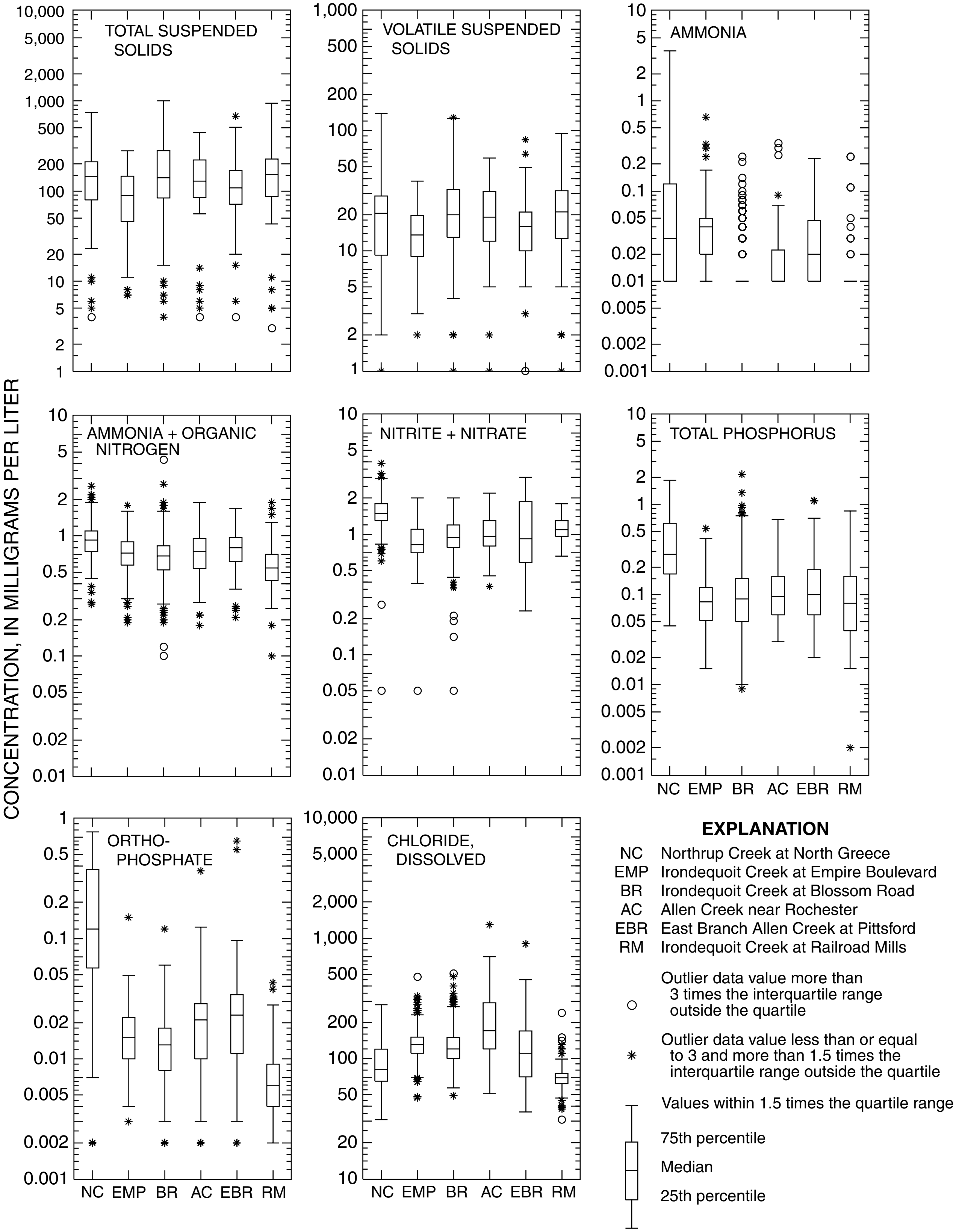


Figure 13. Ranges in concentration of selected constituents in samples from Northrup Creek and five Irondequoit Creek basin sites, Monroe County, N.Y., water years 1994-96. (Locations are shown in fig. 1).

sites were examined through boxplots (fig. 13) and Tukey's MCT (multiple comparison test) on ranks of the concentration data to identify statistically significant ($\alpha = 0.05$) differences in mean concentration among the six sites; results are summarized in table 11. Differences in median concentration of constituents among sites for the periodof record through 1993 and for 1994-96 are plotted in figure. 14.

Irondequoit Creek Basin Sites

Median concentrations of some constituents in the Irondequoit Creek basin differed more than others among sites.

***Nutrients*:** Generally, median concentrations of nutrients were fairly uniform among all sites (table 10). The constituent with the greatest range in concentration was ammonia + organic nitrogen, (0.54 to 0.80 mg/L); the lowest concentration (0.54 mg/L) was at Irondequoit Creek at Railroad Mills, which had the highest median concentration of nitrite + nitrate (1.1 mg/L). The highest median concentrations of total phosphorus (0.10 mg/L) and orthophosphate (0.023 mg/L) and ammonia + organic nitrogen were at East Branch Allen Creek. The nutrient with the greatest number of statistically significant differences among the Irondequoit basin sites was nitrite + nitrate (table 11).

***Chloride and Sulfate*:** The highest median concentration for chloride (170 mg/L) was at Allen Creek, and the highest median for sulfate (180 mg/L) was at Irondequoit Creek at Railroad Mills. The site-to-site differences in chloride concentrations are probably related to road-salt application—sites representing the most urbanized subbasins (those having the highest road density) had the highest median concentrations. The high concentrations of sulfate at the Irondequoit Creek sites probably result from the dissolution of sulfate from the glacial deposits in the region, and from the shale bedrock that underlies much of the area (Young, 1993). Median concentrations of chloride and sulfate differed significantly among most of the sites (table 11).

Table 11. Results of Tukey's Multiple Comparison Test showing statistically significant ($\alpha = 0.05$) differences in mean concentrations of selected constituents among Irondequoit Creek basin sites and Northrup Creek, Monroe County, N.Y., water years 1994-96

[Diss., dissolved. H indicates value for boldface site is significantly higher; L indicates value for boldface site is significantly lower; ND; no significant difference. Locations are shown in fig. 1.]

Site	Turbidity	Total suspended solids	Volatile suspended solids	Ammonia as N, diss.	Ammonia + organic nitrogen as N, total	Nitrite + nitrate as N, total	Total phosphorus as P	Orthophosphate as P, diss.	Chloride, dissolved	Sulfate, dissolved
Irondequoit Creek at Blossom Road in relation to:										
Irondequoit Creek at Railroad Mills	ND	ND	ND	ND	ND	ND	ND	ND	H	L
East Branch Allen Creek at Pittsford	ND	ND	ND	ND	ND	L	ND	ND	ND	H
Allen Creek near Rochester	ND	ND	ND	ND	ND	ND	ND	ND	L	H
Irondequoit Creek at Empire Blvd.	H	H	H	L	ND	ND	H	ND	ND	ND
Northrup Creek at North Greece	L	ND	ND	L	L	L	L	L	H	H
Irondequoit Creek at Railroad Mills in relation to:										
East Branch Allen Creek at Pittsford	ND	ND	ND	ND	L	ND	ND	ND	L	H
Allen Creek near Rochester	H	ND	ND	ND	ND	ND	ND	ND	L	H
Irondequoit Creek at Empire Blvd.	H	ND	H	ND	L	H	ND	ND	L	H
Northrup Creek at North Greece	H	ND	ND	L	L	L	L	L	ND	H
Northrup Creek at North Greece in relation to:										
East Branch Allen Creek at Pittsford	ND	ND	ND	H	H	H	H	H	L	L
Allen Creek near Rochester	ND	ND	ND	H	H	H	H	H	L	ND
Irondequoit Creek at Empire Blvd.	ND	ND	ND	H	H	H	H	H	L	L
East Branch Allen Creek at Pittsford in relation to:										
Allen Creek near Rochester	ND	ND	ND	ND	ND	ND	ND	ND	L	H
IrondequoitCreek at Empire Blvd.	H	ND	ND	ND	ND	H	H	ND	ND	L
Allen Creek near Rochester in relation to:										
Irondequoit Creek at Empire Blvd.	ND	ND	ND	ND	ND	H	ND	ND	H	L

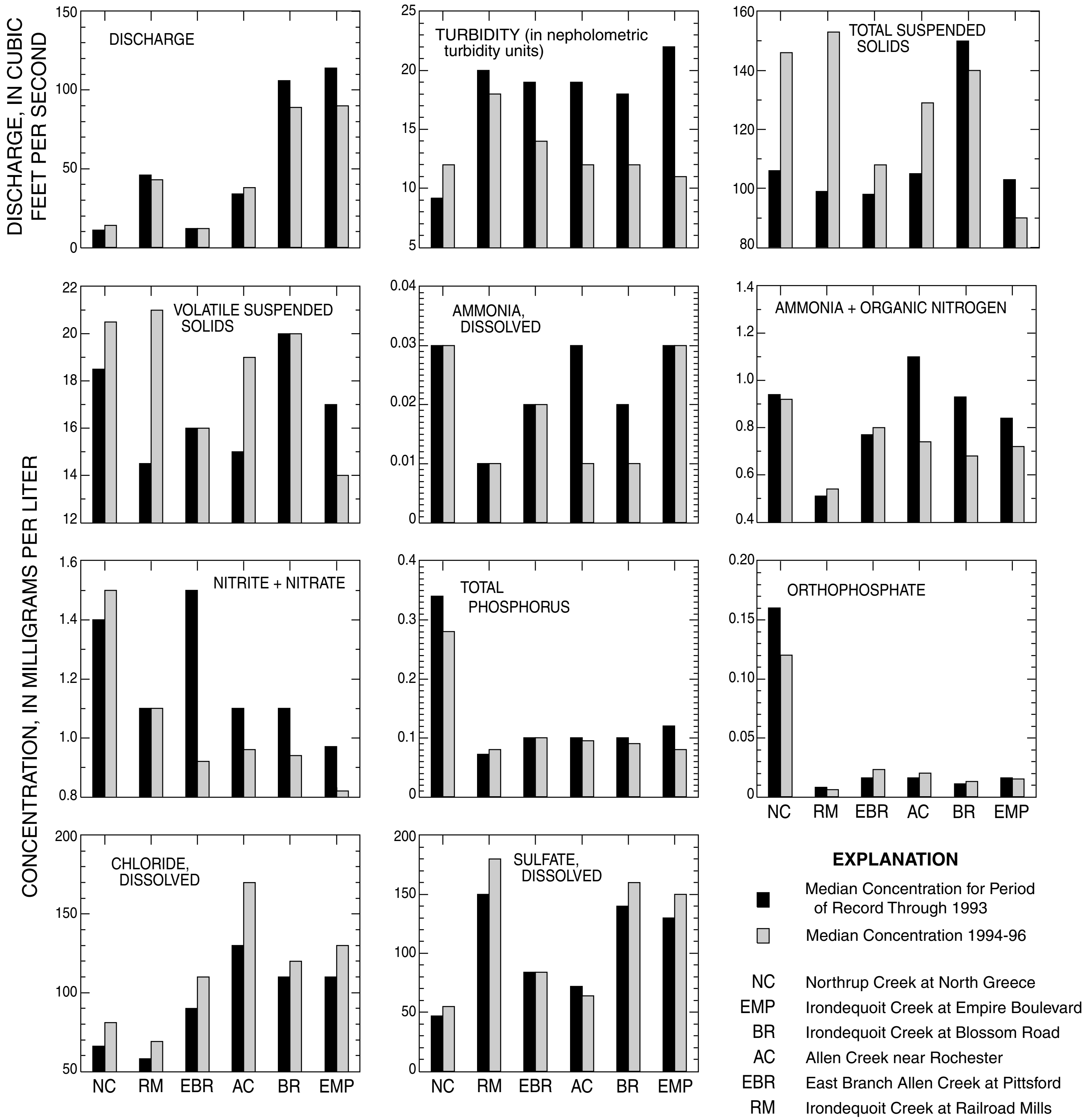


Figure 14. Median concentration of selected constituents in samples from Northrup Creek and Irondequoit Creek basin sites, Monroe County, N.Y., for period of record through 1993 and for 1994-96.

***Suspended Solids*:** Median concentrations of total suspended solids and volatile suspended solids, both of which are related to suspended sediment, varied widely among the Irondequoit Creek basin sites. The highest median concentration of both constituents was at Railroad Mills, and the lowest was at Empire Boulevard; the latter reflects the settling out of these constituents in the wetlands upstream from Empire Boulevard (fig. 1).

Northrup Creek

Median concentrations of total suspended solids and volatile suspended solids at Northrup Creek were within the range found in the Irondequoit Creek basin, but median concentrations of ammonia + organic nitrogen, nitrite + nitrate, total phosphorus, orthophosphate, and ammonia were significantly higher (table 11). The high concentrations of those nutrients are primarily due to discharges from a sewage-treatment-plant upstream from the monitoring site. In August 1995, the sewage-treatment plant began adding iron salts to the treatment process in an effort to reduce the high concentrations of phosphorus. Median concentrations of total phosphorus and orthophosphate thereafter were significantly lower for water year 1996. Median concentration of the nitrogen species remained high however, because the basin is predominantly agricultural. The median concentrations of chloride and sulfate at the Northrup Creek site also were lower than at the Irondequoit sites, probably because the Northrup Creek basin contains less urban development.

Temporal variability

Differences in mean concentration between the period of record through 1993 and the 1994-96 period were evaluated through the oneway analysis of varience and Tukey's multiple comparison test (table 12). The sites with the largest number of significant differences were Empire Boulevard and Allen Creek, and the constituents with the largest number of significant differences between the two periods were dissolved chloride and sulfate. Mean concentrations of these constitutents for 1994-96 were higher at all sites than for the pre-1993 period except those for Allen Creek, where the mean concentration of dissolved sulfate was significantly lower than in the first period. No differences for dissolved chloride and dissolved sulfate were indicated for East Branch Allen Creek. The most upstream site in the Irondequoit Creek basin (Irondequoit Creek at Railroad Mills), had the fewest significant differences between the pre-1993 period and the 1994-96 period. Median streamflow for 1994-96 was lower, and median dissolved chloride and dissolved sulfate concentrations were higher, than in the preceding period. The constituents with the fewest significant differences were suspended solids and total phosphorus. Suspended solids concentration at Irondequoit Creek at Blossom Road, and total phosphorus concentration at Irondequoit Creek at Empire Boulevard, were lower in 1994-96 than before 1993; this is attributed to modifications to the secondary channel in the wetland at Empire Boulevard in mid-1994, which increased the volume of flow to the backwater section of the wetlands to increase the retention time of stormwater and thereby decrease the concentrations of phosphorus at Empire

Table 12. Statistically significant differences between mean concentrations of selected constituents for period of record through 1993 and those for 1994-96 at Irondequoit Creek basin sites and Northrup Creek, Monroe County, N.Y.

[L, mean for 1994-96 is significantly lower than that for pre-1994 period; H, mean value for 1994-96 is significantly higher than that for 1994-96. ND, no significant difference. Locations are shown in fig. 1.]

Constituent or property	Blossom Road	Empire Blvd.	Allen Creek	East Branch Allen Creek	Railroad Mills	Northrup Creek
Discharge	L	ND	L	L	L	ND
Turbidity	L	L	L	L	ND	ND
Conductance	ND	H	L	H	--	H
Suspended solids	L	ND	ND	ND	ND	ND
Volatile suspended solids	ND	L	ND	ND	ND	ND
Ammonia, as N	ND	ND	L	ND	ND	ND
Ammonia + organic nitrogen, as N	L	L	L	ND	ND	L
Nitrite + nitrate, as N	L	L	L	L	ND	ND
Total phosphorus, as P	ND	L	ND	ND	ND	ND
Orthophosphate, as P	ND	L	H	H	ND	L
Chloride, dissolved	H	H	H	ND	H	H
Sulfate, dissolved	H	H	L	ND	H	H

Boulevard (W.F. Coon, U.S. Geological Survey, oral commun, 1999.)

Temporal trends

Rapid development in much of the Irondequoit Creek basin has increased residential land use and decreased the amount of agricultural land. The combined effects of changing land use and water-quality-management practices on surface-water quality can best be evaluated through an analysis of water-quality trends. A trend as defined in this report, is a monotonic (overall) change in concentration of a chemical constituent in water samples from a specific sampling site over a specified time period.

Trends, regardless of magnitude, were considered statistically significant at $p \leq 0.05$ (where p is the probability that an apparent trend resulted from chance arrangement of the data, rather than an actual change in the trend of the data values. The Seasonal Kendall test (Hirsch and others, 1982) is a seasonally adjusted, nonparametric test that looks at all possible seasonal pairs of data values and counts the number of times that the later value is higher (positive difference) or lower (negative difference) than the earlier one. Thus, where the seasons are monthly, each October value is compared to every other October value, November to November etc. If no trend is present in the record, the number of positive and negative differences would tend to be equal. The Seasonal Kendall test incorporates comparisons of the ranks of data and thereby minimizes the effects of outliers on trend detection. This test also can be applied to water-quality records with censored data (data reported as less than a specified reporting limit), provided that a single reporting limit is selected for the entire record.

An estimate of the rate of change in the trend slope for the period analyzed was computed according to Sen (1968). The trend slope, expressed as the change in original units (such as milligrams per liter) per year, was computed as the median of all pairwise comparisons (each paired difference is divided by the number of years separating the pair of observations). If more than 10 percent of the data were censored, the magnitude of the trend slope was likely to be inaccurate, and the trend was not reported (Lanfear and Alexander, 1990).

Constituents concentrations typically reflect seasonal variations in biochemical or hydrologic processes or human activities. The Seasonal Kendall test accounts for these seasonal differences by allowing comparisons only for the same season of different years.

Variability in constituent concentrations resulting from short-term variations in streamflow can be minimized in trend analysis through regression of concentration as a function of flow by use of a LOWESS (locally weighted scatterplot smoothing) procedure (Cleveland, 1979). The LOWESS procedure is a robust method of fitting a smoothed line to bivariate data. The degree of distance weighting is controlled by adjusting the magnitude of the smoothing factor (f). A smoothing factor of 0.5 is generally used for water-quality data (and was used for this analysis) because it tends to give a good fit to the data without masking the essential features of the relation or producing abrupt changes in slope. This regression produces a residual (flow-adjusted concentration) that is then used in the trend test. Occasionally, this flow adjustment is unsuccessful; if so, the trend is reported as a trend in unadjusted concentrations. The techniques used for addressing the effects of seasonal variation, streamflow variation, missing values, and censored data on trend analysis are discussed in detail in Johnston and Sherwood (1996) and Sherwood (1999).

Generally, the seasonal Kendall trend test produces more reliable results when at least 5 years of data are available (Hirsch and others, 1982). Because this report represents only a 3-year period of data collection (1994-96), the trend analysis included all data collected during the period of record for each site through 1996.

At all sites, the period of record through 1996 equaled or exceeded 5 years. The sites with the longest period of record (13 years) were Allen Creek and Irondequoit Creek at Blossom Road (1984-96) , and the site with the shortest (5 years) was Irondequoit Creek at Railroad Mills (1992-96).

Irondequoit Creek Basin

Ten constituents were tested for temporal trends (table 13); results varied with site and constituent. The nutrients that were tested for trends were ammonia, ammonia + organic nitrogen, nitrite + nitrate, total phosphorus, and orthophosphate.

Nitrogen and phosphorus: Three of the five Irondequoit Creek basin sites—Allen Creek, Irondequoit Creek at Blossom Road, and Irondequoit Creek at Empire Boulevard—showed statistically significant downward trends in ammonia + organic

Table 13. Statistical summary and results of trend tests for selected constituents at five sites in Irondequoit Creek basin, Monroe County, N.Y., period of record through 1996.

[Dashes indicate greater than 10-percent censoring. n, number of samples for period of record; Q1, 25th percentile; Q3, 75th percentile; n(s), number of seasons used in trend test; n(t), number of samples used in trend analysis; *p*, significance of trend. Units are in milligrams per liter unless otherwise noted. **Bold type** indicates trend is statistically significant at $\alpha = 0.05$. F (in right column) indicates test was performed on flow-adjusted concentrations, C indicates test was performed on unadjusted concentrations. Locations are shown in fig. 1.]

Constituent and site	Period of record	Descriptive statistics: n	Mean	Q1	Median	Q3	Trend results: n(s)	n(t)	Units per year	Percent per year	p	Trend code
Ammonia as N												
Railroad Mills	**1992-96**	**146**	**0.019**	**0.010**	**0.010**	**0.020**	**12**	**45**	**--**	**--**	**0.001**	**C**
East Branch Allen Creek	1991-96	191	.035	.010	.020	.040	12	55	--	--	1.0	F
Allen Creek	**1984-96**	**819**	**.039**	**.010**	**.030**	**.050**	**12**	**137**	**--**	**--**	**.001**	**F**
Blossom Road	**1984-96**	**2,379**	**.048**	**.010**	**.020**	**.030**	**12**	**156**	**--**	**--**	**.011**	**F**
Empire Blvd.	1990-96	1,070	.038	.020	.030	.050	12	72	+.0004	+1.05	.095	F
Ammonia + organic nitrogen as N												
Railroad Mills	1992-96	146	.58	.41	.51	.71	12	45	0	0	1.0	C
East Branch Allen Creek	1991-96	187	.81	.62	.78	.98	12	53	-.015	-1.85	.480	F
Allen Creek	**1984-96**	**822**	**1.10**	**.80**	**1.00**	**1.30**	**12**	**141**	**-.036**	**-3.27**	**.000**	**F**
Blossom Road	**1984-96**	**2,354**	**1.02**	**.67**	**.88**	**1.20**	**12**	**156**	**-.047**	**-4.61**	**.000**	**F**
Empire Blvd.	**1990-96**	**1,128**	**.83**	**.62**	**.78**	**1.00**	**12**	**72**	**-.057**	**-6.87**	**.003**	**F**
Nitrite + nitrate as N												
Railroad Mills	1992-96	150	1.13	.94	1.10	1.30	12	46	-.041	-3.63	.135	F
East Branch Allen Creek	1991-96	195	1.36	.64	1.40	1.90	12	58	-.003	-.22	1.0	F
Allen Creek	**1984-96**	**839**	**1.16**	**.84**	**1.10**	**1.40**	**12**	**142**	**-.015**	**-1.29**	**.034**	**F**
Blossom Road	1984-96	2,364	1.08	.82	1.00	1.30	12	156	-.010	-.93	.084	F
Empire Blvd.	1990-96	1,098	.96	.73	.89	1.00	12	72	-.022	-2.29	.116	F
Total phosphorus as P												
Railroad Mills	1992-96	292	.109	.040	.070	.015	12	55	-.0004	-.37	.734	F
East Branch Allen Creek	1991-96	379	.147	.065	.100	.180	12	71	-.0012	-.82	.825	F
Allen Creek	1984-96	1,102	.133	.060	.100	.160	12	151	-.0000	0	1.0	F
Blossom Road	1984-96	2,443	.151	.050	.095	.170	12	156	-.0009	-.60	.408	F
Empire Blvd.	1990-96	1,127	.125	.060	.100	.170	12	72	-.0223	-17.84	.116	F
Orthophosphate as P												
Railroad Mills	1992-96	292	.008	.005	.007	.009	12	55	-.000	0	.356	F
East Branch Allen Creek	**1991-96**	**379**	**.026**	**.011**	**.021**	**.032**	**12**	**71**	**+.001**	**+3.85**	**.027**	**F**
Allen Creek	1984-96	1,108	.019	.009	.017	.026	12	151	+.000	0	.768	F
Blossom Road	1984-96	2,488	.014	.006	.011	.018	12	156	-.000	0	.252	F
Empire Blvd.	1990-96	1,084	.018	.010	.016	.023	12	72	-.000	0	1.0	F

nitrogen concentration; these ranged from 3.3 percent per year at Allen Creek to 6.9 percent per year at Empire Boulevard. Allen Creek, Irondequoit Creek at Railroad Mills, and Irondequoit Creek at Blossom Road also showed downward trends in ammonia, but because more than 20 percent of the data are censored, no magnitudes are reported here. Allen Creek also showed a downward trend of 1.3 percent per year in nitrite + nitrate concentration. None of the sites showed a significant trend in total phosphorus (table 13); the East Branch of Allen Creek showed an upward trend of 3.8 percent per year for orthophosphate.

Dissolved chloride and dissolved sulfate: All sites except East Branch Allen Creek showed upward

Table 13. Statistical summary and results of trend tests for selected constituents at five Irondequoit Creek basin sites, Monroe County, N.Y., period of record through 1996 (continued)

Constituent and site	Period of record	Descriptive statistics					Trend results					
		n	Mean	Q1	Median	Q3	n(s)	n(t)	Units per year	Percent per year	p	Trend code
Chloride, dissolved												
Railroad Mills	**1992-96**	**290**	**659**	**56.2**	**65.0**	**72.0**	**12**	**55**	**-2.801**	**-4.25**	**.003**	**F**
East Branch Allen Creek	1991-96	376	120	71.0	96.0	142	12	71	+1.232	+1.03	.825	F
Allen Creek	**1984-96**	**1106**	**181**	**110**	**140**	**210**	**12**	**151**	**+3.788**	**+2.09**	**.000**	**F**
Blossom Road	**1984-96**	**2419**	**121**	**940**	**110**	**130**	**12**	**156**	**+2.157**	**+1.78**	**.000**	**F**
Empire Blvd.	**1990-96**	**1067**	**130**	**100**	**120**	**140**	**12**	**72**	**+4.506**	**+3.47**	**.008**	**F**
Sulfate, dissolved												
Railroad Mills	1992-96	281	179	120	170	240	12	55	+1.747	+.98	.556	F
East Branch Allen Creek	1991-96	372	95.5	59.8	84.5	120	12	70	+.759	+.79	.866	F
Allen Creek	**1984-96**	**1016**	**73.2**	**55.0**	**71.0**	**89.0**	**12**	**150**	**-1.314**	**-1.80**	**.000**	**F**
Blossom Road	1984-96	2328	145	110	150	180	12	156	+.359	+.25	.398	F
Empire Blvd.	1990-96	1055	139	110	140	170	12	76	+2.432	+1.75	.101	F
Turbidity, NTU												
Railroad Mills	1992-96	292	35.2	6.48	18.0	45.0	12	55	+.196	+.56	.675	F
East Branch Allen Creek	1991-96	376	31.2	6.48	17.0	34.2	12	71	-1.184	-3.79	.270	F
Allen Creek	1984-96	736	26.6	6.00	17.0	33.0	4	44	-.412	-1.55	.353	F
Blossom Road	1984-96	1802	34.4	5.90	17.0	36.0	12	120	-.336	-.98	.206	F
Empire Blvd.	**1990-96**	**1067**	**22.4**	**7.20**	**16.0**	**31.0**	**12**	**72**	**-3.063**	**-13.67**	**.000**	**F**
Total suspended solids												
Railroad Mills	1992-96	112	151	70.5	118	190	12	41	-9.000	-5.96	.499	C
East Branch Allen Creek	1991-96	127	130	62.5	98.0	149	12	49	+7.000	+5.38	.326	F
Allen Creek	1984-96	344	137	61.8	105	182	12	109	+1.750	+1.28	.358	C
Blossom Road	1984-96	786	232	89.2	148	288	12	137	+.228	+.10	.383	F
Empire Blvd.	**1990-96**	**330**	**119**	**67.2**	**102**	**154**	**12**	**54**	**-13.06**	**-10.97**	**.004**	**F**
Volatile suspended solids												
Railroad Mills	1992-96	112	47.8	32.0	44.0	66.0	12	41	-2.000	-4.18	.499	C
East Branch Allen Creek	1991-96	126	48.4	26.0	41.5	73.8	12	48	+.482	+1.00	.647	F
Allen Creek	1984-96	344	48.8	29.0	44.0	66.5	12	110	+.423	+.87	.175	C
Blossom Road	1984-96	681	50.7	33.0	46.0	68.0	12	137	+.282	+.56	.225	F
Empire Blvd.	1990-96	328	45.4	29.0	43.0	53.0	12	54	0	0	1.0	F

trends in dissolved chloride; East Branch Allen Creek showed no trend, and Allen Creek showed a downward trend in dissolved sulfate; the rest showed none. Any downward trends in constituent concentration at Allen Creek may be due in part to the downward trend in streamflow noted at that site.

Suspended solids and turbidity: Only Irondequoit Creek at Empire Boulevard showed trends in suspended solids and turbidity; both were downward. Volatile suspended solids showed no significant trends at any of the Irondequoit Creek basin sites. The downward trends in these two constituents is probably a result of the improved settling in the Ellison Park wetland since the modification of the secondary channel, mentioned previously.

Northrup Creek and Genesee River

Constituent concentrations in Northrup Creek and the Genesee River also were tested for trends. Genesee River data used for trend testing in previous reports were collected under the National Stream Quality Accounting Network (NASQAN) program, which discontinued sampling at this site in September 1994. Data used for trend testing in this report were collected by the Monroe County Environmental

Table 14. Statistical summary and results of trend tests for selected chemical constituents at Northrup Creek and Genesee River, Monroe County, N.Y., period of record through 1996.

[Dashes indicate greater than 10-percent censoring. n, number of samples for period of record. Q1, 25th percentile; Q3, 75th percentile; n(s), number of seasons used in trend test; n(t), number of samples used in trend analysis; *p*, significance of trend. Units are in milligrams per liter unless otherwise noted. **Bold type** indicates trend is statistically significant at $\alpha = 0.05$. F (in right column) indicates test was performed on flow-adjusted concentrations, C indicates test was performed on unadjusted concentrations. Locations are shown in fig. 1.]

Site	Descriptive statistics					Trend results					
	n	Mean	Q1	Median	Q3	n(s)	n(t)	Units per year	Percent per year	*p*	Trend code
Northrup Creek 1989-96											
Turbidity, NTU	592	23.9	4.80	9.45	26.0	12	79	+0.455	+1.86	0.363	F
Total suspended solids	**142**	**168**	**65.0**	**111**	**187**	**6**	**39**	**-16.2**	**-9.62**	**0.035**	**F**
Volatile suspended solids	141	51.8	34.0	46.0	74.0	6	39	-0.220	-.42	0.330	F
Ammonia as N, dissolved	589	0.116	0.010	0.030	0.120	12	79	0	0	0.412	F
Ammonia + organic nitrogen as N, total	**595**	**1.05**	**0.76**	**0.93**	**1.20**	**12**	**79**	**-0.045**	**-4.29**	**.004**	**F**
Nitrite + nitrate as N, total	589	1.56	1.10	1.40	1.80	12	78	+0.038	+2.44	0.150	F
Phosphorus, total, as P	593	0.413	0.190	0.310	0.570	12	79	-0.0084	-2.03	0.363	F
Orthophosphate as P, dissolved	596	0.250	0.077	0.145	0.390	12	79	-0.008	-3.20	0.121	F
Chloride, dissolved	**597**	**82.9**	**57.0**	**72.0**	**99.0**	**12**	**79**	**+6.213**	**+7.49**	**0.005**	**F**
Sulfate, dissolved	596	53.0	41.8	50.0	61.0	12	79	+1.385	+2.61	0.066	F
Genesee River 1990-96											
Turbidity, NTU	1413	35.7	5.70	13.0	38.0	12	84	-0.101	-.28	0.663	F
Total suspended solids	383	144	71.0	106	188	12	55	+4.53	+3.15	0.421	F
Volatile suspended solids	378	11.4	6.00	10.0	14.0	12	55	0	0	0.892	C
Ammonia as N, dissolved	1382	0.13	0.06	0.10	0.16	12	84	--	--	0.062	F
Ammonia + organic nitrogen as N, total	**1401**	**0.72**	**0.54**	**0.67**	**0.82**	**12**	**84**	**-0.049**	**-6.81**	**0.0001**	**F**
Nitrite + nitrate, as N, total	1401	1.06	0.76	0.96	1.30	12	84	-0.004	-.38	0.896	F
Phosphorus, total, as P	1408	0.09	0.05	0.06	0.10	12	84	-0.002	-2.22	0.435	F
Orthophosphate as P, dissolved	**1413**	**0.020**	**0.012**	**0.016**	**0.023**	**12**	**84**	**+0.002**	**+10.00**	**0.001**	**F**
Chloride, dissolved	**1411**	**68**	**42**	**56**	**87**	**12**	**84**	**-6.53**	**-9.60**	**0.0001**	**F**
Sulfate, dissolved	1403	72	47	72	92	12	84	+0.925	+1.28	0.209	F

Health Laboratory beginning in 1989 at the Charlotte pump station, about 1.6 mi downstream from the discontinued NASQAN site. Streamflow data associated with these samples are derived from the USGS gaging station, Genesee River at Rochester, about 6 mi upstream from the sampling site.

Northrup Creek showed three statistically significant trends (table 16)—a downward trend for total suspended solids (9.6 percent per year) and ammonia + organic nitrogen (4.3 percent per year) and an upward trend for chloride (7.5 percent per year).

The Genesee River at Charlotte pump station also showed three significant trends—a downward trend for ammonia + organic nitrogen (6.8 percent per year) and for chloride (9.6 percent per year), and an upward trend for orthophosphate (10.0 percent per year). The NASQAN site on the Genesee River (1974-93) 1.6 mi upstream of the Charlotte pump station showed a downward trend in ammonia + organic nitrogen (3.6 percent per year) and total phosphorus (5.5 percent per year), and an upward trend in nitrite + nitrate (1.2 percent per year) and chloride (2.0 percent per year) (Sherwood, 1999). Trends indicated for the two Genesee River sites, are not necessarily comparable, however, because of differences between sampling locations, sampling frequencies, and sampling methods.

Chemical Loads and Yields

Chemical load calculations provide an estimate of the amount (mass) of a particular constituent moving past a given point (gaging station) or into a receiving body of water. Chemical loads presented in this report were calculated by the ESTIMATOR program (Cohn and others 1992). The ESTIMATOR program uses multivariate linear regression to develop a quantitative relation between periodic constituent concentrations and daily streamflows to estimate daily constituent loads, and the minimum-variance unbiased estimator (MVUE) procedure to correct for log-retransformation bias (Cohn and others, 1989). The ESTIMATOR program also uses an adjusted maximum likelihood estimator (AMLE) of the moments of lognormal populations to estimate values for censored data.

The ESTIMATOR program estimates constituent concentration by equation 1, where streamflow, time, and seasonal indicators (sine and cosine transformations of time) serve as explanatory variables to remove the effects of seasonality in the data. It then computes daily loads (eq. 2), applies the MVUE bias correction to those daily estimates, and finally sums those estimates to monthly and annual totals.

$$\ln[C] = \beta_0 + \beta_1 \ln[Q/\tilde{Q}] + \beta_2 \{\ln[Q/\tilde{Q}]\}^2 + \beta_3[T/\tilde{T}] + \beta_4[T/\tilde{T}]^2 + \beta_5 \sin[2\pi T] + \beta_6 \cos[2\pi T] + \varepsilon \quad (1)$$

where

C = constituent concentration, in milligrams per liter

Q = discharge at time of sample collection, in cubic feet per second

T = time, in years

ε = error (assumed to be independent and normally distributed with a mean and varience of zero)

β's = parameters of the equation that must be estimated from the data and

$\tilde{Q}$, $\tilde{T}$ = centering variables that simplify the numerical work and have no effect on the load estimates.

The corresponding load L is given by

$$L = KQ\exp(\beta_0 + \beta_1 \ln[Q/\tilde{Q}] + \beta_2 \{\ln[Q/\tilde{Q}]\}^2 + \beta_3[T/\tilde{T}] + \beta_4[T/\tilde{T}]^2 + \beta_5 \sin[2\pi T] + \beta_6 \cos[2\pi T] + \varepsilon)$$

where:

K = conversion factor,

Q = daily mean discharge, in cubic feet per second, andall other variables are as defined for equation 1.

The precision of the estimated loads can be described in terms of a confidence interval that is based on the estimated mean and the standard error of prediction. At the 95-percent confidence interval (α = 0.05), the confidence limits are the estimated load $\pm$ 1.96 times the standard error of prediction. The value 1.96 is from a statistical table for a Student's t-distribution at the $\alpha/2$ quantile with a large number of samples (more than 250). If, for example, the monthly load estimated for chloride was 145 tons, and the standard error of prediction was 12 tons, the approximate 95-percent confidence limits would be:

$145 \pm (1.96 \times 12) = 121.5$ to 168.5 tons.

The wider the confidence limits, the greater the uncertainty and, hence, the less reliable the load estimates. A more detailed explanation of the MVUE method is given in Cohn and others (1992).

Knowledge of trends in the loads of chemical constituents carried by streams and their tributaries is important in assessing the effectiveness of management practices already in use and in evaluating the effect of land-use changes within the watershed on receiving bodies of water.

Some of the parameter estimates for the terms of the equation used to calculate concentrations (eq. 1) can be directly related to basin characteristics or to physical process. For example β_1, which corresponds to the linear dependence of concentration on streamflow, may depend on the source of the constituent—negative values indicate a dilution effect, suggesting point sources; near-zero values imply no effect from dilution, as is characteristic of some dissolved constituents; and positive values are generally indicative of sediment-related nonpoint sources. The value of β_3 corresponds to the magnitude of the log-linear component of the upward or downward time trends in constituent load. R^2 (coefficient of variation) of the concentration is the variability explained by the equation for the logarithm of concentration and R^2 load is the variability explained by the equation for the logarithm of load. The dependence of concentration on flow (β_1), the direction and magnitude of trends in loads (β_3), and coefficients of variation (R^2) for concentration and load are summarized in table 15.

β_1 values for total suspended solids, volatile suspended solids, and total phosphorus, indicate a statistically significant positive dependence on flow at all sites; this implies a probable nonpoint source for these constituents. The β_1 values for dissolved chloride and dissolved sulfate indicate a statistically significant negative dependence on flow at all sites,

Table 15. Equation parameter estimates showing linear dependence of concentration on flow (β_1) and magnitude (β_3), in percent per year, of estimated trends in loads for selected constituents, and R^2 values for concentrations and loads at four sites in the Irondequoit Creek basin, Northrup Creek, and the Genesee River, Monroe County, N.Y., 1994-96.

[*, Significantly different from zero at the 5-percent confidence level. Negative value for parameter β_1 indicates dilution effect; positive or negative value for parameter β_3 indicates upward or downward trend, respectively. Locations are shown in fig. 1.]

Site	Equation 1 parameter[1]	Constituent								
		Total suspended solids	Volatile suspended solids	Ammonia as N	Ammonia + organic nitrogen as N	Nitrite + nitrate as N	Total phosphorus as P	Orthophosphate as P	Chloride, dissolved	Sulfate, dissolved
Irondequoit Creek at Railroad Mills	β_1	0.608*	0.389*	0.100	0.213*	-0.070*	0.788*	0.654*	-0.160*	-0.318*
	β_3	6	2	226*	-3.9	4.3	-11	0	6.9*	1.4
	R^2 Conc	28.0	30.0	48.6	30.5	46.1	30.2	57.0	40.9	81.9
	R^2 Load	63.3	68.1	61.6	87.5	96.0	71.0	87.2	93.2	84.8
East Branch Allen Creek near Pittsford	β_1	.478*	.270*	-0.014	.116*	.196*	.411*	.344*	-.156*	-.265
	β_3	-0.67	2.5	-12	-9.1*	17*	7.4	0	12*	5.3
	R^2 Conc	43.4	42.3	33.0	47.9	75.3	47.9	53.9	73.2	68.3
	R^2 Load	83.8	88.0	58.9	93.9	95.6	86.0	82.9	94.4	85.1
Allen Creek near Rochester	β_1	.769*	.483*	.268	.088*	.035	.391*	.204*	-.175*	-.202*
	β_3	-4.2	-12.0	-7.1	-14.0*	13.0*	-16.0*	5.1	13.5	-2.0
	R^2 Conc	59.3	60.2	48.9	35.3	66.7	34.3	64.7	77.0	59.1
	R^2 Load	84.1	88.1	64.6	92.2	96.9	82.3	85.2	93.2	94.3
Irondequoit Creek at Blossom Road	β_1	1.04*	.687*	.074	.153	-.041*	1.23*	.358*	-.174*	-.330*
	β_3	-11.4	-15.0	9.1	-7.7*	8.0*	-6.8*	-2.7	7.2*	1.1
	R^2 Conc	39.7	38.2	22.0	27.3	47.7	51.9	58.1	67.1	85.1
	R^2 Load	73.3	73.8	42.7	85.7	91.4	80.4	84.1	94.4	91.5
Northrup Creek near North Greece	β_1	.666*	.427*	.071	.003	-.209*	.010	-.284*	-.116*	-.092*
	β_3	2.3	-1.5	23.0*	-7.7*	2.4	-30.2*	-39.4*	3.5	-2.2
	R^2 Conc	35.6	31.1	55.9	38.4	45.2	69.8	81.2	67.5	57.1
	R^2 Load	77.1	78.6	77.5	94.3	94.4	81.1	65.5	96.2	97.3
Genesee River at Charlotte Pump station	β_1	1.17*	1.17*	-.406*	-.083*	-.005	.555*	.045	-.259*	-.303*
	β_3	8.1	10.5*	-2.7	-8.1*	9.5*	2.3	8.3*	-13.1*	2.2*
	R^2 Conc	37.1	50.2	48.4	20.0	57.4	48.6	41.4	52.6	75.7
	R^2 Load	74.0	83.0	65.9	91.7	95.8	90.6	75.9	89.4	93.1

[1] β_1 estimates were retransformed from log units as $100*(e^{\beta 1} - 1)$; β_3 estimates were retransformed from log units as $100*(e^{\beta 3} - 1)$.

which implies the strong probability of point sources for these constituents. The near-zero β_1 value for nutrients at some sites suggests a combination of point and nonpoint sources.

Ammonia showed statistically significant increasing trends of 226 percent per year at Irondequoit Creek at Railroad mills and 23 percent per year at Northrup Creek. Total suspended solids showed no statistically significant trends in constituent loads during 1994-96 at at any of the sites. Volatile suspended solids and dissolved sulfate showed upward trends of 10.5 percent and 2.2 percent, respectively, at the Genesee River. Ammonia + organic nitrogen showed statistically significant downward trends in constituent loads at all sites except Irondequoit Creek at Railroad Mills; annual decreases ranged from 7.7 percent per year at Irondequoit Creek at Blossom Road and Northrup Creek to 14 percent per year at Allen Creek. The largest decreases in annual constituent loads were at Northrup Creek, where total phosphorus loads decreased at the rate of 30.2 percent per year, and orthophosphate loads decreased at the rate of 39.4 percent per year. Most of this downward trend in loads probably took place during water year 1996, when increased phosphorus controls (addition of iron salts) were implemented at the sewage-treatment plant that discharges its treated effluent into Northrup Creek.

The loads of most constituents generally are greatest during the spring (February through May), when snowmelt and spring rains cause high runoff. The loads of constituents analyzed for total concentration (suspended and dissolved), such as ammonia + organic nitrogen, nitrite + nitrate, and total phosphorus, are greatest at these times. Concentrations of dissolved constituents, such as orthophosphate, ammonia nitrogen, chloride, and sulfate, vary with flow to a far lesser degree and usually are diluted by high flows; however, the large volumes of flow during spring generally are enough to overcome the effect of dilution and produce large loads of these constituents during high flows.

Irondequoit Creek Basin

In previous reports in this series (Johnston and Sherwood, 1996, and Sherwood, 1999), constituent loads to Irondequoit Bay were estimated by multiplying loads obtained at Irondequoit Creek at Blossom Road by 1.17 to account for contribution from the intervening area between the monitoring site at Blossom Road and the bay. Data from a gaging station and sampling site established on Irondequoit Creek at Empire Boulevard (fig. 3) in 1990 to monitor constituent loads leaving the Ellison Park wetland and entering Irondequoit Bay (W. F. Coon, U. S. Geological Survey written commun, 1999.) indicated that these estimates provided a reasonably accurate assessment of the loads of some constituents entering Irondequoit Bay, but for others they did not. The 1.17 intervening-area factor tended to overestimate loads of particulate constituents, such as total suspended solids, volatile suspended solids, total phosphorus, and ammonia + organic nitrogen, and to underestimate the loads of certain dissolved constituents, such as ammonia and orthophosphate. The overestimation of particulate-constituent loads results from the settling of these constituents in the wetland between Blossom Road and Empire Boulevard, and the underestimation of ammonia and orthophosphate result from the conversion of nitrogen and phosphorus to these constituents within the wetland. The loads of chloride and sulfate estimated from the Empire Boulevard data were consistent with those previously estimated from Blossom Road data because these constituents are conservative and are little changed by chemical or biological activity in the Ellison Park wetland. Thus, the estimated loads presented in table 16 are based on data from Empire Boulevard, multiplied by an adjusted value of 1.10 to account for the intervening area.

The loads of chemical constituents transported to Irondequoit Bay by Irondequoit Creek were consistent with annual runoff (table 16); that is, the largest loads were mostly transported during the spring (February through May), and loads of the constituents analyzed for the total (suspended plus dissolved) component, such as ammonia + organic nitrogen, nitrite + nitrate, and total phosphorus, are greatest at these times. Water year 1996, which had the highest runoff during the 1994-96 period, also had the largest loads of all constituents except of ammonia + organic nitrogen, which were nearly the same as in 1994. Loads of all constituents were considerably lower during 1995, when runoff was about half that of 1994 and 1996.

Yields (load per unit area) are more helpful than loads in basin-to-basin comparisons. For example, one basin may have a greater total load than another simply because it has a larger area; yet, it may have a smaller yield than the other basin. Thus, the interpretation as to the difference in the yields from

Table 16. Annual loads of selected constituents transported by Irondequoit Creek to Irondequoit Bay, Monroe County, N.Y., water years 1994-96, and percentage of total annual load transported during spring (February through May).

[Annual loads are in tons. Locations are shown in fig. 1.]

Water year	Total suspended solids	Volatile suspended solids	Ammonia, dissolved	Ammonia + organic nitrogen, total	Nitrite + nitrate, total	Total phos-phorus	Ortho-phosphate, dissolved	Chloride, dissolved	Sulfate, dissolved	Runoff (inches)
A. Annual loads (multiplied by 1.10 to account for drainage area between Empire Boulevard and mouth)										
1994	11,400	1,730	5.26	118	150	15.4	2.18	19,400	17,700	13.5
1995	5,140	916	3.82	60.3	88.6	6.45	1.25	13,800	13,400	7.94
1996	17,300	2,130	7.28	113	170	17.0	2.83	22,200	18,200	14.8
94-96 mean	11,300	1,590	5.54	97.1	136	13.0	2.09	18,500	16,400	12.1
B. Percentage of total annual loads transported from February through May (spring snowmelt and runoff period)										
1994	66	58	54	58	63	60	44	58	46	53
1995	40	37	37	38	45	34	24	46	38	37
1996	51	61	56	55	50	47	34	49	42	43
94-96 mean	52	52	49	50	53	47	34	51	42	44

Table 17. Mean annual yield of selected constituents at the four Irondequoit Creek basin sites and Northrup Creek, Monroe County, N.Y., for indicated water years.

[All values are in tons per square mile; locations are shown in fig. 2.]

			Irondequoit Creek basin sites									
	Northrup Creek		Irondequoit Creek at Railroad Mills		East Branch Allen Creek		Allen Creek			Irondequoit Creek at Blossom Road		
Constituent	(90-93)	(94-96)	(92-93)	(94-96)	(91-93)	(94-96)	(84-88)	(89-93)	(94-96)	(84-88)	(89-93)	(94-96)
Total suspended solids	240	246	124	173	199	164	143	117	142	170	277	143
Volatile suspended solids	30.8	29.6	16.9	20.3	28.5	21.3	17.4	19.0	17.9	19.0	35.1	17.7
Ammonia as N, dissolved	0.16	.21	0.01	0.01	0.05	.042	.044	0.04	0.018	.038	0.03	0.013
Ammonia + organic nitrogrn as N, total	1.37	1.05	0.62	0.55	1.34	1.05	1.26	1.06	0.67	1.13	1.18	0.64
Nitrite + nitrate as N, total	1.55	1.57	0.73	0.99	2.45	1.71	1.30	1.14	0.91	1.15	1.09	0.91
Phosphorus, total, as P	0.38	.32	0.10	0.10	0.26	0.17	.146	0.14	0.11	.138	0.24	0.14
Orthophosphate as P, dissolved	0.18	.13	0.01	0.007	0.03	0.033	.021	0.02	0.018	.015	0.01	0.011
Chloride, dissolved	84.1	107	42.3	62.8	136	143	161	173	178	99.7	115	114
Sulfate, dissolved	48.3	54.6	124	155	102	97.0	72.1	60.4	51.4	112	111	106

each basin might be quite different than for differences in loads. Annual yields (in tons per square mile of basin above the measuring point) for Northrup Creek, and for the four sites representing the Irondequoit Creek subbasins, are summarized in table 17 and figure 15.

Yields of chloride for 1994-96 at East Branch Allen Creek, Allen Creek, and Blossom Road, were nearly the same (within 5 percent) as for the previous period of analysis (1989-93), but the primarily agricultural areas of Northrup Creek and Irondequoit Creek at Railroad Mills showed increases from the

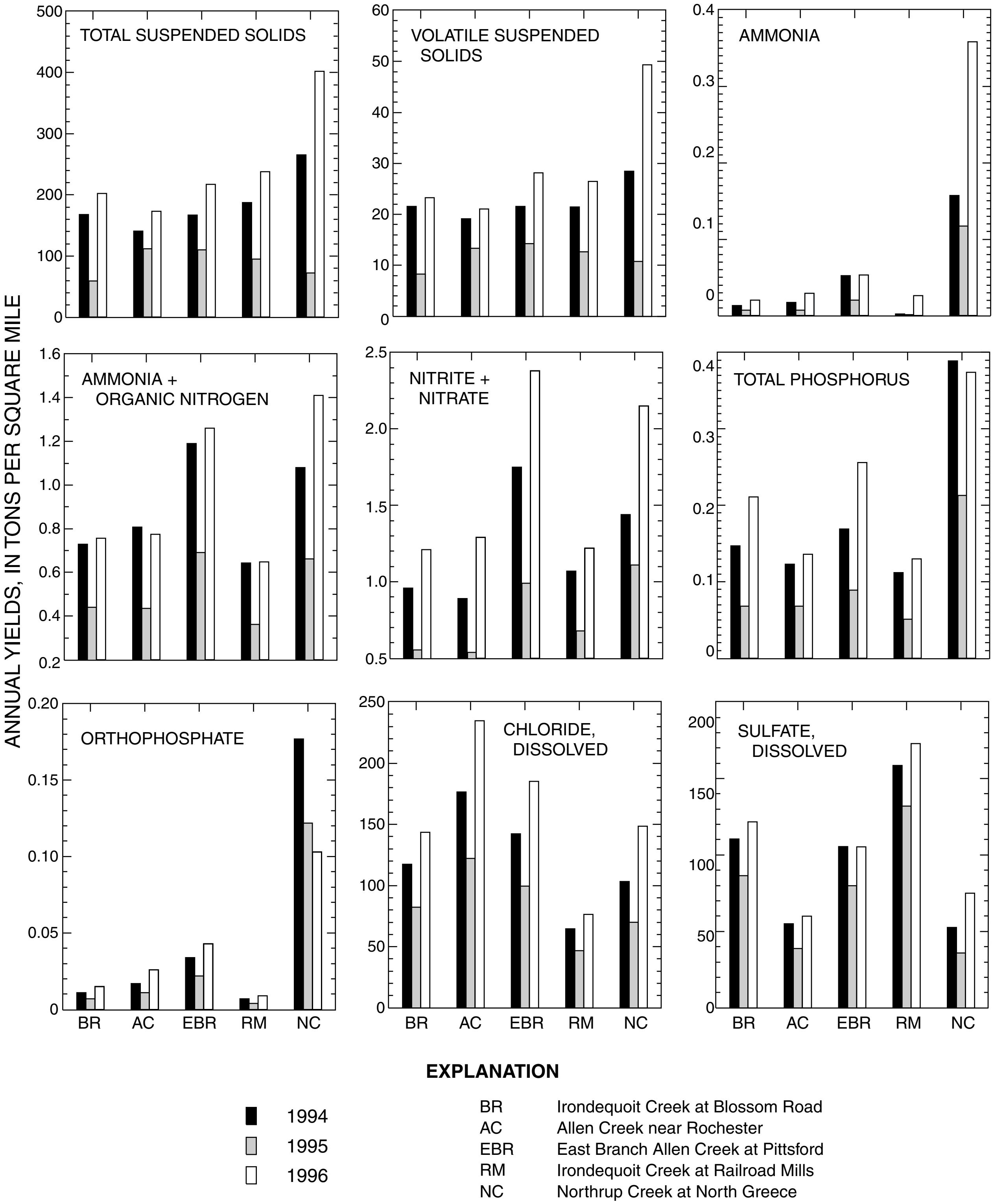


Figure 15. Annual yield of selected constituents at four sites in the Irondequoit Creek basin and Northrup Creek, Monroe County, N. Y., water years 1994-96. (Locations are shown in fig. 1.)

previous period of record; this probably is a result of increased road-salt useage in those areas during the winter. Yields of most other constituents for 1994-96, particularly total suspended solids, nitrite + nitrate, chloride, and sulfate, at Irondequoit Creek at Railroad Mills were slightly higher than for 1992-93. The concentrations of these constituents increase with increasing flow; thus, the greater runoff for the 1996 water year probably accounted for much of the increased yield for 1994-96. Allen Creek and East Branch Allen Creek by contrast, generally had lower yields of all constituents except chloride, for the 1994-96 period than for 1989-93. Mean annual yields of nutrients were fairly consistent among the Irondequoit Basin sites, except for East Branch Allen Creek, which had greater yields of all constituents except chloride per square mile than the downstream site at Allen Creek. The downstream decrease in yield probably resulted from the low stream gradients, which allow settling of constituents, and from intervening wetlands, which provide filtration as well as settling of particulate matter. Allen Creek had the highest mean annual chloride yield (178 ton/mi^2) of any of the sites. It is primarily an urban area with high road density, and thus, larger amount of road salt usage. Mean annual yields of nutrients and sulfate at Allen Creek show a steady decline over the three analysis periods (1984-88, 1989-93, and 1994-96), whereas yields of chloride show an increase. Irondequoit Creek at Blossom Road shows a general decrease in nutrient yields over the three periods and fairly constant yields of chloride and sulfate.

Northrup Creek and Genesee River

Mean annual yields of all constituents, especially nutrients, at Northrup Creek for water years 1990-93 were higher than at any of the Irondequoit Creek basin sites except East Branch Allen Creek, which had a higher yield of nitrite + nitrate (table 17). Northrup Creek's drainage area is mainly agricultural, but the relatively high nutrient yields are derived primarily from sewage-treatment-plant discharge upstream from the sampling site and, to a lesser extent, from fertilizers and agricultural runoff. The relatively high annual yields of suspended and volatile solids, and relatively low yields of dissolved chloride and sulfate, also are consistent with the agricultural character of this basin. Yields of all constituents at Northrup Creek for 1994-96 were similar to those for 1990-93 except those of chloride, which were higher.

Annual yields for the Genesee River (table 18) were estimated from stream discharges recorded at the gaging station Genesee River at Rochester (04232000) and concentration data collected at the Charlotte pump station, 6 mi downstream (fig. 2). Yields for all constituents were within the range noted for Northrup Creek and the four Irondequoit basin sites.

Total annual loads of selected constituents entering Lake Ontario from the Genesee River (table 18) were estimated from daily mean discharges at Rochester. Loads and yields of all constituents were considerably lower during water year 1995 than during 1994 and 1996. The annual mean flow of 1,760 ft^3/s for water year 1995 was only 65 percent of the 3-year mean annual flow of 2,720 ft^3/s for 1994-96.

Table 18. Annual constituent loads and associated error and annual yield for Genesee River at Charlotte Pump Station, Monroe County, N.Y., water years 1994-96.

[Loads are in thousands of tons. Error multiplied by 1.96 and added to and subtracted from the estimated load gives approximate 95-percent confidence limits of load estimate. Location is shown in fig. 1.]

Constituent	1994		1995		1996		1994	1995	1996
	Load	Error	Load	Error	Load	Error	Yield	Yield	Yield
Suspended solids	367	87	178	47.6	713	176	149	72.1	289
Volatile solids	25.4	4.38	11.9	2.32	51.4	8.92	10.3	4.82	20.8
Ammonia nitrogen as N, dissolved	0.23	.028	.18	.021	.23	.028	0.093	.071	.093
Ammonia + organic nitrogen as N, total	1.94	0.14	1.06	.075	2.04	.15	0.79	.43	.83
Nitrite + nitrate as N, total	2.81	.16	1.85	.102	4.16	.24	1.14	.75	1.68
Total phosphorus as P	.33	.037	.16	.018	.51	.061	0.14	.063	.21
Orthophosphate as P, dissolved	.05	.006	.036	.004	.073	.009	.020	.014	.029
Chloride, dissolved	162	11.0	75.9	5.09	134	9.30	65.6	30.8	54.1
Sulfate, dissolved	160	6.75	114	4.71	181	7.71	65.0	46.4	73.2

SUMMARY AND CONCLUSIONS

Many years of systematic collection of hydrologic data in Monroe County have provided a foundation for a comprehensive assessment of the County's water resources. Long-term records of precipitation and unregulated streamflow provide the basis for determining the normality of much shorter periods of record, such as the 1994-96 water-year period analyzed in this report.

Precipitation records collected and analyzed by the National Weather Service at Rochester indicate that the average annual rainfall for 1994-96 was 1.44 in. (5 percent) greater than normal. Precipitation for water year 1996 was 12 in. (38 percent) above normal; that for 1995 was 6.5 in. (20 percent) below normal, and that for 1994, was 1.24 in. (4 percent) below normal. Annual yields of chemicals deposited in the Irondequoit Creek basin from atmospheric sources ranged from 28.5 lb/mi^2 for dissolved lead to 19,500 lb/mi^2 for dissolved sulfate. Atmospheric deposition of nitrogen declined slightly from 1984-93 averages, while deposition of phosphorus more than doubled.

Ground-water levels in Ellison Park indicate that water-table gradients are subject to frequent reversals in direction of the lateral component of flow to or from Irondequoit Creek as well as in direction of vertical component of flow in the aquifer. Trend analysis of ground-water levels in Ellison Park for the period of record through 1996 showed a downward trend of 0.2 percent per year at well Mo 659 (confined), and an upward trend of 6.6 percent per year at Mo 667 (unconfined).

Ground water in Ellison Park showed few statistically significant trends in nutrients over the period of record through 1996; total phosphorus showed an upward trend at wells Mo 2 which is upgradient of the Pinnacle Hills moraine, and at wells Mo 665, and Mo 667, both of which are downgradient of the moraine and adjacent to Irondequoit Creek. A downward trend in total phosphorus was noted at Mo 3 upgradient of the moraine and adjacent to the Creek. Orthophosphate showed a downward trend at Mo 665, and ammonia nitrogen a downward trend at Mo 2 and an upward trend at Mo 659, a deep well (215ft) down gradient of the moraine and away from the creek. Trends in commom ions were more numerous, especially at wells Mo 2 and Mo 659. Those at Mo 2 were downward, and those at Mo 659 were upward, except for dissolved potassium, which was downward. The only constituents that did not show trends at Mo 2 were dissolved magnesium and sulfate, and at Mo 659, dissolved sulfate and iron.

Monthly mean streamflow for 1994-96 was in the normal range (25th to 75th percentile) throughout the county, except for Black Creek at Churchville in June, which exceeded normal by 37 percent because of 6.6 in. of precipitation during that month in 1996. Trend analysis of monthly mean flows for each stream's period of water-quality record indicated a downward trend of 2.6 percent per year for Allen Creek near Rochester.

Stream-water temperatures in the Irondequoit Creek basin were typical of large low-gradient streams in New York. Except for the furthest upstream monitoring site (Irondequoit Creek at Railroad Mills), maximum monthly temperatures in June, July, and August at the five monitored sites in the basin exceeded the optimum temperature range for rainbow trout by several degrees.

Median concentrations of some constituents in Irondequoit Creek basin streams differed more widely from site to site than others. The highest median concentration of ammonia + organic nitrogen (0.80 mg/L) was in East Branch Allen Creek, and the highest median concentration of nitrite + nitrate (1.1 mg/L) was in Irondequoit Creek at Railroad Mills. Median concentrations of ammonia nitrogen, total phosphorus, and orthophosphate were fairly consistent among the five sites. Of the nutrients, the median concentration of nitrite + nitrate showed the greatest number of statistically significant differences from site to site. The largest median concentration of dissolved chloride (170 mg/L) was in Allen Creek, and the largest median concentration of dissolved sulfate (180 mg/L) was in Irondequoit Creek at Railroad Mills. Site-to-site differences in chloride concentration are directly related to road density and the rate of road-salt application, and the highest concentrations were at sites that represent urbanized subbasins. The high median concentrations of sulfate at sites on the main stem of Irondequoit Creek probably result from the dissolution of sulfate from bedrock and glacial deposits, as well as from atmospheric sources.

Based on available data, there is little evidence that diversion of water from the Erie (Barge) Canal to supplement flows in Irondequoit Creek and Allen Creek has any effect on constituent concentrations in those Creeks.

Median concentrations of constituents in Northrup Creek were generally within the range of those in the Irondequoit Creek basin, except those for the nutrients, which were considerably higher, and for sulfate, which was considerably lower. The relatively high median concentrations of nutrients in Northrup Creek result primarily from sewage-treatment-plant discharge and, to a lesser extent, agricultural runoff upstream from the sampling site.

Trends in the concentrations of constituents for the period of record through 1996 differed from site to site, and the individual sites differed in the number and type of trends for certain constituents. Ammonia + organic nitrogen showed downward trends of 3.3 percent per year, 4.6 percent per year and 6.9 percent per year at Allen Creek near Rochester, Irondequoit Creek at Blossom Road, and Irondequoit Creek Empire Boulevard, respectively. Nitrite + nitrate showed a downward trend of 1.3 percent per year at Allen Creek. Orthophosphate showed an upward trend of 3.8 percent per year at East Branch Allen Creek. Total phosphorus showed no detectable trends at any of the sites. Dissolved chloride concentration showed upward trends at Allen Creek (2.1 percent per year), Irondequoit Creek at Blossom Road (1.8 percent per year), and Irondequoit Creek at Empire Boulevard (3.5 percent per year), and a downward trend of 4.2 percent per year at Irondequoit Creek at Railroad Mills. Dissolved sulfate showed a downward trend of 1.8 percent per year at Allen Creek. Turbidity and total suspended solids showed downward trends of 13.7 and 11.0 percent per year, respectively, at Irondequoit Creek at Empire Boulevard. Volatile suspended solids showed no detectable trends at any of the Irondequoit basin sites.

The Northrup Creek site showed detectable trends in concentrations of three constituents for 1989-96—a downward trend of 4.3 percent per year for ammonia + organic nitrogen and 9.6 percent per year for total suspended solids, and an upward trend of 6.2 percent per year for dissolved chloride. The Genesee River site also showed detectable trends for three constituents for 1990-96; downward trends of 6.8 percent per year for ammonia + organic nitrogen and 9.6 percent per year in dissolved chloride, and an upward trend of 10.0 percent per year for orthophosphate.

Total suspended solids were transported to Irondequoit Bay during 1994-96 at a rate of about 11,300 ton/yr, of which volatile suspended solids constituted about 1,590 tons. Nutrient transport to the bay averaged 97.1 ton/yr for ammonia + organic nitrogen, 136 ton/yr for nitrite + nitrate, 5.5 ton/yr for ammonia, 13.0 ton/yr for total phosphorus, and 2.1 ton/yr for orthophosphate. Dissolved chloride transport to the bay averaged 18,500 ton/yr, and sulfate transport averaged 16,400 ton/yr.

Generally, mean annual yields of constituents were similar among the five Irondequoit Creek basin sites. Irondequoit Creek at Railroad Mills had the highest yield of total suspended solids, Allen Creek had the highest yield of dissolved chloride, Irondequoit Creek at Blossom Road had the highest yield of dissolved sulfate, and East Branch Allen Creek had the highest yield of all nutrients. Northrup Creek had higher yields of total suspended solids and volatile suspended solids, ammonia nitrogen, total phosphorus, and orthophosphate than any of the Irondequoit Creek basin sites. The relatively high nutrient yields at Northrup Creek result primarily from the discharge from an upstream wastewater-treatment plant and, to a lesser extent, from agricultural runoff. Annual yields of the Genesee River were within the range of those found at Northrup Creek and the five Irondequoit Creek basin sites.

Data analysis provided in this report indicate that stream-water quality during 1994-96 was similar to that for the previous period of record, but with some differences. Nitrogen and phosphorus concentrations have declined or are unchanged at all sites. Phosphorus loads in Northrup Creek declined by almost a third in response to additional treatment implemented by a sewage treatment plant, but, Northrup Creek continues to have the highest nutrient concentrations of all sites described herein. The increased chloride concentrations correlates closely with the increased development and the increased road density; this indicates that chloride concentrations are increased by road salting. Flow diversions at the Erie (Barge) Canal that supplement creek flow in Allen Creek and Irondequoit Creek, are lower in total phosphorus and nitrogen than creek water; thus canal water has little effect on stream-water quality.

Some general differences among basins are apparent. Northrup Creek has the highest nutrient concentrations, and Irondequoit Creek at railroad Mills had the lowest. Allen Creek has higher nutrient concentrations than Irondequoit Creek. Although Allen Creek tends to have higher concentrations of all constituents than Irondequoit Creek, the Allen Creek subbasins tend to have low, if not the lowest yields for all constituents. Northrup Creek has high, if not the highest nutrient yields, but these yields are influenced by sewage-treatment-plant releases rather than water shed practices.

Water-quality-management practices and improved treatment, or diversion, of sewage treatment plant effluent, have produced decreases in the yields of some constituents throughout the county, particularly in the Irondequoit Creek basin, where the loads of nutrients delivered to Irondequoit Bay have been decreased.

REFERENCES CITED

Bubeck, R. C. and Burton, R. S., 1989, Changes in chloride concentrations, mixing patterns, and stratification characteristics of Irondequoit Bay, Monroe County, New York, after decreased use of road-deicing salts, 1974-84: U.S. Geological Survey Water-Resources Investigation Report 87-4223, 52 p.

Bidgood, B. F. and Berst, A. H., 1969. Lethal temperatures for Great Lakes rainbow trout. Journal of Fisheries Research Bd Canada. v. 26, p. 456-459.

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots: Journal of the American Statistical Association, v .74, p. 829-836.

Cohn, T.A., DeLong, L.L, Gilroy, E.J., Hirsch, R. M., and Wells, D.K., 1989, Estimating constituent loads: Water Resources Research, v. 25, no. 5, p. 937-942.

Cohn, T.A., Caulder, D.L., Gilroy, E.J., Zynjuk, L.D., and Summers, R.M., 1992, The validity of a simple statistical model for estimating fluvial constituent loads–an empirical study involving nutrient loads entering Chesapeake\ Bay: Water Resources Research, v. 28, no. 9, p. 2353-2363.

Coon, W. F., 1996, Hydrology, sedimentology, and biology of Ellison Park Wetland at the Mouth of Irondequoit Creek near Rochester, New York: U.S. Geological Survey Water-Resources Investigations Report 96-4269, 41 p.

Heffner, R.L., and Goodman, S.D., 1973, Soil survey of Monroe County, New York: U.S. Department of Agriculture, 172 p.

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

Johnston, W.H., and Sherwood, D.A., 1996, Water Resources of Monroe County New York, Water Years 1984-88, with emphasis on water quality in the Irondequoit Creek basin, part 2: U.S. Geological Survey Open-File Report 96-4054, 84 p.

Kappel, W. M., Yager, R. M., and Zarriello, P. J., 1986, Quantity and quality of urban storm runoff in the Irondequoit Creek basin near Rochester, New York, Part 2—Quality of storm runoff and atmospheric deposition, rainfall-runoff-quality modeling, and potential of wetlands for sediment and nutrient retention: U.S. Geological Survey Water-Resources Investigations Report 85-4113, 93 p.

Kappel, W. M. and Young, R. A., 1989, Glacial history and geohydrology of the Irondequoit Creek valley, Monroe County, New York: U.S. Geological Survey Water-Resources Investigations Report 88-4145, 34 p.

Lanfear, K. J. and Alexander, R. B., 1990, Methodology to derive water-quality trends for use by the national water summary program of the U. S. Geological Survey: U.S. Geological Survey Open-File Report 90-359, 10 p.

Makarewicz, J. C., Lewis, T. W., Brooks, Anna, and others, 1990, Chemical analysis and nutrient loading of Salmon Creek, Otis Creek, Black Creek, Spencerport Sewage Treatment Plant, Precipitation falling in Western Monroe County, with a discussion on the trophic status of Long Pond and stress stream analysis of Northrup Creek and Buttonwood Creeks: Brockport, N.Y., State University of New York at Brockport, unpublished report, 120 p.

National Oceanic and Atmospheric Administration, 1983-96, Climatological data annual summary, New York: Asheville, N.C., National Climatic Data Center, no. 13, v. 106-108 [issued annually].

Rantz, S. E., and others, 1982a, Measurement and computation of streamflow–volume 1, measurement of stage and discharge: U.S. Geological Survey Water-Supply Paper 2175, 284 p.

Sen, P. K., 1968, Estimates of regression coefficient based on Kendall's tau: Journal of the American Statistical Association, v. 63, p. 1379-1389.

Sherwood, D. A., 1999, Water Resources of Monroe County New York, Water Years 1989-93, with emphasis on water quality in the Irondequoit Creek basin, part 2: U.S. Geological Survey Open-File Report 99-4084, 50 p.

Wagner, L.A., and Dixson, H.L., 1985, Drainage areas of New York streams by river basins—a stream gazetteer: U.S. Geological Survey Open-File Report 81-1055, 359 p.

Yager, R.M., Zarriello, P.J., and Kappel, W.M., 1985, Geohydrology of the Irondequoit Creek basin near Rochester, New York: U.S. Geological Survey Water-Resources Investigations Report 84-4259, 6 pl.

Young, R. A., 1993, Analysis and recommendations for ground-water sampling program (1988-93), Irondequoit Creek basin, with emphasis on the Ellison Park-Browncroft Boulevard reach: Rochester, N.Y., Monroe County Health Department, unpublished report , 20 p