Effects of a Cattail Wetland on Water Quality of Irondequoit Creek near Rochester, New York

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 00-4032

Prepared in cooperation with the
MONROE COUNTY DEPARTMENT OF HEALTH

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By WILLIAM F. COON, JOHN M. BERNARD, AND FRANZ K. SEISCHAB

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Ithaca, New York
2000

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INCH-POUND TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	0.4047	hectare
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
cubic foot (ft^3)	0.02832	cubic meter
acre-foot (acre-ft)	1,233	cubic meter
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
	Mass	
ounce, avoirdupois (oz)	28.35	gram
pound, avoirdupois (lb)	0.4536	kilogram
ton, short (2,000 lb)	0.9072	megagram

INTERNATIONAL SYSTEM (SI) TO INCH-POUND UNITS

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
	Area	
hectare (ha)	2.471	acre
square meter (m^2)	10.76	square foot
square kilometer (km^2)	0.3861	square mile
	Volume	
cubic meter (m^3)	35.31	cubic foot
cubic meter (m^3)	0.0008107	acre-foot
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second
	Mass	
gram (g)	0.03527	ounce, avoirdupois
kilogram (kg)	2.205	pound, avoirdupois
gram per square meter (g/m^2)	.0002049	pound per square foot
megagram (Mg)	1.102	ton, short (2,000 lb)

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 ˚C).

Temperature: degrees Celsius (˚C) = 5/9 (degrees Fahrenheit (˚F) minus 32)

Concentrations of chemical constituents in water are given either in:

milligrams per liter (mg/L) ≈ micrograms per gram (mg/g) = parts per million (ppm); or

micrograms per liter (µg/L) ≈ micrograms per kilogram (µg/kg) = parts per billion (ppb)

National Geodetic Vertical Datum of 1929 (NGVD) is a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Effects of a Cattail Wetland on Water Quality of Irondequoit Creek near Rochester, New York

by William F. Coon, John M. Bernard[1], and Franz K. Seischab[2]

ABSTRACT

A 6-year (1990-96) study of the Ellison Park wetland, a 423-acre, predominantly cattail (*Typha glauca*) marsh in Monroe County, N.Y., was conducted to document the effect that this wetland has on the water quality of Irondequoit Creek, which flows through it. Irondequoit Creek drains 151 square miles of mostly urban and suburban land and is the main tributary to Irondequoit Bay on Lake Ontario. The wetland was a sink for total phosphorus and total suspended solids (28 and 47 percent removal efficiencies, respectively, over the 6-year study period). Sedimentation and vegetative filtration appear to be the primary mechanisms for the decrease in loads of these constituents. Total nitrogen loads were decreased slightly by the wetland; removal efficiencies for ammonia-plus-organic nitrogen and nitrate-plus-nitrite were 6 and 3 percent, respectively. The proportions of total phosphorus and total nitrogen constituents were altered by the wetland. Orthophosphate and ammonia nitrogen were generated within the wetland and represented 12 percent of the total-phosphorus output load and 1.8 percent of total-nitrogen output load, respectively. Conservative chemicals, such as chloride and sulfate, were little affected by the wetland. Concentrations of zinc, lead, and cadmium showed statistically significant decreases, which are attributed to sedimentation and filtration of sediment and organic matter to which these elements adsorb.

Sediment samples from open-water depositional areas in the wetland contained high concentrations of (1) trace metals, including barium, manganese, strontium, zinc (each of which exceeded 200 parts per million), as well as chromium, copper, lead, and vanadium, and (2) some polycyclic aromatic hydrocarbons. Persistent organochlorine pesticides, such as chlordane, dieldrin, DDT and its degradation products (DDD and DDE), and polychlorinated biphenyls (PCB's), also were detected, but concentrations of these compounds were within the ranges often found in depositional environments in highly urbanized areas.

Cattail shoots attained a maximum height of 350 centimeters, a density of more than 30 shoots per square meter, and total biomass of more than 5,600 grams per square meter (46 percent of which was in above-ground tissues during the growing season). Nitrogen and potassium were three times more abundant in above-ground tissues (2.4 and 1.5 percent by dry weight, respectively) than in below-ground tissues (0.8 and 0.5 percent, respectively). Concentrations of phosphorus, molybdenum, and manganese in above-ground tissues were similar to those in below-ground tissues, but the concentrations of all other constituents were considerably higher in below-ground tissues. Concentrations of several elements exceeded those typically found in natural wetlands; these included manganese (417 ppm, parts per million) and sodium (3,600 ppm) in above-ground tissues, and aluminum (1,540 ppm), iron (15,400 ppm),

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manganese (433 ppm), and sodium (10,000 ppm) in below-ground tissues.

Large quantities of nutrients are assimilated by wetland vegetation during the growing season, but neither tissue production nor microbial metabolic processes appeared to play a significant role in the observed patterns of surface-water chemical input-to-output relations on a seasonal basis. Presumably, internal cycling of nutrients sequestered in the sediments and detritus, combined with a summer increase in microbially mediated chemical transformations, obscured the effects of vegetative assimilation during the summer on surface-water chemical loads. Additionally, the natural confinement of most flows within the banks of Irondequoit Creek, which resulted in passage of stormwater through the wetland with little dispersion or detention in the cattail and backwater areas, diminished the capability of the wetland to improve water quality. Additional factors that probably affected the chemical-removal efficiency of the wetland included chemical inflow loading rates, storage and release mechanisms of the sediments (sedimentation, adsorption, filtration, precipitation, dissolution, and resuspension), and accretion and burial of organic matter.

Measurements of chlorophyll_*a* concentrations, and calculations of potential phosphorus concentrations, since the 1970's indicate an improvement in the trophic state of Irondequoit Bay. Estimated average annual loads (1990-96) of selected constituents entering Irondequoit Bay indicate that, since 1980, the loads of all major forms of nitrogen have decreased, chloride loads have increased, and sulfate loads have changed little. Inputs of total phosphorus and suspended solids to the wetland have increased since 1980, possibly as a result of increased erosion by stormflows from an increasingly developed watershed. The wetland decreases the loads of these constituents, but the trends of these loads entering Irondequoit Bay cannot be reliably defined because the removal efficiencies during the two earlier study periods (1980-81 and 1984-88) are unknown.

INTRODUCTION

Wetlands have been recognized as important ecosystems that provide unique habitats for fish, wildlife, and plants. They provide many other functions and values, including ground-water recharge and discharge, flood storage and desynchronization of flood waves, shoreline anchoring and dissipation of erosive forces, sediment trapping and removal of adsorbed chemicals (heavy metals and organic compounds), nutrient retention and removal, nutrient cycling, food-chain support (production, decomposition, consumption, and detrital export), recreation (swimming, boating, fishing, nature study), and scientific research (Adamus and Stockwell, 1983; and Mitsch and Gosselink, 1986). Among these functions is the potential to improve water quality by facilitating the retention or removal of sediment and nutrients carried by urban stormwater. This function can be achieved through various processes, including sedimentation (settling), adsorption, chemical precipitation, filtration, biochemical interactions and microbially mediated transformations, nutrient assimilation, volatilization and aerosol formation, infiltration (Strecker and others, 1992), ion exchange, biodegradation (U.S. Environmental Protection Agency, 1993), and long-term storage of chemicals through accretion and burial (Mitsch and Gosselink, 1986). These processes can cause a wetland to act as either a temporary or permanent sink for certain constituents. Other processes, such as leaching, decomposition, dissolution, diffusion from sediments, and, again, microbially mediated transformations, can cause a wetland to act as a source for certain constituents by generating these constituents and exporting them in quantities larger than those that entered the wetland (Kadlec and Knight, 1996; Strecker and others, 1992; Mitsch and Gosselink, 1986; U.S. Environmental Protection Agency, 1993).

Mitsch and Gosselink (1986) note that the effects of nutrient uptake by macrophytes, algae, bacteria, and fungi on water quality in the wetland can be similar to those of secondary and advanced treatment of wastewater. Johnston (1991) points out that physical and microbial processes in a wetland generally have a greater effect than vegetative uptake in the retention of sediment and nutrients. Hickok and others (1977) conclude that, barring flooded or cold soil conditions, which inhibit microbial processes, microbial activity is the principal mechanism for removing phosphorus from the soil-water solution.

Natural and constructed wetlands have been studied since the 1960’s and are receiving widespread use as cost-effective and environmentally beneficial means of mitigating the deleterious effects of storm runoff and wastewater on receiving surface-water bodies and ground-water systems (Kadlec and Knight, 1996; Strecker and others, 1992; U.S. Environmental Protection Agency, 1993; Livingston, 1989; Gadbois, 1989). One factor that largely determines a wetland’s removal efficiency for the primary nutrients (phosphorus and nitrogen) is macrophyte density — that is, the amount of surface area to which bacteria, fungi, and epiphytic algae can adhere (Kadlec and Knight, 1996). These microbes facilitate the assimilation and transformation of nutrients and form a biofilm on substrate surfaces.

The processes of water-quality improvement in a wetland are interrelated, and the relative importance of any one mechanism can vary from wetland to wetland. The broad range in the effectiveness of wetlands in treating stormwater results from (1) the diversity among wetlands in terms of vegetation, depth and duration of inundation, climatic factors, soils, and hydraulic characteristics, and (2) differences in water sources (surface water, ground water, or atmospheric deposition) and in water chemistry. The balance between chemical uptake and retention, and chemical release (through leaching, decomposition, and plant-facilitated transfer from the sediments to overlying waters) and export (through surface flow and atmospheric exchange) determines a wetland’s net effect on water quality. Chemical retention or export can be affected by many factors, including the wetland’s size and water-storage capacity; the rate and velocity of flow; the detention time of stormwater; the flow pattern and degree of dispersal or mixing (circulation); the presence or absence of pools for sediment accumulation; the frequency, duration, and depth of inundation; the types and density of vegetation; the water pH, temperature, dissolved-oxygen concentration, and turbidity or amount of light penetration; the season; the types of maintenance practices used (removal of sediment or vegetation); and the chemical-exchange rates between water and sediment (Livingston, 1989; Strecker and others, 1992; Kadlec and Knight, 1996; Adamus and Stockwell, 1983).

The hydrologic characteristics of a wetland play a major role in its structure and water-quality-improvement function in that they (1) determine or modify the composition, diversity, and distribution of wetland flora; (2) affect the level of productivity through volume and circulation of flow and through duration and frequency of inundation; and (3) affect (a) rates of sedimentation, resuspension, and erosion; (b) rates of organic accumulation and export; and (c) the input, output, transformation, and cycling of nutrients and other constituents (Mitsch and Gosselink, 1986).

Irondequoit Creek Basin

The Irondequoit Creek basin, east and southeast of Rochester, in Monroe and Ontario Counties, has been the subject of numerous water-quality studies in response to public concern over the sedimentation and eutrophication of Irondequoit Bay on Lake Ontario (fig. 1). Irondequoit Creek, the bay’s main tributary, is the source of (1) nutrients that, in the past, supported summertime algal blooms in the bay (Pixley, 1982); (2) dissolved chloride, which can alter the bay’s chemical and thermal stratification and interfere with seasonal mixing of the bay’s waters (Diment and others, 1974; Bubeck and Burton, 1989); and (3) sediment to which heavy metals and organic compounds can adhere (Schroeder, 1985). Until the spring of 1977, effluent from 14 wastewater-treatment facilities within the basin and combined-sewer overflows from the city of Rochester were discharged into the creek (M. Schifano, Monroe County Pure Waters, oral commun., 1999). At present, these wastewaters are treated at a central location at the north end of Rochester and are discharged into Lake Ontario. These diversions of wastewater out of the basin have improved the water quality of Irondequoit Bay, but further improvement has been slowed by the continued input of contaminants from nonpoint sources in the basin—primarily nutrients, metals, and organic compounds washed from impervious surfaces by rain and snowmelt (R. Burton, Monroe County Environmental Health Laboratory, written comm., 1996).

Previous Studies

The hydrologic characteristics of the Irondequoit Creek basin were studied during 1979-81 as part of the Nationwide Urban Runoff Program (NURP) (O’Brien and Gere, 1983; Zarriello and others, 1985; Kappel and others, 1986). One goal of that study was to assess the effect of storm runoff and its associated nutrients and contaminants on the quality of water in Irondequoit Bay. Kappel and others (1986) estimated annual loads (1980-81) of selected constituents that entered the bay: 214 tons of ammonia-plus-organic nitrogen, 20.2 tons of total phosphorus, and 19,100 tons of total suspended solids. O'Brien and Gere (1983, p. iv) used a steady-state model and estimated that 15.7 tons of phosphorus were entering Irondequoit Bay annually (1980-81) from external sources and that, from an assumption of a zero net phosphorus release from the bottom sediments of the bay, the external loading would need to be decreased to about 5.6 tons annually to maintain the bay in a trophic state appropriate for recreational usage. They also indicated that 50 to 75 percent of the annual phosphorus loads entered the bay during a 3-month period that included the major seasonal snowmelt and spring runoff. A unique component of the Irondequoit Creek NURP study (Kappel and others, 1986) was the inclusion of an in-stream natural wetland (Ellison Park) in the study's monitoring program (fig. 2). Several NURP projects considered wetlands to be promising mechanisms for treatment of urban runoff, but these projects did not include development of performance or design criteria (U.S. Environmental Protection Agency, 1983).

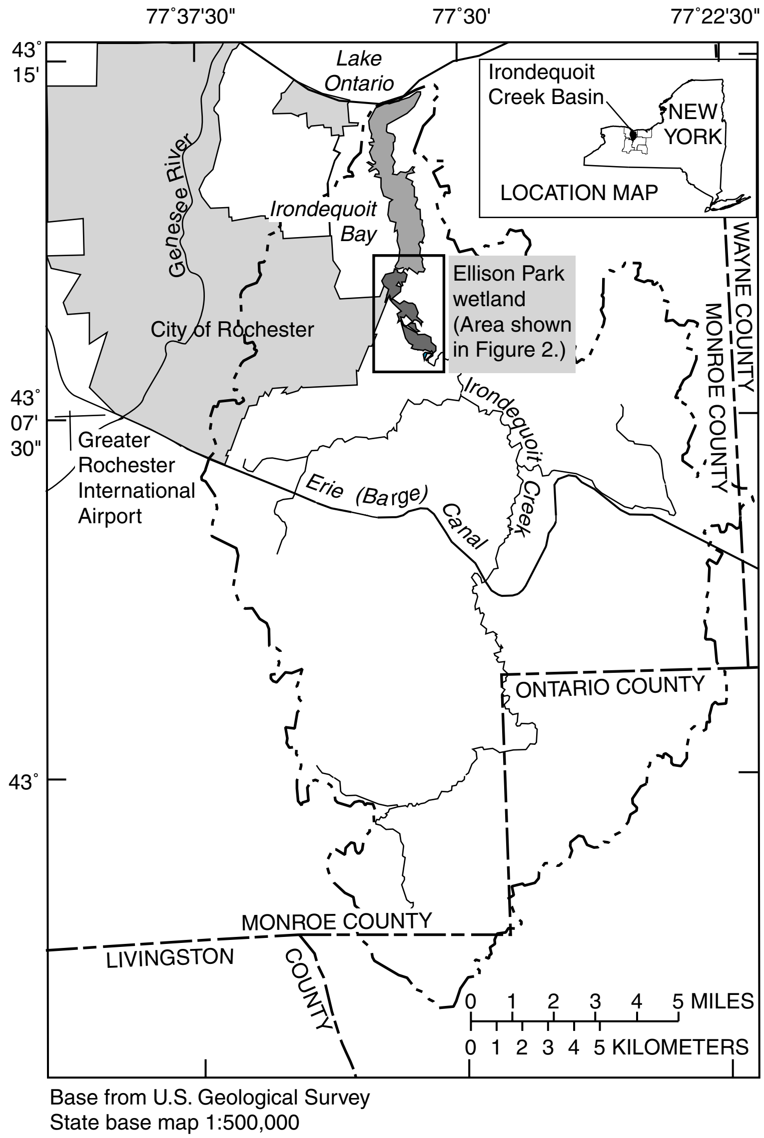

Figure 1. Location of study area and major geographic features of Irondequoit Creek basin, Monroe County, N.Y.

Ellison Park Wetland

The Irondequoit Creek NURP study identified the large, predominantly cattail-covered Ellison Park wetland near the mouth of Irondequoit Creek, just south of Irondequoit Bay, as the most cost-effective means of decreasing nutrient loads entering the bay (O'Brien and Gere, 1983). Kappel and others (1986) estimated that the wetland provided a 10-percent decrease in phosphorus loads and theorized that an additional 15 percent decrease (primarily through deposition and mineralization of particulate phosphorus associated with the silt-clay sediment fraction) could be achieved if flows through the wetland were regulated and water-dispersal and detention time increased. Similarly, O'Brien and Gere (1983) estimated an annual phosphorus removal of 24 percent could be attained through operation of a flow-control structure installed at a natural constriction in the wetland midway between Browncroft and Empire Boulevards (fig. 2).

In 1990, the U.S. Geological Survey (USGS), in cooperation with the Monroe County Department of Health, began a 6-year study of the wetland to evaluate its potential for water-quality improvement. Streamflow and water chemistry of Irondequoit Creek at the upstream and downstream ends of the wetland were monitored. Concurrent biological studies of the fish, bird, and benthic-macroinvertebrate communities in the wetland were conducted (Miller and Ringler, 1992). Wetland flora and vegetation studies were conducted in 1991 and 1996 (Bernard and Seischab, 1991 and 1997) between Browncroft and Empire Boulevards to (1) identify individual species, (2) map plant communities, (3) measure cattail density (shoots per square meter) and above- and below-ground biomass, and (4) provide chemical analyses of above- and below-ground cattail tissues.

A description of the hydrologic, sedimentological, and biological characteristics of the wetland is given by Coon (1997), who noted that (1) water levels in the wetland are controlled by the surface elevation of Lake Ontario; (2) bankfull and lower flows of Irondequoit Creek do not disperse through the wetland, but are mostly confined within the banks of the main channel and usually pass through the wetland in less than 3.5 hours; dispersal of stormflows occurs only when flows exceed the capacity of the channel (overbank flows), which on average occurs twice a year; (3) dispersed water moves into the cattail-covered backwater areas of the wetland, where it can be detained for 3 to 15 hours or more (the maximum detention time has not been determined); (4) dispersal of flows also occurs during backwater conditions that result from high water levels on Lake Ontario, usually from April to July; (5) the channel sediments in the wetland range from sand, which is found in the main channel of Irondequoit Creek, to silt and clay with a high concentration of organic matter (about 4 percent total organic carbon by weight), in the backwater areas; (6) sedimentation in the wetland is sporadic, but an annual sedimentation rate from 0.006 to 0.016 ft has been estimated. Data on the biological structure of the wetland are summarized in Coon (1997) and include (1) the identification and distribution of fish species during 1991-92 (Miller and Ringler, 1992); (2) results of the bird surveys conducted during 1980-85 (Andrle and Carroll, 1988) and 1991-92 (Miller and Ringler, 1992); (3) a cursory description of the macroinvertebrate community based on the analyses of the stomach contents of fishes (Miller and Ringler, 1992); and (4) a general description of the wetland flora (Bernard and Seischab, 1991).

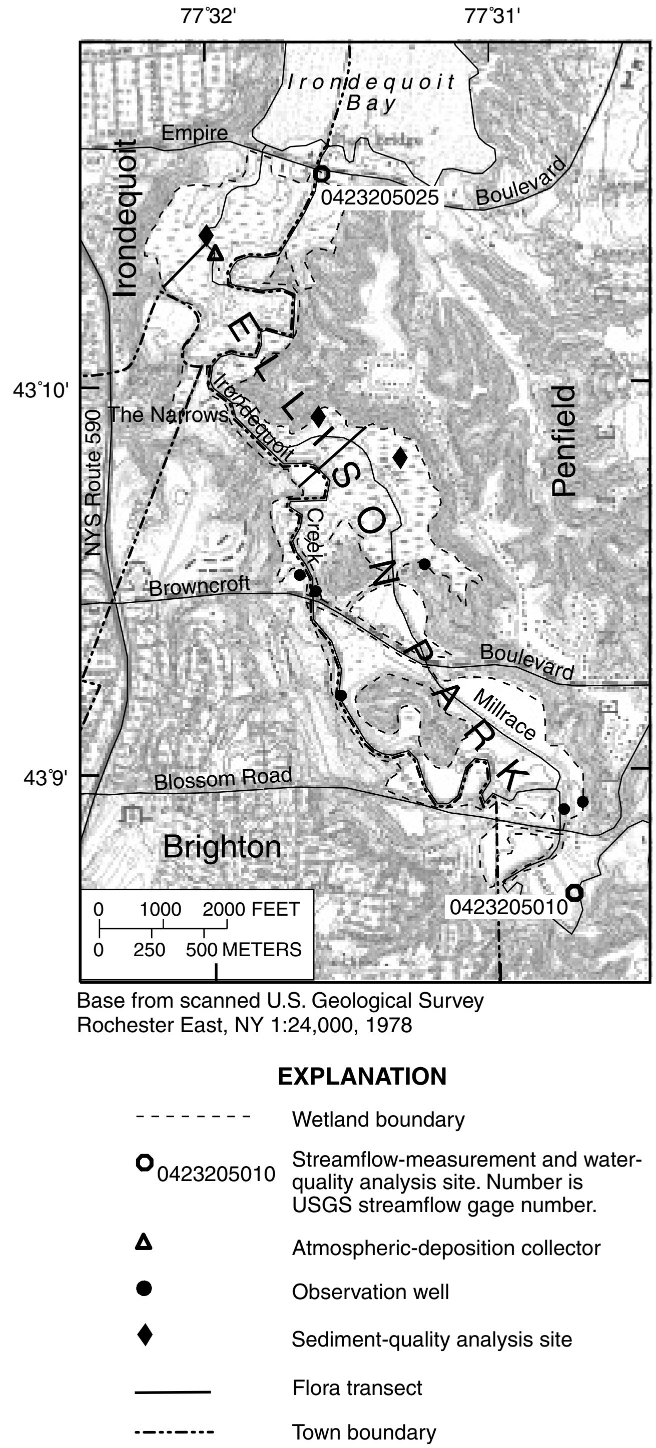

Figure 2. Locations of data-collection sites and Ellison Park wetland within the Irondequoit Creek basin, Monroe County, N.Y. (Location is shown in fig. 1.)

Purpose and Scope

This report (1) presents Ellison Park wetland's monthly and annual inflow and outflow loads of total nitrogen, ammonia-plus-organic nitrogen, ammonia, organic nitrogen, nitrate-plus-nitrite nitrogen, total phosphorus, orthophosphate, total and volatile suspended solids, chloride, and sulfate, during the 1990-96 water years (a water year is the period from October of one year to September of the following year); (2) gives the wetland's computed monthly and annual removal efficiencies for the above constituents; (3) assesses the effect of the wetland on surface-water temperature; (4) describes the physical and chemical characteristics of the vegetation and recently deposited sediment in the wetland; (5) discusses the role of the wetland sediment and vegetation, primarily cattail (*Typha glauca*), in the retention or export of nutrients; and (6) assesses the current ecological status of Irondequoit Bay in terms of trophic state and trends in estimated constituent loads entering the bay. Detailed chemical analyses of water and sediment samples are given in the appendixes.

Study Area

The Irondequoit Bay watershed covers an area of 169 mi^2 (fig. 1), of which 151 mi^2 is drained by Irondequoit Creek, which flows into the south end of Irondequoit Bay. About 54 percent of the watershed is urban or suburban, and about 34 percent is agricultural (Christopher Sciacca, Monroe County Planning Board, written commun., 1998). The upstream (southern) part of the basin is dominated by forest and agricultural areas but is becoming increasingly developed.

Precipitation

Average annual precipitation in the Rochester area is 32.4 in. (168 years of record), including that from an average snowfall of about 90 in. (55 years of record), as recorded by the National Weather Service station at the Greater Rochester International Airport (National Climatic Data Center, 1996). Monthly precipitation quantities during the 1990-96 study period (table 1) are plotted with 30-year (1961-90) mean monthly precipitation values in figure 3A. Monthly precipitation greatly exceeded the long-term average during July 1992, October 1995, and June 1996, and was substantially below average during February and June 1991; May, July and August 1993; July and October 1994; and February through June 1995.

Location

The wetland (referred to in this report as the Ellison Park wetland) lies at the mouth of Irondequoit Creek along the township boundaries of Irondequoit, Brighton, and Penfield in Monroe County (fig. 2). The wetland, which forms a transition zone between the riparian environment of the creek and the lacustrine environment of Irondequoit Bay, encompasses about 423 acres at and below an elevation of 250 ft (DeGaspari and Bannister, 1983) and covers less than 0.5 percent of the creek's total drainage area. Bounded by steep valley sides on the east and west, it covers the entire valley floor from Blossom Road to Empire Boulevard. Between Browncroft and Empire Boulevards, the wetland is dominated by cattails and is divided into southern and northern segments (263 acres and 160 acres, respectively, DeGaspari and Bannister, 1983) by a natural constriction that is locally referred to as the Narrows (fig. 2). The width of the wetland ranges from 200 ft at the Narrows to 2,500 ft in the southern and northern parts.

Table 1. Monthly and annual total precipitation recorded at Greater Rochester International Airport, Rochester, N.Y., 1990-96, with normal 30-year (1961-90) means

[Data from National Climatic Data Center (1996). Values are in inches. Location is shown in fig. 1]

Year	Monthly												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1990	1.61	3.93	1.56	3.58	5.76	2.88	3.05	3.59	3.36	4.37	2.27	4.18	40.14
1991	1.69	1.16	4.70	4.07	2.43	1.19	2.37	1.80	2.86	1.65	2.39	2.92	29.23
1992	1.46	1.87	3.53	3.43	2.83	1.98	6.03	4.45	3.02	1.78	2.90	2.98	36.26
1993	2.32	1.52	2.44	3.07	1.24	2.76	1.67	1.67	4.37	3.21	3.27	1.60	29.14
1994	2.68	1.63	1.70	4.08	2.56	2.43	0.61	4.27	2.68	1.34	3.24	2.32	29.54
1995	2.46	1.58	1.15	1.18	1.75	2.07	3.85	3.05	1.50	5.70	4.21	1.50	30.00
1996	3.18	1.72	2.07	4.84	3.51	6.65	2.18	3.33	5.09	5.40	4.12	2.97	45.06
Normal mean, 1961-90	**2.08**	**2.10**	**2.28**	**2.61**	**2.72**	**3.00**	**2.71**	**3.40**	**2.97**	**2.44**	**2.92**	**2.73**	**31.96**

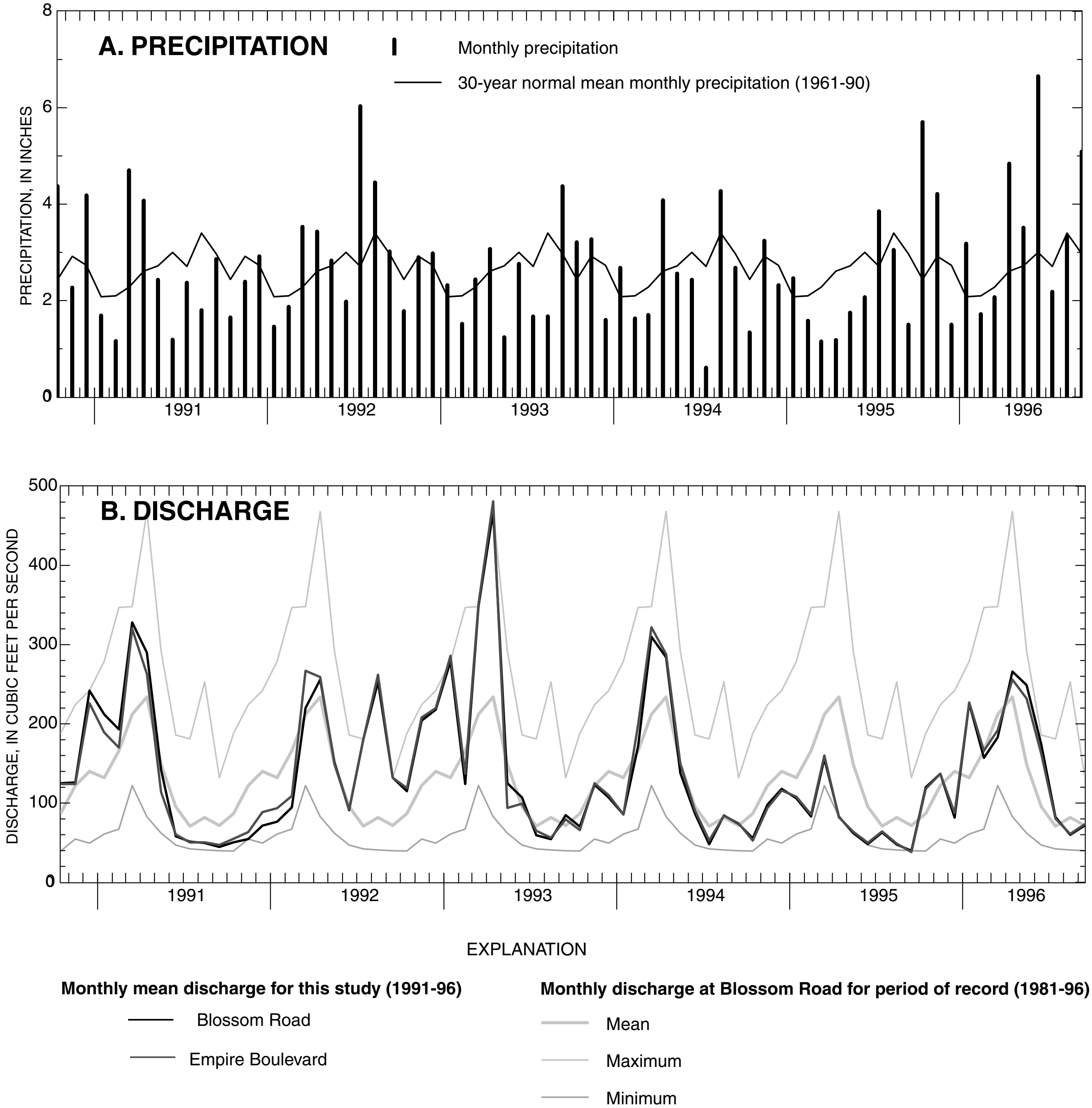

Figure 3. A. Monthly precipitation, 1990-96, and normal (1961-90) mean monthly precipitation, recorded at the Greater Rochester International Airport, Rochester, N.Y. B. Monthly mean discharges at Irondequoit Creek above Blossom Road and at Empire Boulevard, 1990-96, with monthly maximum, mean, and minimum discharges for the period of record at Blossom Road, 1981-96, Monroe County, N.Y. (Locations are shown in figs. 1 and 2.)

Wetland Characteristics

The Ellison Park wetland is classified as a palustrine persistent emergent wetland by the U.S. Fish and Wildlife Service (Cowardin and others, 1979); that is, a nontidal marsh characterized by erect, rooted, herbaceous hydrophytes that may be temporarily or permanently flooded at the base and normally remain standing at least until the beginning of the next growing season. Cattails, primarily *Typha glauca*, cover about 265 acres, or 63 percent of the wetland surface area, which is most of the unponded area of the wetland between Browncroft and Empire

Boulevards. (Acreages were digitized from a USGS 7.5-minute topographic map, Rochester East, N.Y. quadrangle.) Plant diversity is greatest on the banks of the main channel of Irondequoit Creek and along the wetland margins, where soil wetness varies with slight elevation differences. Open-water areas, including channels, cover about 99 acres, or 23 percent of the wetland. A hardwood-forested wetland between Browncroft Boulevard and Blossom Road covers about 25 acres, or 6 percent of the wetland, and maintained grass areas of the county park below the wetland-demarcation elevation of 250 ft (National Geodetic Vertical Datum, NGVD) cover the rest of the wetland (about 34 acres, or 8 percent of the wetland).

The Ellison Park wetland contains hydric soil, defined by the U.S. Soil Conservation Service (1985) as soil that in its undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation. It is a mineral soil, formed through the deposition of alluvium (flood-plain deposits) from the Irondequoit Creek basin. The upper layer consists of a dense accumulation of partly decomposed organic material.

Hydrology

Wetland conditions in Ellison Park are wholly or partly dependent on the surface elevation of Lake Ontario, which is maintained within a narrow range through regulation of control structures on the St. Lawrence Seaway. Data collected at a streamflow-monitoring station at Empire Boulevard indicate that water-surface elevations at the mouth of the wetland fluctuated only 4.1 ft during 1990-96 (fig. 4). Lake Ontario water levels usually rise during the spring-runoff period and are maintained through the summer for navigational and recreational purposes and for hydroelectric-power generation on the St. Lawrence River near Massena, N.Y. Water levels are lowered in December and January to increase the storage capacity for spring runoff (Paul Yu, U.S. Army Corps of Engineers, oral commun., 1997). When the water-surface elevation recorded at the streamflow-monitoring site at Empire Boulevard is at or above 246.9 ft, most of the cattail-covered area in the southern and northern wetland sections is inundated. At a slightly lower elevation, 246.5 ft, the water levels in the southern wetland area drop below land surface, and only the northernmost part of the northern wetland area remains inundated. Water levels range from 2 ft or more above land surface to 1.5 ft below. Flat vegetated areas of the wetland can be briefly inundated by runoff from large storms and are seasonally inundated for periods of 4 to 7 months. The duration of seasonal inundation (hydroperiod) varies from year to year and from south to north; in some years, the water level rises only enough to inundate the southern wetland area for several days, but in other years, high water levels can persist from January through August (fig. 4 and table 2). The 6 years of water-level data from this study (1990-96) show that the hydroperiod averaged 136 days per year in the southern wetland area and 189 days per year in the northern wetland area. The maximum depth of inundation during these periods ranged from 0.1 to 2.4 ft (average 1.1 ft) in the southern wetland area, and from 0.5 to 2.8 ft (average 1.5 ft) in the northern area.

Two channels convey water through the wetland—the main channel of Irondequoit Creek, which carries most of the flow, and a smaller channel, locally referred to as the Millrace, which formerly was the outlet raceway for a flour mill on the east bank of the creek just upstream from Blossom Road but currently is a diversion from the main channel downstream from Blossom Road to the eastern part of the southern wetland area north of Browncroft Boulevard. In the vicinity of Blossom Road, the main channel is about 70 ft wide and from 10 to 12 ft deep at bankfull stage, whereas the Millrace is 20 to 25 ft wide and 5 to 6 ft deep. Between Browncroft Boulevard and the Narrows, the main channel dimensions decrease to a bankfull width of 50 to 60 ft and depth of 5 to 8 ft. The extension of the Millrace channel into the southern wetland area widens to about 50 ft but is only about 3 ft deep. North of the Narrows, the depth of Irondequoit Creek generally continues to decrease to 3 or 4 ft.

Low flows usually occur during late summer; whereas peak flows result from snowmelt and rain during late winter and spring, and from summer thunderstorms. Daily mean flow in the creek, based on 16 years of record at the inflow-monitoring site (Blossom Road), exceeded 45 ft^3/s 90 percent of the time, 87 ft^3/s 50 percent of the time, and 251 ft^3/s 10 percent of the time (Hornlein and others, 1997). Annual peak discharges ranged from 658 ft^3/s (November 2, 1994) to 1,710 ft^3/s (April 2, 1993) and usually exceeded 1,000 ft^3/s. Overbank flows occur twice a year on average. Overbank flows causing inundation of the Ellison Park wetland occurred 3 to 4

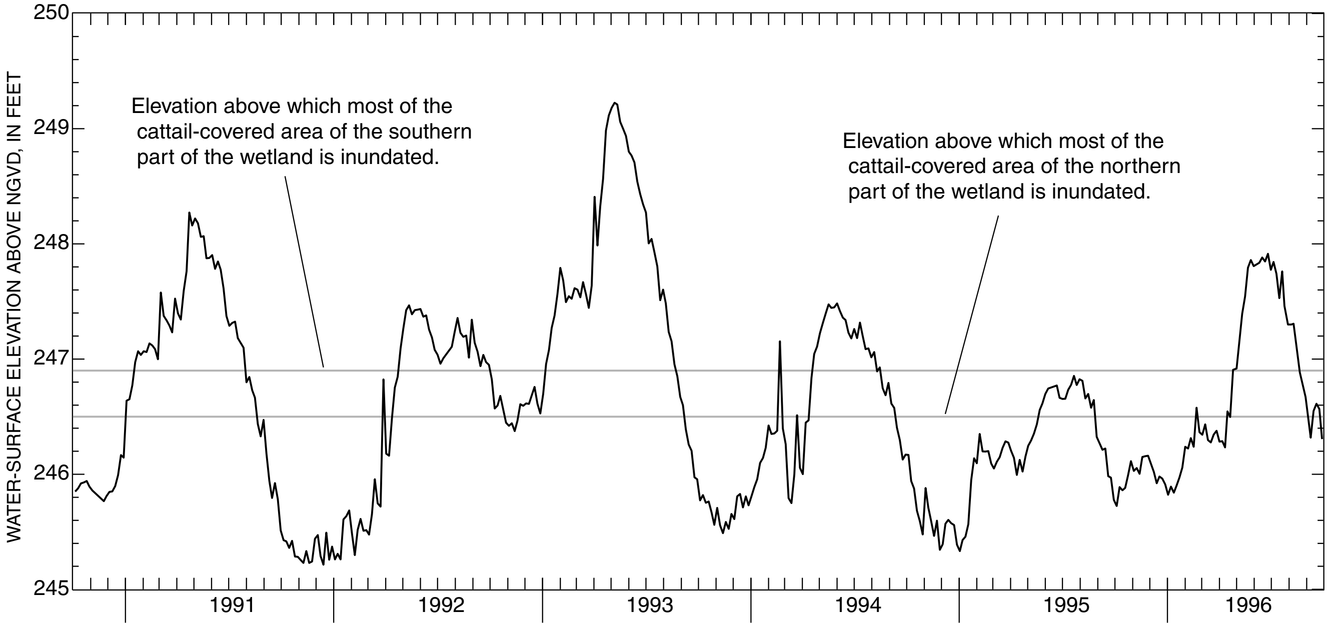

Figure 4. Daily mean water-surface elevation of Ellison Park wetland as measured at Empire Boulevard (wetland outlet), Monroe County, N.Y., 1990-96. (Location is shown in fig. 2.)

times yearly in 1990-92 and 1994, and once in 1993, which was the 16-year period-of-record peak flow; then did not occur at all in 1995. Monthly mean discharges of Irondequoit Creek above Blossom Road and at Empire Boulevard during the study period (fig. 3B) were below average for two extended periods—June 1991 through February 1992 and October 1994 through September 1995. The period-of-record peak discharge occurred during a period of above-average flow, March to April 1993. Monthly discharges also were above average from December 1990 through April 1991, July 1992 through January 1993, and March through April 1994.

The slope of the main channel decreases from about 0.003 upstream from the Blossom Road streamflow-monitoring site (measured from USGS 7.5-minute topographic maps, Rochester East and Fairport, N.Y., quadrangles) to 0.0006 within the wetland from Blossom Road to Empire Boulevard (from survey data). This decrease in channel gradient, in conjunction with the wide wetland flood plain, promotes the sedimentation and filtering functions of the wetland and the attenuation of peak flows. Time-of-travel and flow-dispersion studies conducted in the wetland during 1991 (Coon, 1997) indicate the following:

(1) Medium-to-high flows (600 to 800 ft^3/s) in the main channel are contained by banks that are higher than the cattail-covered areas beyond and move through the wetland with little dispersal into the cattail areas. The high banks are a result of preferential sediment deposition at the point where overbank flow

Table 2. Periods of inundation and average maximum depth of inundation in southern and northern areas of Ellison Park wetland, Monroe County, N.Y., 1991-96

[ft, feet. Locations are shown in fig. 2.]

	Southern wetland area		Northern wetland area	
Water Year[1]	Period of inundation (days)	Average maximum depth (ft)	Period of inundation (days)	Average maximum depth (ft)
1991	194	1.5	234	1.9
1992	155	0.8	194	1.2
1993	230	2.4	289	2.8
1994	113	0.7	157	1.1
1995	1	0.1	100	0.5
1996	121	1.1	159	1.5
Mean	**136**	**1.1**	**189**	**1.5**

[1]Water year is the period from October of one year to September of the following year.

velocities decrease and sediment is trapped by the dense vegetation along the bank tops.

(2) Overbank flows (greater than about 900 ft^3/s) disperse through the cattail-covered areas.

(3) Water that leaves the main channel and flows through the Millrace into the backwater area of the southern part of the wetland becomes detained in that area for 3 to 15 hours or more; the maximum detention time has not been determined. The channel in this part of the wetland is shallower than the main channel and does not have well-defined banks; therefore, high flows are not confined to the channel and easily move into and through the adjacent cattail areas.

(4) Dispersal and detention of flows in both channels is facilitated by backwater from high water levels in Irondequoit Bay and Lake Ontario.

Increasing the detention time and the dispersal of stormflows, or maximizing the conditions that facilitate these results, presumably could result in water-quality improvement. Therefore, modifications were made to increase flow into the Millrace and into the eastern part of the southern wetland area, where detention and dispersal occur naturally. Discharge measurements made during 1991 indicated that the Millrace could convey as much as a quarter of the total flow during low-flow periods but carried a decreasing proportion of the flow as total flow in the creek increased (Coon, 1997). The diversion from the main channel to the Millrace downstream from Blossom Road was modified during the summer of 1994 by lowering and paving the top of the bank above the two diversion culverts (48-in.- and 36-in.-diameter pipes); thereby increasing flows in the Millrace for near-bankfull discharges.

Ground-water movement in the unconfined aquifer of the lower Irondequoit Creek basin moves from the valley walls toward Irondequoit Creek and underflow moves northward (downgradient) toward Irondequoit Bay and Lake Ontario (Yager and others, 1985). High water levels in the creek might cause short-term reversal of groundwater flow by recharging the streambank and flood-plain deposits, but generally the Ellison Park wetland is a ground-water discharge point (Kappel and Young, 1989).

Acknowledgments

Thanks are extended to the employees of Monroe County Environmental Health Laboratory (MCEHL) who assisted in the maintenance and operation of the streamflow- and water-quality-monitoring sites and analyzed water samples. Richard Burton, laboratory administrator, provided guidance and suggestions throughout the data-collection period.

METHODS

The study included (1) collection and chemical analyses of surface-water, sediment, and cattail-tissue samples, (2) a program to assess the accuracy and validity of streamflow and water-quality data provided by the cooperating agency (Monroe County Environmental Health Laboratory), and (3) use of a USGS chemical-load estimation program (Cohn and others, 1989) to compute surface-water constituent loads in the wetland inflow and outflow. Each of these is described below.

Data Collection

The following paragraphs describe (1) field methods for the measurement of surface-water stage, velocity, and temperature, the collection of water and sediment samples, and the survey of the wetland flora and collection of cattail-tissue samples, and (2) laboratory methods used for chemical analyses of water, sediment, and cattail-tissue samples.

Surface Water

Stream discharge and water temperature were measured, and water samples collected, at the inlet (Blossom Road) and outlet (Empire Boulevard) of the Ellison Park wetland. Each monitoring station included an electronic data logger, water-stage and temperature sensors, and an automatic water sampler. The outlet station also had a water-velocity sensor. Sensors made measurements every 15 minutes, and the measured values were stored in the data loggers.

Stream Discharge

The upstream monitoring site was 4,000 ft (channel distance) above Blossom Road (fig. 2). Discharge was computed from a stage-to-discharge relation by standard USGS procedures for gaging streamflow (Carter and Davidian, 1968; Rantz and others, 1982), measuring stage and discharge (Buchanan and Somers, 1968 and 1969, respectively), and analyzing stage-to-discharge relations (Kennedy, 1984). Periodic field measurements of discharge were made to identify any deviations from the established stage-to-discharge relation. The downstream site (fig. 2) was on the bank of the short channel that connects the wetland with Irondequoit Bay. Computation of discharge for this site was complicated by backwater conditions caused by fluctuating water levels in Irondequoit Bay and Lake Ontario. Therefore, water velocity was measured with an acoustic velocity meter (AVM), and the recorded velocity was correlated with the mean velocity in the channel as calculated from discharge measurements made from the Empire Boulevard bridge. Discharge was computed from this relation and from the relation between stage and flow area. Standard USGS procedures for gaging streamflow with an AVM and analyzing stage-and-velocity-to-discharge relations (Laenen, 1985) were followed.

Temperature

Water temperatures were measured at each site intermittently during 1990-94 and continuously (every 15 minutes) from December 1994 through September 1996. The continuous measurements were made by temperature probes connected to the data loggers. Temperatures were measured manually during site inspections to verify the recorded temperatures and to permit correction, if necessary.

Water Quality

Automated samplers, which extracted water samples from the channel (near the centroid of flow) hourly and stored them in refrigerated bottles, were maintained by the Monroe County Environmental Health Laboratory (MCEHL). Samples were composited on the basis of discharge. If base-flow conditions prevailed during the entire sampling cycle (3 to 4 days), all samples were composited, and a single analysis was performed. During storms, samples were composited to represent conditions during the rising and falling phases of the storm hydrograph, and one or two near-peak samples were analyzed separately. Laboratory analyses were done by MCEHL, which participated in the USGS quality-assurance program for cooperating analytical laboratories. Analytical procedures are described in American Public Health Association and others (1995). Samples were analyzed for phosphorus (total and orthophosphate), nitrogen (total, ammonia-plus-organic, nitrate-plus-nitrite, and ammonia), chloride, sulfate, and suspended solids (total and volatile). Samples collected during stormflows, and periodically during low-flow periods, were analyzed additionally for total organic carbon, biochemical and chemical oxygen demand, alkalinity, specific conductance, and trace metals (zinc, lead, copper, and cadmium). (See Appendix 1.)

Sediment Quality

The chemical quality of sediment in the Ellison Park wetland was assessed through analyses of three fine-grained samples (plus one duplicate sample) collected in October 1994 from two sites in the backwater areas of the southern part of the wetland and one site in the northern part (fig. 2). These sites were within open-water long-term depositional areas and distant from channels that might carry high-velocity, erosive flows. Samples were carefully scooped under shallow water from the top 2 to 3 in. of sediment, packed in ice and shipped to the USGS National Water Quality Laboratory in Arvada, Colo., and analyzed by methods described by Shelton and Capel (1994) and Radtke (1997). The sediment fraction with particle sizes less than 2 mm (sand size and smaller), which constituted 100 percent of each sample, was analyzed for (1) polycyclic aromatic hydrocarbons by gas chromatography with a mass-spectrometric detector, and (2) organochlorine compounds by gas chromatography with electron-capture detectors as described in Wershaw and others (1987). The clay fraction (particle size less than 63 micrometers) was analyzed for major and trace elements following procedures listed in Timme (1995) and described in Fishman and Friedman (1989).

Flora Survey, Plant-Tissue Analyses, and Biomass Measurements

Wetland-flora studies conducted during 1991 and 1996 included (1) identification of individual species, (2) mapping of plant communities, (3) measurements of cattail density and above- and below-ground biomass, and (4) chemical analyses of above- and below-ground tissues of cattails. During the 1991 study, flora identification and mapping, and measurements of cattail density, were conducted on June 5 and July 5; cattail tissues for biomass calculations and chemical analyses were collected between August 15 and September 10. All components of the 1996 study were conducted between July 25 and August 25.

Two permanent transects (fig. 2) were established—one across the southern part of the wetland, and one across the northern part—along which 3.3-ft^2 (1-m^2) plots were established every 33 ft (10 m) and marked with 1.5-in. PVC pipe. The height of cattail shoots, the cattail density, the percentage of plot surface covered by cattails, and the water depth were measured at each of 31 plots across the southern transect and 26 plots across the northern transect. Only 20 plots were sampled along the northern transect in 1996. Samples of above-ground tissues were harvested from a 3.3-ft^2 (1-m^2) area adjacent to each permanent plot, and samples of below-ground tissues were collected within these areas from a 1.6-ft^2 (0.5-m^2) area to a depth of about 12 in. (30 cm). Each sample was washed free of sediment and debris, then air-dried and weighed, and the biomass per unit area was computed. Unusually high water levels and hazardous walking conditions in the field necessitated modification of the above protocols for biomass collection across the northern transect during the 1991 study. At that time and location, a representative sample of above-ground biomass (2 or 3 cattail shoots) was collected adjacent to each permanent plot, and the rhizomes and roots of these harvested cattails were used for the below-ground biomass sample. After drying and weighing, the above-ground biomass per unit area was computed as the product of the average weight per shoot and the number of shoots in the adjacent permanent plot. The below-ground biomass per unit area was calculated similarly from the average rhizome-plus-root weight per shoot. This method of calculation was reported to give reliable results for a *Carex sp.* (sedge) wetland in New York (Bernard and Gorham, 1978).

Prior to drying, a small subsample of each above- and below-ground sample was processed for chemical analysis. These subsamples were washed in a solution of detergent and 0.4 percent hydrochloric acid for 30 seconds, rinsed twice in distilled water, oven-dried at 70˚C, and ground in a Wiley mill with a 40-mesh screen. Samples were composited on the basis of soil wetness at the permanent plots, and at least three composite samples from each of three “wetness” environments (dry, shallow-water, and deep-water areas) along each transect were analyzed for metals (copper, nickel, chromium, cobalt, molybdenum, zinc, aluminum, iron, boron, manganese, and lead) and nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sodium) at the Soil and Plant Testing Laboratory in the Soils, Crops and Atmospheric Sciences Department at Cornell University, Ithaca, N.Y.

Quality-Assurance and Quality-Control Program

Much of the data presented in this report were collected and analyzed by the MCEHL, whose responsibilities included (1) measurement of stream discharge and collection of water samples at the streamflow- and water-quality-monitoring stations, and (2) analysis of the water samples. A quality-assurance and quality-control (QA/QC) program was established to ensure that the data collected by MCEHL met USGS standards. QA/QC for discharge measurements included (1) periodic instruction of MCEHL personnel in USGS measurement techniques; (2) monthly review of MCEHL stream-discharge measurements; and (3) semiannual discharge measurements and inspections of the monitoring sites by USGS personnel. The semiannual discharge measurements checked the correctness of MCEHL measurement techniques and the validity of the stage-to-discharge relation that had been developed by the USGS for a particular year.

QA/QC for the water-sampling and analysis program included (1) a comparison of constituent concentrations measured in depth-integrated cross-sectional samples (manual samples) with those measured concurrently in samples collected with automatic samplers; (2) MCEHL participation in the semiannual USGS Standard Reference Water Sample program for cooperating analytical laboratories; and (3) comparison of results from analyses of split samples by MCEHL and the USGS National Water Quality Laboratory (NWQL) in Denver, Colo.

Automatic water samplers provided nearly continuous water-chemistry data at the wetland inlet and outlet. The reliability of these data depends on how well constituent concentrations in each sample represent the mean concentrations of those constituents across the entire flow area. This representation was evaluated through a statistical test to compare manually collected sample data with the automatically collected sample data to determine whether the mean of the differences between paired data—(manual and automatic)—was significantly different from zero (paired t-test). A significant difference would indicate a systematic bias in the data collected by the automatic sampler. Results indicated that (1) the concentrations for total suspended solids (TSS) and total phosphorus (TP) in the automatically collected samples at Blossom Road were significantly greater (p-value = 0.0001) than those in manually collected samples, and (2) the ammonia-nitrogen (NH_3) concentrations in automatically collected samples at Empire Boulevard were significantly less (p-value = 0.0017) than those in manually collected samples. No other significant differences ($\alpha = 0.05$) between concentrations obtained with the two methods were detected for any other constituent at Blossom Road or Empire Boulevard.

The higher concentrations of TSS and TP in automatically collected samples than in the manual samples from the Blossom Road site could have reflected the location and position of (1) the gage, which was at a point where the channel slope and, hence, flow velocity were decreasing; (2) the water intake, which was in the channel thalweg such that it was close to the bottom during medium and high-stage flows (repositioning of the intake in the water column would have jeopardized collection of low-stage samples); and (3) the manual-sample-collection site for high flows, which was about 3,500 feet downstream from the automatic-sample-collection site—a distance that, given the decrease in gradient, would allow removal of suspended sediment and adsorbed chemicals through settling or overbank deposition. These discrepancies would cause the computed loads and removal efficiencies of these constituents calculated for the automatically collected samples to be larger than those calculated for the manually collected samples. The suggested causes for these discrepancies are plausible, and except in extreme floods, the automatically collected samples might reflect the concentrations of these constituents more accurately than the manually collected samples.

The higher ammonia concentrations in the depth-integrated manually collected samples than in the automatically collected samples from the Empire Boulevard site could have resulted from the inclusion of water with high ammonia concentrations near the bottom of the channel (generated by ammonification of decomposing organic matter in the bed sediments) in the manually collected samples. A similar vertical difference in ammonia concentration was reported in a wastewater-treatment pond by Davido and Conway (1989). The NH_3 output load computed from the automatically collected samples is significantly larger than the computed input load; the negative removal efficiency for this constituent indicates that the wetland is a source of NH_3. The NH_3 concentrations in the manually collected samples suggest that NH_3 output loads should be larger than those computed from the concentrations in the automatically collected samples. The computed loads could have been adjusted to account for this discrepancy, but was not done because, even though the magnitude of the difference between input and output loads would increase, it would not affect the conclusion that the wetland is a source of NH_3.

MCEHL participated in the semiannual USGS Standard Reference Sample (SRS) program, wherein reference samples were submitted to participating laboratories by USGS for analysis for trace constituents, major constituents, and nutrients. The analytical results from all participating laboratories were transmitted to USGS, and a “most probable value” (MPV) was statistically calculated for each constituent. MCEHL results were consistently rated “satisfactory” to “good” (within 1.50 to 0.51 standard deviations of the MPV) for trace elements; and “good” to “excellent” (within 1.00 to 0.00 standard deviations of the MPV) for major ions, nutrients, and mercury, and for analyses of low-ionic strength samples, which simulated precipitation.

An additional check on the analytical accuracy of MCEHL included the analyses of samples by both MCEHL and NWQL and comparison of the results. Samples collected on September 18, 1991, and October 20, 1993, were divided into eight equal parts (split samples), and four subsamples were analyzed by each laboratory for dissolved or total ammonia-plus-organic nitrogen, nitrate-plus-nitrite, and total phosphorus. The results of paired t-tests, conducted on the analytical data from samples collected at all USGS stations in the Monroe County monitoring network to identify statistically significant differences between the two laboratories for specific constituents, are given in Sherwood (1997). Of the samples collected on September 18, 1991, only nitrate-plus-nitrite concentrations differed significantly between the two laboratories, and of the samples collected on October 20, 1993, only total ammonia-plus-organic nitrogen and total phosphorus concentrations showed significant differences. P-values associated with these tests of significance were not presented in Sherwood

(1997). No conclusions from these comparisons have been drawn because only two split samples were analyzed during the 6-year study period, and the results were inconsistent.

Computation of Constituent Loads and Removal Efficiency

Monthly and annual constituent loads at the two water-quality-monitoring stations were calculated with the USGS program, Estimator (G. Baier, T. Cohn, and E. Gilroy, U.S. Geological Survey, written commun., 1995), which is based on a log-linear regression model that relates nutrient concentrations to surrogate variables of discharge, time (year and decimal-date), and season (Cohn and others, 1989; 1992). Nine variables were considered for each model: a constant; a quadratic fit to the logarithm of discharge (log flow and square of log flow); a quadratic fit to time (decimal time and square of decimal time); and two sinusoidal (first- and second-order Fourier) functions to account for the effects of annual seasonality (Cohn and others, 1992). Data from the entire period of study (October 1990 through September 1996) were used to develop the load model for each constituent at each sampling site. For a given constituent, if the coefficient for a variable was found to be significantly different from zero (p-value less than 0.05) for either the input or output load models, it was included in both models to maintain comparability of the results from both models (table 3). The constituent loads were computed from continuous water-quality (composited hourly samples) and flow data—typically, at least two samples were provided per week, but more were obtained if a storm occurred. Typically, stormwater samples were composited in a similar manner at both sites; one sample each for the rising and falling stages and one or two samples during the peak. The discharge associated with a given water sample was computed as the mean of the 15-minute discharges indicated by the stage-to-discharge relation at the Blossom Road monitoring station and the stage-and-velocity-to-discharge relation at the Empire Boulevard site for the period covered by the hourly water samples that were composited into the analyzed sample. Daily loads were computed by the load model from the daily mean discharges recorded at each site. From these data, total monthly, annual, and period-of-record loads were computed for nitrogen and phosphorus compounds, chloride, sulfate, and suspended solids. (See appendix 2.) The precision of the estimated loads can be described in terms of a confidence interval, which is based on the estimated mean and the standard error of

Table 3. Explanatory variables used in regression models developed to compute constituent loads for Irondequoit Creek above Blossom Road (wetland inlet) and at Empire Boulevard (wetland outlet), Monroe County, N.Y., 1990-96

[Coefficient for a specified variable was found to be significantly different from zero (p-value less than 0.05) for one or both of the input- and output-load models. If, for a given constituent, a variable was significant for only one of the load models, it was nevertheless used in both models to maintain comparability of the models' results.]

	Explanatory Variable								
						Seasonality function (T, time, in years)			
Constituent	Constant	Log flow	Log flow squared	Decimal time	Decimal time squared	Sin(2πT)	Cos(2πT)	Sin(4πT)	Cos(4πT)
Total nitrogen, as N[1]									
Ammonia-plus-organic nitrogen, as N	X	X		X		X	X	X	X
Ammonia nitrogen, as N	X	X		X		X	X	X	X
Organic nitrogen, as N[1]									
Nitrate plus nitrite, as N	X	X	X	X	X	X	X	X	X
Total phosphorus, as P	X	X	X	X	X	X	X		
Orthophosphate, as P	X	X	X	X	X	X	X	X	X
Total suspended solids	X	X		X	X	X	X		
Volatile suspended solids	X	X		X	X	X	X		
Nonvolatile suspended solids[1]									
Chloride	X	X	X	X		X	X	X	X
Sulfate	X	X	X	X	X				

[1]Loads for this constituent were not computed from a regression model.

prediction calculated by the equation. At a 95-percent confidence interval ($\alpha = 0.05$), the confidence limits are the estimated load ±1.96 times the standard error of prediction (appendix 2).

Potential problems in calculating loads based on regression models include multiply censored water-quality data, logarithm retransformation bias, and lack of fit between predicted and observed values. The Estimator program handles multiply censored data through an adjusted maximum-likelihood estimation procedure (Cohn, 1988; 1995). Loads computed from the logarithm of constituent concentrations can show bias when the loads are transformed back into non-logarithmic units. This bias, which tends to underestimate the loads, is corrected in the Estimator program by a minimum-variance unbiased estimator (Cohn, 1988; 1995; Cohn and others, 1992). Misspecification of a regression model, which is likely to result when linear regression is used to describe the relation among time-series data, can be indicated by serial correlation (non-independence) of the residuals. In the Estimator program, serial correlation of residuals and the effect of seasonality is minimized by inclusion of sinusoidal functions of time ($\sin 2\pi T$, $\cos 2\pi T$, $\sin 4\pi T$, $\cos 4\pi T$, where T is time, in years) (Cohn and others, 1992). Lack of fit of a regression model can be indicated by low coefficients of determination and nonnormal distribution and serial correlation of the residuals. Cohn and others (1992) point out that (1) load estimators based on log-linear models, in general, appear to be relatively insensitive to violations of the assumptions of linear regression, that is, nonnormality and independence of the residuals; (2) a minimum variance unbiased estimator, in particular, which is based on the assumptions of a log-linear model, provides good estimates of loads despite these violations; and (3) the variances of annual or monthly load estimates based on infrequent sampling appear to be well described by log-linear model theory. Model validity or goodness of fit was evaluated by regression diagnostic statistics—standard error of prediction (appendix 2), coefficient of determination, and probability plot-correlation coefficient as a measure of the normality of the residuals—with consideration given to the number of total and censored observations included in the development of each model (table 4).

The effectiveness of the wetland in decreasing chemical loads can be evaluated in terms of removal efficiency—the percentage of an input load that is retained in, or exported from, the wetland. Removal efficiency for a given constituent was computed as the ratio of the difference between input and output load to the input load, expressed as a percentage. Monthly and annual removal efficiencies were computed for each constituent. A positive value indicated a net retention of a constituent in the wetland, and a negative value indicated the generation of a constituent within the wetland (or, possibly, its adjacent drainage area) and a net export of a constituent.

Statistical analyses were conducted through SAS (SAS Institute, Inc., 1989; 1990). Most of the monthly load and removal-efficiency data did not show normal distributions; therefore, nonparametric tests were used to analyze the data. Statistically significant differences between the monthly input and output loads were identified by the Wilcoxon signed-ranks test on the ranked differences between the paired (input and output) loads (table 5). This test indicated whether the mean of the differences between input and output loads was significantly different from zero.

As a measure of the strength of association between variables, Spearman correlation coefficients were computed between monthly efficiencies and loads, and season and monthly mean discharges and water-surface elevations (table 6). A numeric dummy variable was used for "season" as follows: (1) October through November, when plant senescence occurs, and water levels in the wetland drop in response to the lowering of Lake Ontario in anticipation of storage requirements during spring runoff; (2) December through February, when stream discharges and water levels are generally low; (3) March and April, when stream discharges are usually greatest, and water levels begin to rise in the lake and the wetland; and (4) May through September, when water levels are high, and stream discharges can vary substantially. The season variable was used to assess the wetland's water-quality-improvement function that could be attributed to nutrient uptake and release by wetland vegetation and microbes. The combined variables—season and monthly mean discharge and water-surface elevation—were used as surrogate variables to assess the effect of the duration and depth of wetland inundation on wetland processes. Frequency of inundation, which could be quantified by the number of overbank flows that occurred during a given month, was not included in this analysis because (1) overbank flows occurred infrequently (from zero to four times a year), and (2) the regulated water level in

Table 4. Regression statistics for models used to compute constituent loads for Irondequoit Creek above Blossom Road (wetland inlet) and at Empire Boulevard (wetland outlet), Monroe County, N.Y., 1990-96

[Dash indicates no data. Locations are shown in fig. 2.]

Constituent	Number of observations	Number of censored observations	Coefficient of determination[1]	Residuals probability plot correlation coefficient[2]	Standard error of regression[3]	Serial correlation of residuals[4]
Blossom Road						
Total nitrogen, as N [5]	--	--	--	--	--	--
Ammonia-plus-organic nitrogen, as N	1016	1	0.850	0.988	0.379	0.375
Ammonia nitrogen, as N	985	440	.571	.955	.865	.449
Organic nitrogen, as N [5]	--	--	--	--	--	--
Nitrate plus nitrite, as N	1007	0	.938	.948	.216	.633
Total phosphorus, as P	1021	0	.745	.988	.665	.299
Orthophosphate, as P	1022	3	.749	.989	.483	.501
Total suspended solids	313	4	.671	.981	.806	.137
Volatile suspended solids	309	21	.648	.986	.725	.228
Nonvolatile suspended solids[5]	--	--	--	--	--	--
Chloride	1028	0	.931	.973	.192	.582
Sulfate	1015	1	.847	.933	.175	.159
Empire Boulevard						
Total nitrogen, as N [5]	--	--	--	--	--	--
Ammonia-plus-organic nitrogen, as N	875	0	.883	.993	.298	.510
Ammonia nitrogen, as N	857	100	.502	.986	.715	.580
Organic nitrogen, as N [5]	--	--	--	--	--	--
Nitrate plus nitrite, as N	875	0	.957	.992	.188	.625
Total phosphorus, as P	886	0	.837	.980	.439	.421
Orthophosphate, as P	887	1	.866	.981	.321	.536
Total suspended solids	233	3	.745	.984	.623	.228
Volatile suspended solids	232	28	.762	.987	.493	.293
Nonvolatile suspended solids[5]	--	--	--	--	--	--
Chloride	890	0	.933	.977	.196	.599
Sulfate	874	0	.877	.978	.160	.274

[1]Coefficient of determination (R^2): the proportion of the total variance in computed loads that is accounted for by regression model.

[2]Probability-plot correlation coefficient: a measure of the likelihood that the residuals are normally distributed. A value greater than 0.97 implies that the data are from a population with a normal distribution.

[3]Standard error of regression: a measure of the dispersion of the data around the regression line.

[4]Serial correlation of residuals: a measure of the dependence or correlation in time sequence between residuals. Serial correlation coefficient ranges from zero (no serial correlation) to 1.00 (strong serial correlation).

[5]Loads for this constituent were not computed from a regression model.

this system would have obscured any short-term effects from overbank flows. Correlation coefficients between monthly removal efficiencies, their respective input and output loads, and monthly mean discharges were computed, but some amount of artificial or spurious correlation between these variables was expected because the loads were based on discharges, and removal efficiencies were based on loads.

Table 5. Statistics (p values) related to tests of significant difference between monthly constituent loads computed for Irondequoit Creek above Blossom Road (wetland inlet) and at Empire Boulevard (wetland outlet), Monroe County, N.Y., 1990-96

[Statistics are based on differences between monthly paired data; that is, input (Blossom Road) load minus output (Empire Boulevard) load. Dash indicates test is inappropriate for nonnormally distributed data, or that no conclusion can be stated.]

Constituent	Shapiro-Wilk test of normality (p-value)	Tests of significance (p-value)		Significant difference	Location of greater load
		Paired-difference t-test	Wilcoxon Signed ranks test		
Total nitrogen, as N	0.0001	--	0.0028	yes	inflow
Ammonia-plus-organic nitrogen, as N	.0001	--	.1005	no	--
Ammonia nitrogen, as N	.1358	.0001	.0001	yes	outflow
Organic nitrogen, as N	.0001	--	.0006	yes	inflow
Nitrate plus nitrite, as N	.0030	--	.0163	yes	inflow
Total phosphorus, as P	.0001	--	.0001	yes	inflow
Orthophosphate, as P	.0001	--	.0001	yes	outflow
Total suspended solids	.0001	--	.0001	yes	inflow
Volatile suspended solids	.0001	--	.0001	yes	inflow
Nonvolatile suspended solids	.0001	--	.0001	yes	inflow
Chloride	.0019	--	.0001	yes	outflow
Sulfate	.0692	.0024	.0007	yes	inflow

EFFECTS OF WETLAND ON WATER QUALITY

Chemical concentrations in a stream are affected by the volume of flow at the time the sample is collected. Concentrations (mass per volume) of constituents in the dissolved phase generally decrease through dilution as flow increases, whereas the loads (total mass) of these constituents generally increase during high flows. Dissolved constituents in the Ellison Park wetland, such as ammonia nitrogen (NH_3), generally followed this pattern. The range of ammonia-nitrogen concentrations, and the maximum concentrations (fig. 5A), were greater during low flows (0.01 to 0.66 mg/L) than during high flows (0.01 to 0.09 mg/L), and, similarly, the maximum concentrations of orthophosphate were greater during low flows (0.12 mg/L) than during high flows (0.03 mg/L). Concentrations of constituents in the particulate phase generally increase with increasing flow, as do their corresponding loads, when the sediment and organic matter to which these constituents adsorb is washed into the stream by overland flow or resuspended from the channel bottom by turbulence. The concentration-to-flow relations for constituents in the Ellison Park wetland that are associated with particulate matter, such as total phosphorus (TP; fig. 5B), show discrepancies, however. The concentrations of TP in most low-flow samples clustered between 0 and 0.4 mg/L but in some samples were as high as 1.5 mg/L. Generally, TP concentrations increased with increasing discharge to the 700- to 900-ft^3/s flow range, at least at the Blossom Road (inflow) site, then decreased as discharge increased further. These apparent discrepancies might be explained by (1) the time of sample collection in relation to the peak discharge for a given storm, and (2) the duration of high flows prior to collection of a sample. Despite these discrepancies in the concentration-to-flow relation for particulate constituents, the loads of these chemicals were directly related to discharge (table 6).

The effectiveness of any wetland in decreasing chemical loads depends on the balance between chemical-removal and chemical-generation processes because this balance determines whether a wetland acts as a sink or a source of a given constituent at a given time. In general, the Ellison Park wetland had little effect on the surface-water concentrations and loads of dissolved constituents, except ammonia nitrogen and orthophosphate, which were generated by

Table 6. Spearman correlation coefficients between constituent loads and removal efficiencies and four variables, Ellison Park wetland, Monroe County, N.Y., 1990-96

Constituent	Variables			
	Monthly mean discharge[1]	Season[2]	Monthly mean water-surface elevation	Removal efficiency
LOADS				
Total nitrogen, input	0.98	-0.20	0.25	0.30
Total nitrogen, output	.98	-.27	.16	.18
Ammonia-plus-organic nitrogen, input	.96	-.13	.32	.67
Ammonia-plus-organic nitrogen, output	.96	-.17	.27	.57
Ammonia nitrogen, input	.90	-.18	.25	.71
Ammonia nitrogen, output	.88	-.17	.17	.13
Organic nitrogen, input	.96	-.13	.32	.59
Organic nitrogen, output	.95	-.17	.27	.46
Nitrate-plus-nitrite nitrogen, input	.96	-.24	.19	-.20
Nitrate-plus-nitrite nitrogen, output	.96	-.33	.07	-.34
Total phosphorus, input	.87	.06	.41	.55
Total phosphorus, output	.79	.12	.47	.30
Orthophosphate, input	.79	-.06	.27	.25
Orthophosphate, output	.78	.00	.33	.04
Total suspended solids, input	.93	.00	.38	.35
Total suspended solids, output	.89	-.02	.36	.12
Volatile suspended solids, input	.94	-.05	.34	.41
Volatile suspended solids, output	.92	-.17	.24	.12
Nonvolatile suspended solids, input	.93	.01	.38	.33
Nonvolatile suspended solids, output	.88	.00	.38	.10
Chloride, input	.91	-.34	.06	-.04
Chloride, output	.92	-.36	.01	-.13
Sulfate, input	.99	-.19	.25	-.05
Sulfate, output	.99	-.22	.19	-.20
REMOVAL EFFICIENCIES				
Total nitrogen	.31	.47	.59	1.00
Ammonia-plus-organic nitrogen	.64	.11	.44	1.00
Ammonia nitrogen	.45	-.10	.19	1.00
Organic nitrogen	.59	.13	.42	1.00
Nitrate-plus-nitrite nitrogen	-.18	.67	.59	1.00
Total phosphorus	.54	-.11	.05	1.00
Orthophosphate	.15	-.18	-.08	1.00
Total suspended solids	.30	.02	.07	1.00
Volatile suspended solids	.32	.31	.30	1.00
Nonvolatile suspended solids	.29	-.02	.03	1.00
Chloride	.14	.19	.32	1.00
Sulfate	-.06	.24	.23	1.00

[1] Measured at Irondequoit above Blossom Road (wetland inlet)).
[2] Season was defined by a numeric value: 1 = October-November,; 2 = December-February, 3 = March-April, and 4 = May-September.

wetland processes and exported from the wetland in quantities larger than those which entered the wetland. Conversely, the wetland facilitated a substantial decrease in particulate constituents, such as suspended solids and total phosphorus, through sedimentation and vegetative filtration.

Constituent Loads and Removal Efficiencies

Two factors that could have affected the calculated constituent loads and removal efficiencies for the Ellison Park wetland were chemical inputs from atmospheric deposition and ground water. Atmospheric deposition was collected monthly in the northern part of the wetland, about 1,700 ft south of Empire Boulevard (fig. 2). Precipitation-quality data are given in Coon (1997) or in the annual USGS water-resources-data reports for western New York State, for example, Hornlein and others (1997). Kappel and others (1986) noted that atmospheric deposition in the Irondequoit Creek basin is a significant source of chemicals and, except for chloride, can make substantial contributions to chemical loads in the creek. Atmospheric-deposition sampling has inherent uncertainties that are related to

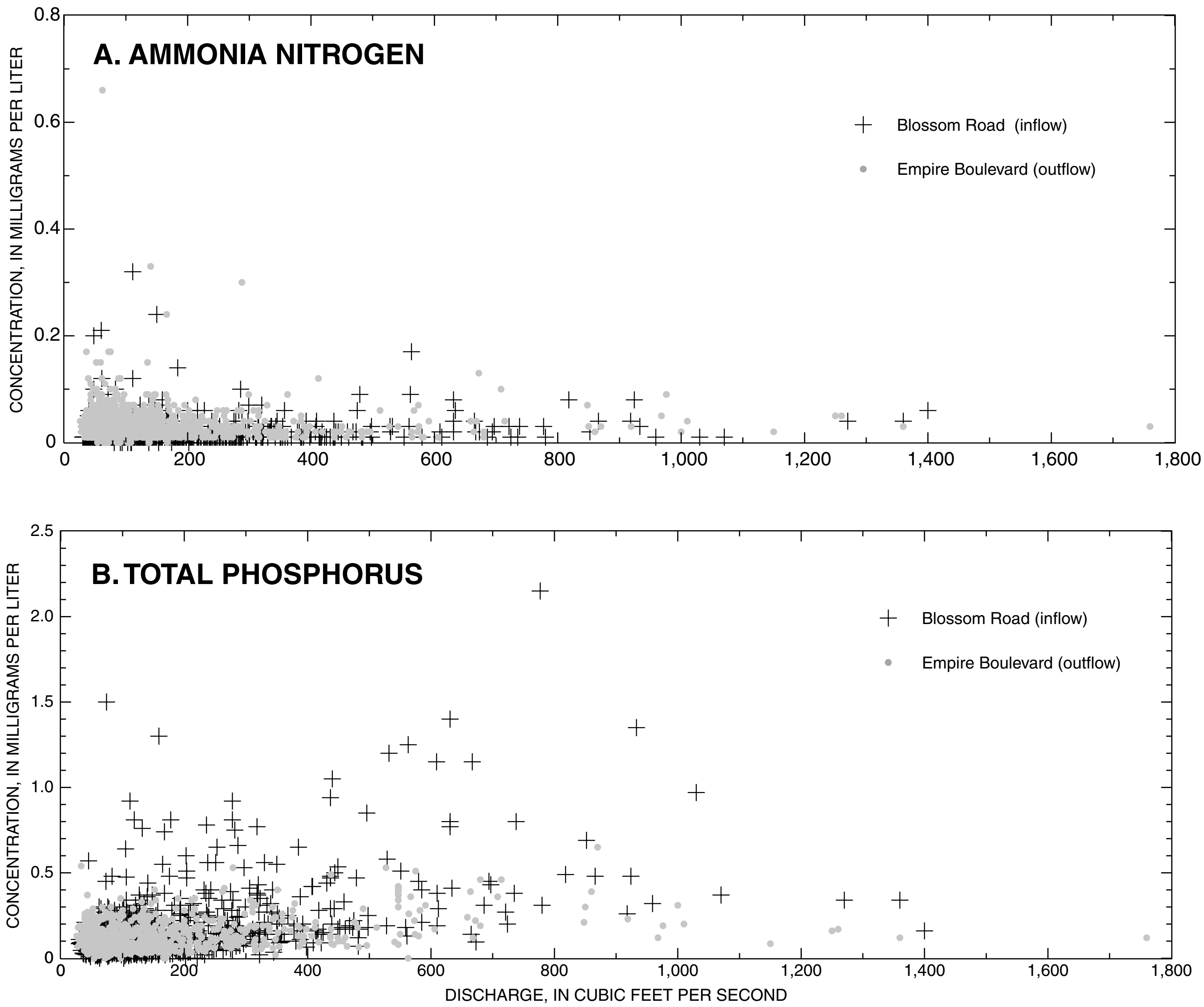

Figure 5. Concentration of (A) a dissolved constituent (ammonia nitrogen), and (B) a particulate constituent (total phosphorus) as a function of discharge in Irondequoit Creek above Blossom Road and at Empire Boulevard, Monroe County, N.Y., 1990-96

possible contamination by wildlife (primarily birds), areal variability in precipitation and dryfall, and a lack of information on the interactions and fate of chemicals after deposition; therefore, Kappel and others (1986) cautioned against using chemical contributions from atmospheric sources to compute seasonal rates of deposition, accumulation, or washoff to streams. Furthermore, atmospheric deposition that falls directly on freshwater marshes dominated by surface-water inflow is a relatively small source of nutrients (Mitsch and Gosselink, 1986). The Ellison Park wetland is surface-water dominated, and the difference in drainage area between the inflow-sampling site above Blossom Road (142 mi^2) and the outflow-sampling site at Empire Boulevard (151 mi^2) is only 6 percent; therefore, chemical inputs from atmospheric deposition were considered too small to affect the results of this study.

Ground-water levels and chemical quality in Ellison Park were measured at nine observation wells in the vicinity of Browncroft Boulevard and Blossom Road (fig. 2) (not in the cattail-covered area of the wetland). Ground-water levels and ground-water-quality data are given in Coon (1997) or in the annual USGS water-resources-data reports for western New York State, for example, Hornlein and others (1997). The Ellison Park wetland is a regional and local ground-water-discharge area (Yager and others, 1985), but no studies to date have been conducted to map ground-water movement in the wetland, measure ground-water-discharge rates, define the interactions between ground water, surface water, and atmospheric deposition, or to compute chemical loads that enter the wetland from ground water. Ground-water contributions to nutrient loads in freshwater wetlands dominated by surface-water flow are reported to be relatively small (Mitsch and Gosselink, 1986); therefore, surface-water output loads from the Ellison Park wetland were not adjusted for inputs from this source.

Monthly and annual surface-water loads of selected constituents at the Ellison Park wetland inflow and outflow monitoring sites (Irondequoit Creek above Blossom Road and at Empire Boulevard, respectively) are presented in appendix 2; the monthly and annual removal efficiencies for each constituent are given in appendix 3. The average annual input and output loads, and the annual and period-of-study removal efficiencies for each of these constituents are summarized in table 7. The following sections describe the effect of the wetland on loads of nitrogen, phosphorus, suspended solids, chloride, and sulfate, and the wetland's removal efficiency for each. Note that:

1. The method used to compute loads is an estimation technique, where results have been shown to compare reasonably well with observed loads (Cohn and others, 1992).

2. Loads and removal efficiencies are based on annual and period-of-study results, and tests of significance are based on the differences between the monthly input and output loads.

3. Removal efficiencies are computed in relation to the input loads; therefore, large absolute values must be analyzed in relation to the constituent mass that is entering the wetland. Large monthly fluctuations in removal efficiencies, and large negative values during low-flow periods, which suggest a net exportation of a constituent, can be misleading. The monthly removal efficiencies were calculated to indicate seasonal trends (if present) and long-term trends in the capability of the wetland to improve water quality.

Nitrogen

The mechanisms by which nitrogen can enter a wetland include surface-water or ground-water inflow, atmospheric deposition, and nitrogen fixation—the conversion of nitrogen gas in the atmosphere to ammonia (Kadlec and Knight, 1996). Nitrogen can be stored in live or standing-dead plants, detritus, microbes, wildlife, soils, and in the water column. The amount of nitrogen storage in vegetation changes with plant species, plant part, above- or below-ground tissue, and season (Kadlec and Knight, 1996). Ammonia can be removed from solution through cation-exchange adsorption reactions with detritus and inorganic sediments (Kadlec and Knight, 1996). Burial of organic matter results in long-term storage of nitrogen. Nitrogen can be transformed within a wetland by the processes of (1) ammonification, or mineralization of organic nitrogen to ammonia —the initial step in the microbial breakdown of organic tissues containing amino acids; (2) nitrification—the conversion of ammonia to nitrate under aerobic conditions; (3) denitrification—the reduction of nitrate or nitrite to nitrogen gas under anoxic conditions; and (4) nitrogen assimilation—the conversion of inorganic nitrogen forms to organic compounds for cell and tissue growth (Kadlec and Knight, 1996). Most of

Table 7. Concentrations and average annual input and output loads, and removal efficiency, for selected constituents, Ellison Park wetland, Monroe County, N.Y.,1990-96

[Inflow and outflow locations are shown in fig. 2. Dash indicates concentration not measured.]

A. Inflow and outflow concentrations (in milligrams per liter) and average annual load (in tons)

Constituent	Inflow concentration		Outflow concentration		Average annual load	
	Interquartile range	Median	Interquartile range	Median	Input (Blossom Rd.)	Output (Empire Blvd.)
Total nitrogen	--	--	--	--	275	263
Ammonia-plus-organic nitrogen	0.99 - 0.58	0.77	0.98 - 0.61	0.78	126	118
Ammonia nitrogen	0.02 - 0.01	.01	0.05 - 0.02	.03	2.59	4.76
Organic nitrogen	--	--	--	--	124	114
Nitrate plus nitrite	1.2 - 0.79	.96	1.2 - 0.73	.885	149	145
Total phosphorus	0.17 - 0.055	.11	0.16 - 0.06	.10	26.2	19.0
Orthophosphate	0.016 - 0.007	.011	0.023 - 0.01	.016	1.69	2.33
Total suspended solids	244 - 95	139	152 - 73	102	28,500	15,200
Volatile suspended solids	30.5 - 15	21	21 - 12	16	3,540	2,080
Nonvolatile suspended solids	--	--	--	--	24,900	13,100
Chloride	140 - 95	110	140 - 100	120	16,800	17,500
Sulfate	180 - 110	140	170 - 110	140	16,000	15,700

B. Removal efficiency, as percentage of input load, by water year[1]

Constituent	1991	1992	1993	1994	1995	1996	Study period
Total nitrogen	9.6	-1.8	4.6	0.3	2.7	7.6	4.3
Ammonia-plus-organic nitrogen	13.5	1.2	8.1	0	-3.2	8.7	6.1
Ammonia nitrogen	15.3	-42.2	-61.8	-137	-262	-315	- 84.0
Organic nitrogen	13.4	2.2	9.5	2.3	1.5	13.4	8.0
Nitrate plus nitrite	5.9	-5.0	1.3	.1	6.4	6.8	2.7
Total phosphorus	14.5	17.1	33.0	26.0	21.1	49.0	27.6
Orthophosphate	-34.1	-67.1	-45.5	-46.0	-28.8	-10.5	- 38.1
Total suspended solids	31.9	40.4	51.3	51.1	49.4	58.6	46.7
Volatile suspended solids	28.1	34.6	43.5	43.8	42.1	55.4	41.0
Nonvolatile suspended solids	32.4	41.2	52.4	52.2	50.7	59.0	47.5
Chloride	3.4	-10.6	-3.7	-6.8	-3.2	-3.8	- 3.9
Sulfate	7.4	-2.4	1.1	-.9	3.1	3.8	2.0

[1]Water year is the period from October of one year to September of the following year.

these processes are microbially mediated and, therefore, temperature dependent—that is, in northern wetlands, these processes proceed at faster rates during the summer than during the winter. Nitrogen-releasing processes include decomposition of organic matter, leaching, denitrification, and ammonia desorption (Kadlec and Knight, 1996).

Total Nitrogen

Total nitrogen (TN) consists of the reduced forms of nitrogen (ammonia and organic nitrogen) and the oxidized forms of nitrogen (nitrate and nitrite). The 6-year average input load of TN in the Ellison Park wetland was 275 tons, whereas the average output load was 263 tons (table 7). Monthly input and output loads were similar (fig. 6), but the differences were statistically significant (p-value = 0.0028; table 5) and indicated that the wetland facilitated a small net removal of TN. Annual removal efficiencies for TN ranged from 9.6 to -1.8 percent and averaged 4.3 percent.

Ammonia plus Organic Nitrogen

Median concentrations of ammonia-plus-organic nitrogen (TKN) at the inflow and outflow were 0.77 and 0.78 mg/L, respectively, and the interquartile ranges at these two sites also were similar (table 7). Maximum TKN inflow concentrations were often twice as high as the corresponding outflow concentrations, indicating that peak TKN concentrations decreased within the wetland. The 1990-96 plot of TKN concentrations (fig. 7A) indicates a seasonal pattern of high TKN concentrations during the summer and low concentrations during the winter, at least during 1991-94. The average estimated annual input load of TKN was 126 tons, and the average output load was 118 tons (table 7). Annual removal efficiencies ranged from -3.2 to 13.5 percent and averaged 6.1 percent for the study period, but the monthly input and output loads (fig. 7B) did not differ

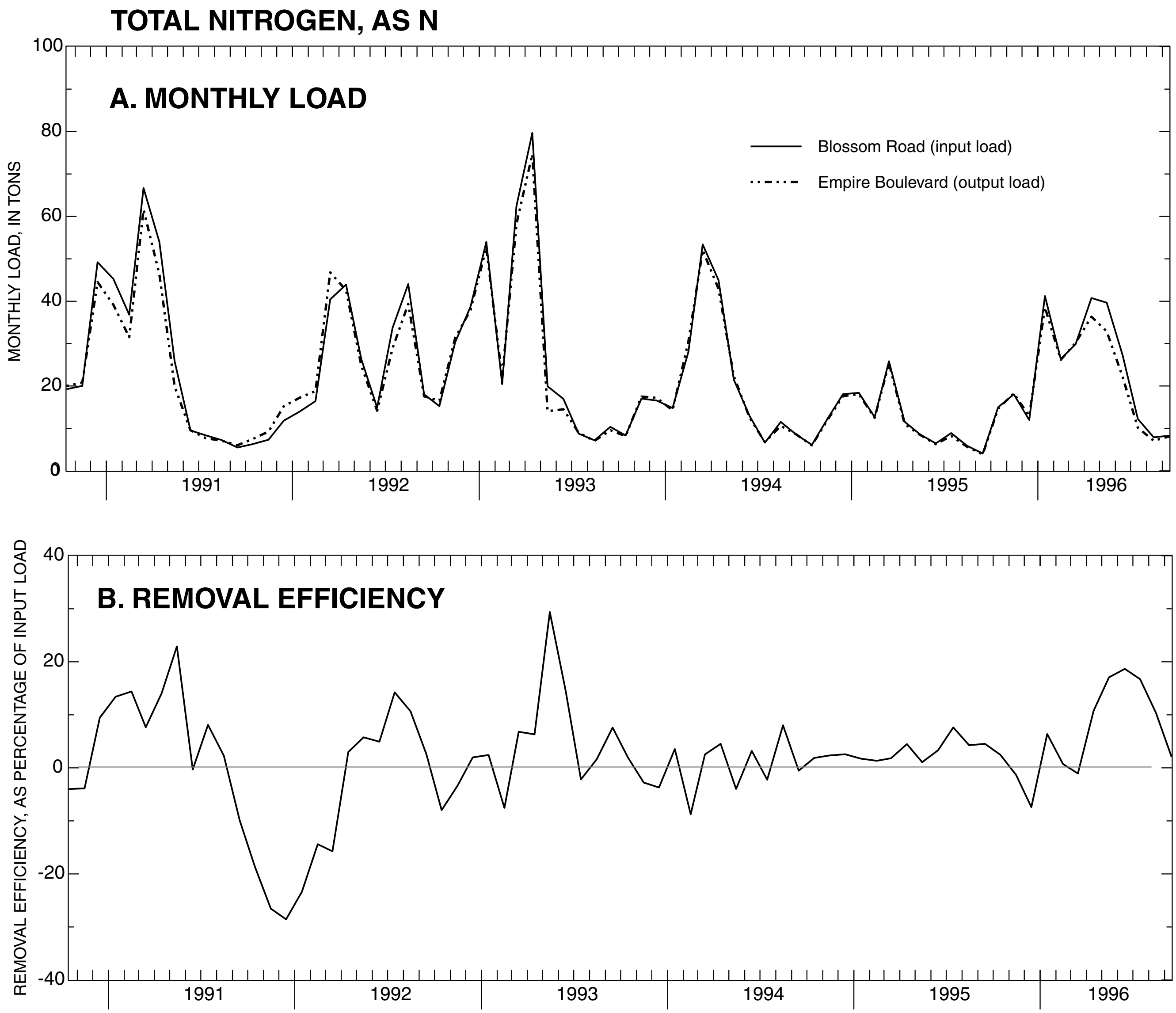

Figure 6. Monthly load and wetland's removal efficiency for total nitrogen, Ellison Park wetland, Monroe County, N.Y., 1990-96

significantly (p-value = 0.1005; table 5). Input loads generally exceeded output loads during high-flow periods, but the two were similar during low-flow periods (fig. 7).

Ammonia Nitrogen

Concentrations of ammonia (NH_3) at the inflow (fig. 8A) were typically lower than outflow concentrations, and the median values and interquartile ranges for the inflow also were lower than those for the outflow (table 7). No seasonal pattern in NH_3 concentrations is apparent (fig. 8A). Output loads of NH_3, which constituted 4 percent of the TKN output loads and 1.8 percent of the TN loads exiting the Ellison Park wetland, were consistently greater than the input loads (fig. 8B). The average estimated annual input load of NH_3 was 2.59 tons (2 percent of the annual TKN input load and 0.9 percent of the TN load); the average output load was 4.76 tons (table 7). Annual removal efficiencies ranged from -315 to 15.3 percent and averaged -84.0 percent for the study period (fig. 8C). The significant difference (p-value = 0.0001) between monthly input and output loads (table 5) indicated that the Ellison Park wetland was a source of NH_3. The general downward trend of the monthly removal efficiencies (fig. 8C) indicated that generation of NH_3 in the wetland increased through the study period. The increase in NH_3 loads was obscured in the TKN data by the large loads of Org-N, which were 2 orders of magnitude larger than the NH_3 loads. These results suggest that the increase in NH_3 loads was caused by transformation processes within the wetland, such as ammonification and dissimilatory nitrate reduction, and diffusion of NH_3 from anaerobic sediments. A net increase in NH_3 loads within the wetland can be expected because the rate of ammonification exceeds the rate of nitrification (Kadlec and Knight, 1996). Rates of NH_3 production would be expected to be higher under flooded (anaerobic) conditions than under low-water conditions, but coefficients of correlation of NH_3 loads and removal efficiencies with monthly mean water levels (table 6) were less than 0.26 and, thus, do not support this interpretation.

Organic Nitrogen

Organic nitrogen (Org-N) made up 98 percent of the TKN input load; therefore, monthly Org-N loads showed a temporal variation similar to that of TKN during the study period, and the monthly output loads were similar to or slightly less than the monthly input loads. Removal efficiencies for Org-N were slightly higher than those for TKN; annual removal efficiency ranged from 1.5 to 13.4 percent and averaged 8.0 percent for the study period (table 7). The monthly Org-N input loads and output loads differed significantly (p-value = 0.0006; table 5). The significant difference for Org-N loads, but not TKN loads, is attributed to the generation of NH_3 in the wetland, which offset the slight decrease in Org-N loads.

Nitrate plus Nitrite Nitrogen

Concentrations of nitrate-plus-nitrite nitrogen (NO_x) fell within the interquartile range of 1.2 to 0.73 mg/L at both sites; the outflow median concentration was slightly less than the inflow median concentration (table 7). A strong seasonal pattern in NO_x concentrations is evident in fig. 9A; NO_x concentrations at both monitoring sites increased during late fall and early winter, attained peak values during winter and spring, and decreased through the summer. This pattern could result from denitrification during the summer, but this water-quality improvement did not occur entirely in the wetland because the inflow and outflow concentrations were comparable. The average estimated annual input load of NO_x was 149 tons and the average output load was 145 tons (table 7). Monthly input loads were similar to monthly output loads (fig. 9), but the difference is significant (p-value = 0.0163) (table 5). The annual removal efficiencies for NO_x ranged from -5.0 to 6.8 percent and averaged 2.7 percent (table 7) for the study period.

Nitrogen loads entering and leaving the wetland were directly related to discharge (table 6) and were highest during high-flow periods. Coefficients of correlation between discharge and loads of all forms of nitrogen were equal to or greater than 0.90, except for the output loads of ammonia, whose coefficient of correlation with discharge was 0.88 (table 6). Removal efficiencies for all nitrogen constituents (except NO_x), in contrast, appeared not to be correlated with discharge, season, or water level (table 6). The possible exception of NO_x, had a fairly strong association with season (0.67) and water level (0.59). Graphical analyses of nitrogen-removal efficiencies indicate differing seasonal trends: (1) Although NO_x input loads were generally similar to output loads (fig. 9B), the removal efficiencies (fig. 9C) were low

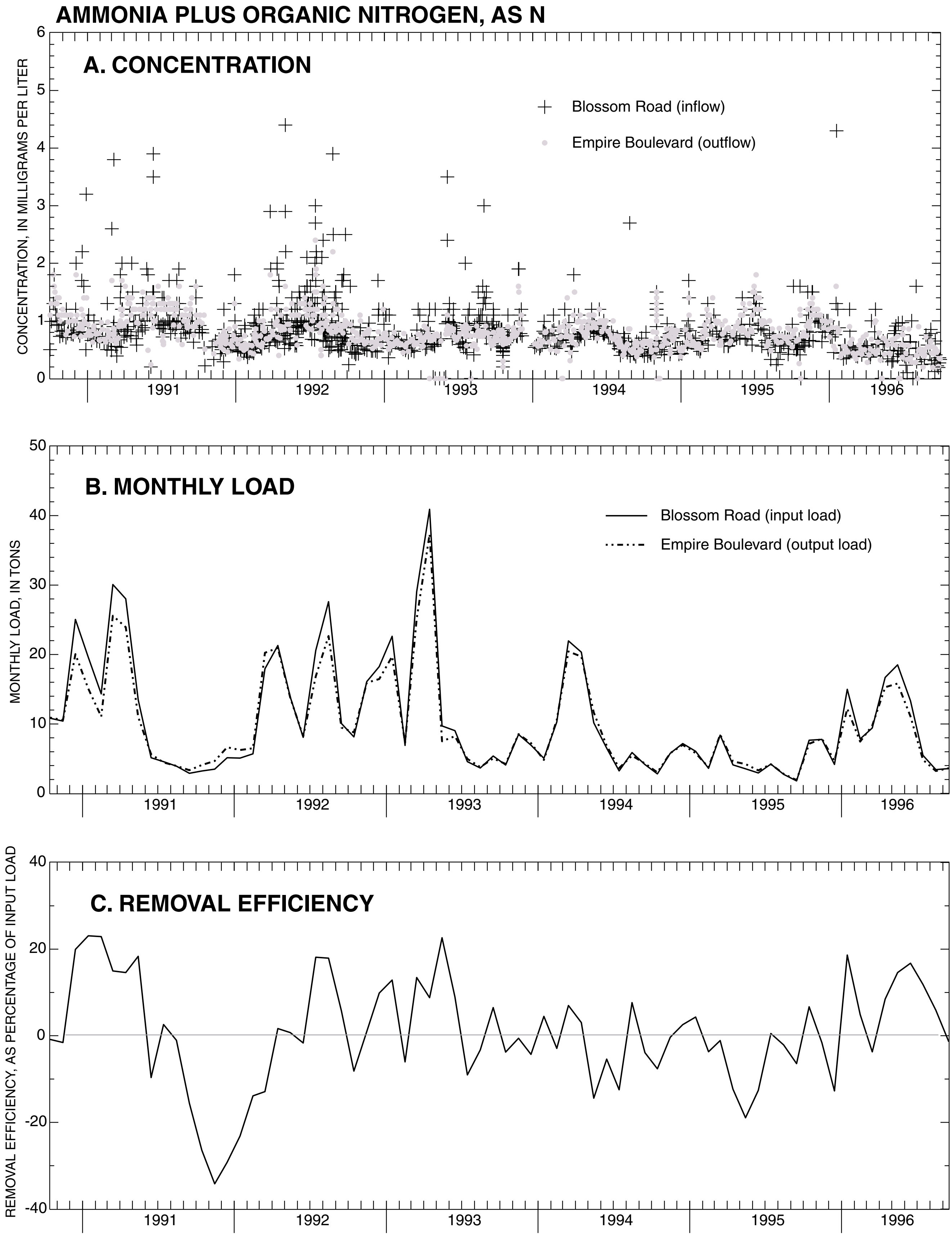

Figure 7. Concentration, monthly load, and removal efficiency of ammonia-plus-organic nitrogen, Ellison Park wetland, Monroe County, N.Y., 1990-96

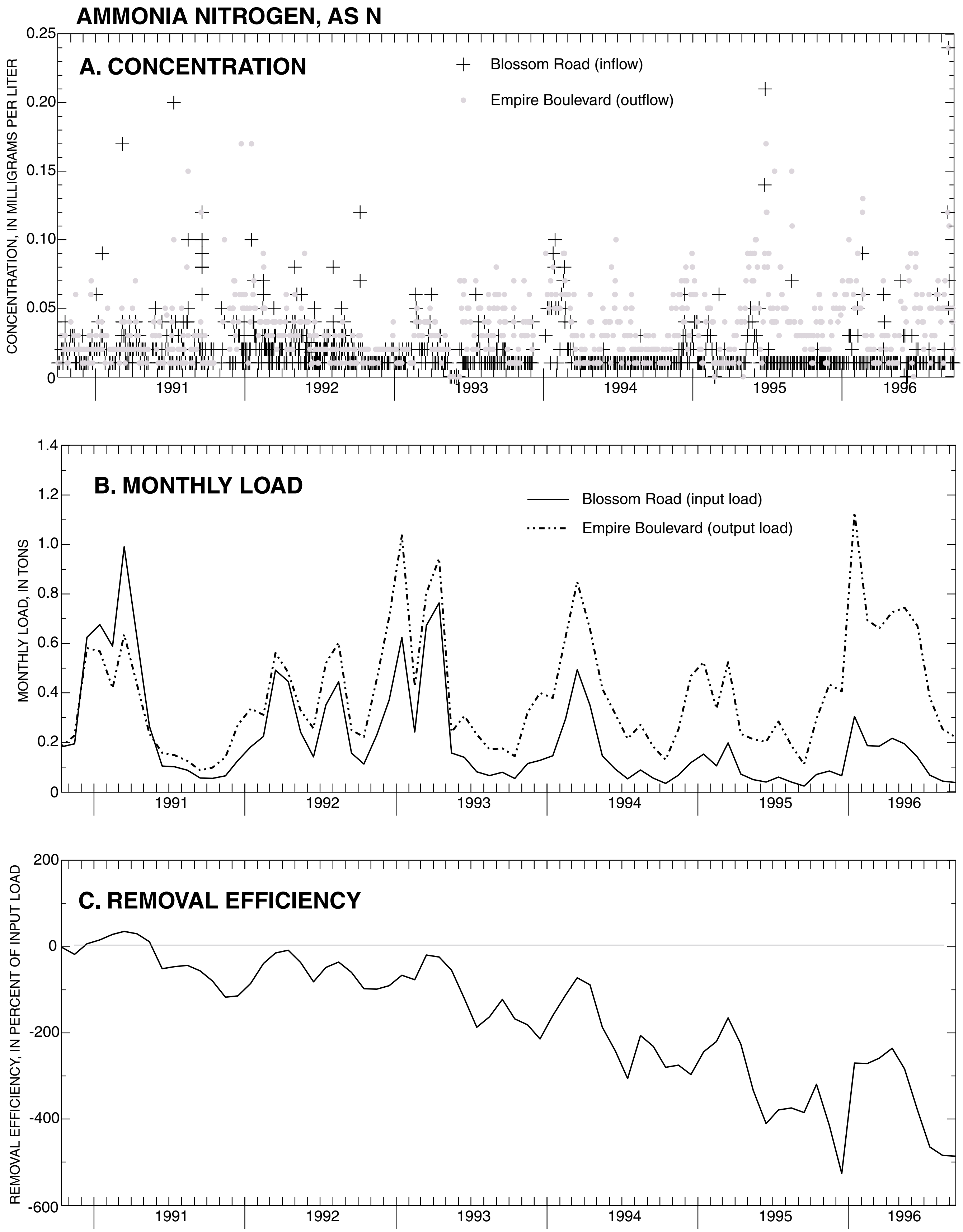

Figure 8. Concentration, monthly load, and wetland's removal efficiency for ammonia nitrogen, Ellison Park wetland, Monroe County, N.Y., 1990-96

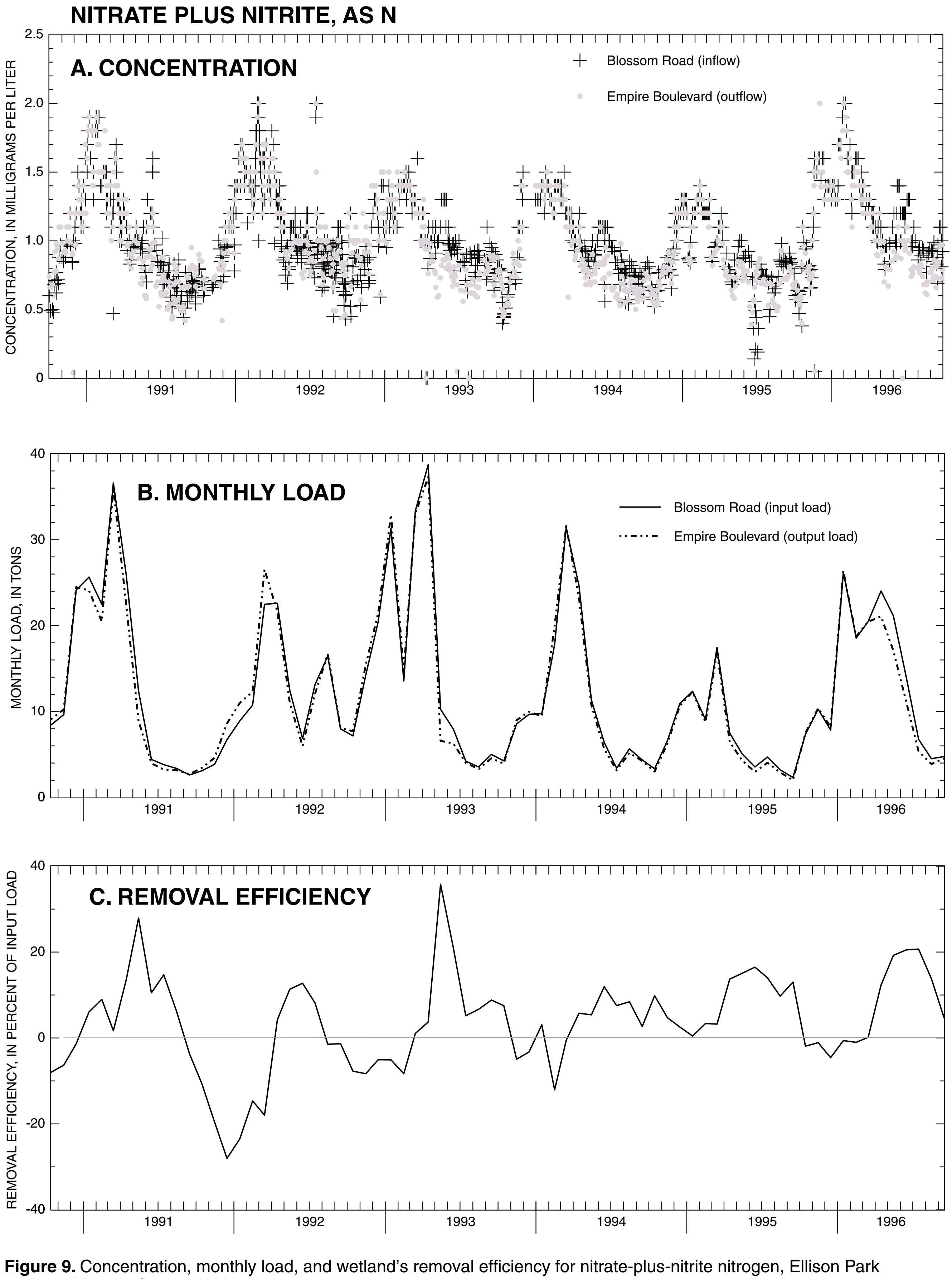

Figure 9. Concentration, monthly load, and wetland's removal efficiency for nitrate-plus-nitrite nitrogen, Ellison Park wetland, Monroe County, N.Y., 1990-96

or negative during the fall and winter and high during the spring and summer. (2) The exportation of NH_3 decreased during late winter and spring (fig. 8C), presumably from the winter decrease in biological activity and an increase in aerobic conditions resulting from low regional water levels. The generation of NH_3 increased during the other seasons, presumably as a result of increased biological activity, anaerobic conditions caused by high regional water levels in summer, and plant senescence in fall. TKN input loads were similar to the output loads (fig. 7B), and the removal efficiencies (fig. 7C) fluctuated around zero and formed no noticeable seasonal trend.

An additional observation is that the input loads for NH_3 appeared to decrease after 1993 (fig. 8B), while output loads remained about the same. The net result was an increasing trend in the percentage of NH_3 that was exported from the wetland. This trend indicates an increase in the rate of transformation of Org-N to NH_3 or in the rate of reduction of NO_x to NH_3, if inputs of NH_3 from external sources remained constant. This trend in NH_3 export increased noticeably around 1993-94 (figs. 8B, 8C), the period of increased flow into the southeastern part of the southern wetland area after the flow-diversion modifications to the Millrace and, thus, could result from the increased residence time and prolonged contact between stormwaters and wetland biota, and the subsequent increase in the rate of mineralization of organic nitrogen.

Phosphorus

Surface inflow and its associated suspended-sediment load (primarily clay) is the primary source of phosphorus to a wetland; atmospheric contributions are considered insignificant (Kadlec and Knight, 1996). Phosphorus-storage mechanisms within a wetland include assimilation by plants, microbial utilization, deposition of particulate phosphorus through sedimentation, accretion of biomass in soils, sorbtion to clay and organic particles, and formation of insoluble precipitates with metal cations (iron and aluminum in acidic soils, or calcium and magnesium in alkaline soils) (Kadlec and Knight, 1996; Hickok, 1978; Mitsch and Gosselink, 1986). Phosphorus-releasing processes include oxidation (or decomposition) of organic matter, desorption from clay and organic particles, translocation from soils to above-ground plant tissue, followed by leaching and decay of organic matter, and, in reduced environments, solubilization of iron minerals and subsequent release of phosphorus coprecipitates (Kadlec and Knight, 1996; Gehrels and Mulamoottil, 1989).

Total Phosphorus

Median concentrations of total phosphorus (TP) at the inflow and outflow were 0.11 and 0.10 mg/L, respectively, and the interquartile ranges for both sites were similar (table 7). Maximum TP concentrations at the inflow were higher, sometimes an order of magnitude higher, than the corresponding concentrations at the outflow, indicating that peak TP concentrations decreased within the wetland. A time plot of TP concentrations (fig. 10A) suggests a slight seasonal pattern of high TP concentrations during the summer and low concentrations during the winter, excepting periods of peak inflows. The average estimated annual input load of TP during the study period was 26.2 tons; the average output load was 19.0 tons (table 7). The monthly input and output loads differed significantly (p-value = 0.0001; table 5). The wetland was effective in decreasing TP loads; annual TP-removal efficiency ranged from 14.5 to 49.0 percent and averaged 27.6 percent for the study period (table 7). Inflow TP loads were correlated with discharge (Spearman correlation coefficient, 0.87; table 6); they increased in late winter and spring, the period of rapid melting of accumulated snow (“first flush”), and during heavy storms and periods of high runoff during the summer and fall (fig. 10). Unusually large loads of TP (53 percent of the 1992 annual load) entered the wetland during July and August 1992, when three overbank flows occurred, and during March and April 1993, when high flows that included the period-of-record maximum discharge on Irondequoit Creek, carried 58 percent of the 1993 annual TP load into the wetland.

Orthophosphate

Concentrations of orthophosphate (PO_4, the dissolved phase of phosphorus) at the inflow were typically lower than at the outflow, as were the median values and interquartile ranges (table 7). A seasonal pattern, although inconsistent, is apparent in the time plot in figure 11A, which indicates that, during most years, high PO_4 concentrations occurred during the summer and fall. The presence of this pattern at both monitoring sites indicates that it cannot result solely from processes within the wetland; superimposed upon this pattern, however, are three summer (1991,

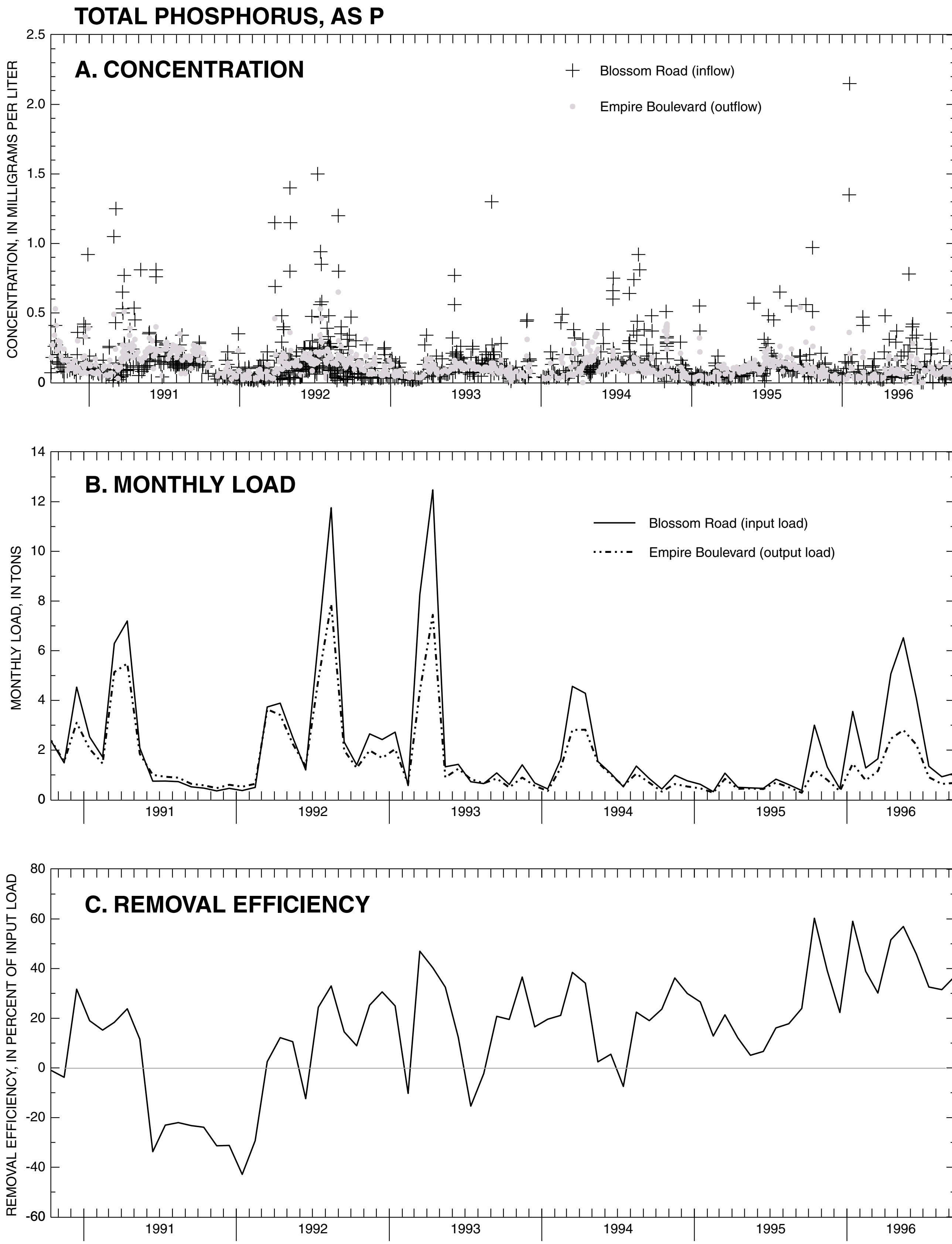

Figure 10. Concentration, monthly load, and wetland's removal efficiency for total phosphorus, Ellison Park wetland, Monroe County, N.Y., 1990-96

1993, and 1995) periods of elevated PO_4 concentrations that occur only at the outlet (fig. 11A) and, therefore, can be attributed to wetland processes. The average estimated annual input load of PO_4 was 1.69 tons (6.5 percent of the annual TP input load); the average output load was 2.33 tons (12.3 percent of the TP output load) (table 7). The monthly input and output loads differed significantly (p-value = 0.0001; table 5). The annual removal efficiency ranged from -10.5 to -67.1 percent and averaged -38.1 percent for the study period (table 7). The generation of PO_4 is attributed to the release processes mentioned above. Similar seasonal patterns have been documented by Klopatek (1978) and Kadlec and Knight (1996). The peak loads of PO_4 coincided with those for total phosphorus (figs. 10 and 11); that is, peak loads occurred during high-flow periods, but the export of PO_4 occurred throughout the study period.

High TP removal efficiency was associated with peak flows, and low removal efficiency was evident during summer low-flow periods (fig. 10C), although the correlation between removal efficiency and inflow loads of total phosphorus was weak (Spearman correlation coefficient, 0.55; table 6). The removal efficiency for phosphorus appears to have increased around mid-1994 (fig. 11C), probably as a result of the 1994 Millrace modifications that increased flow into the southeastern backwater section of the wetland. Neither water depth nor duration of inundation were related in a consistent manner to phosphorus-removal efficiency when evaluated separately from other factors (table 6). When evaluated in conjunction with inflow loading rates, hovever, they appeared to correlate with phosphorus removal, as evidenced by high removal efficiency during the prolonged periods of inundation in the spring of 1991 and 1993 (figs. 4 and 10C). The correlation between water depth and removal efficiency was probably obscured by the effects of other phosphorus-cycling mechanisms within the wetland.

Phosphorus uptake and retention in temperate-climate marshes, such as the Ellison Park wetland, generally increase during the growing season and decrease during the senescence period; but exceptions have been observed. For example, a 1-year phosphorus-budget study of a *Typha* marsh in Ontario, Canada, by Gehrels and Mulamoottil (1989) found that seasonal PO_4 outputs approximately equaled inputs during winter, spring, and summer but were 60 percent greater than inputs during the fall. Seasonal trends reported by Kadlec and Knight (1996) at five Canadian cattail-monocultural (*Typha latifolia*) constructed wetlands indicated that (1) large decreases in TP loads resulted from assimilation by biota during the spring growing season and from translocation of nutrients to the rhizomes during the fall; (2) TP removal decreased during the summer, probably as a result of phosphorus-releasing processes (leaching and decomposition of organic matter), which generated more phosphorus than was being retained by phosphorus-assimilation processes; and (3) midwinter decreases in phosphorus removal coincided with a decrease in biological activity. These processes could explain some of the seasonal variations in the TP and PO_4 removal efficiencies in the Ellison Park wetland, but the pattern was not consistent from year to year. The summer release of phosphorus by leaching and decomposition of organic matter could be the reason for the non-flow-related decrease in removal efficiency (increase in exportation) of PO_4 during the summer of 1992 (fig. 11C).

Suspended Solids

The primary source of suspended solids in the Irondequoit Creek basin is sediment eroded from stream channels and upland soils. Construction activities and development have disrupted the soil protection afforded by natural vegetation and have increased the amount of sediment-laden runoff. The increase in impervious surface area (buildings, roads, and parking lots) has increased the volume of storm runoff and thereby increased peak discharges for a given rainfall. This, in turn, has altered the hydrologic equilibrium of Irondequoit Creek and probably has aggravated erosion and sediment aggradation. Even if upland erosion and runoff volumes were decreased, channel storage of silt and clay particles from construction and development would be a long-term source of sediment to the wetland (Harbison, 1974). A substantial point source of sediment is a steep bluff composed of fine-grained glacial material about 3 mi upstream from the wetland. Young and Burton (1993) estimated the erosion rate of this bluff and concluded that the volume of sediment derived from it was equal to about 50 percent of the total sediment load delivered to the wetland.

Median concentrations of total suspended solids (TSS) at the inflow and outflow were 139 and 102 mg/L, respectively. Median concentrations of volatile suspended solids (VSS), the organic

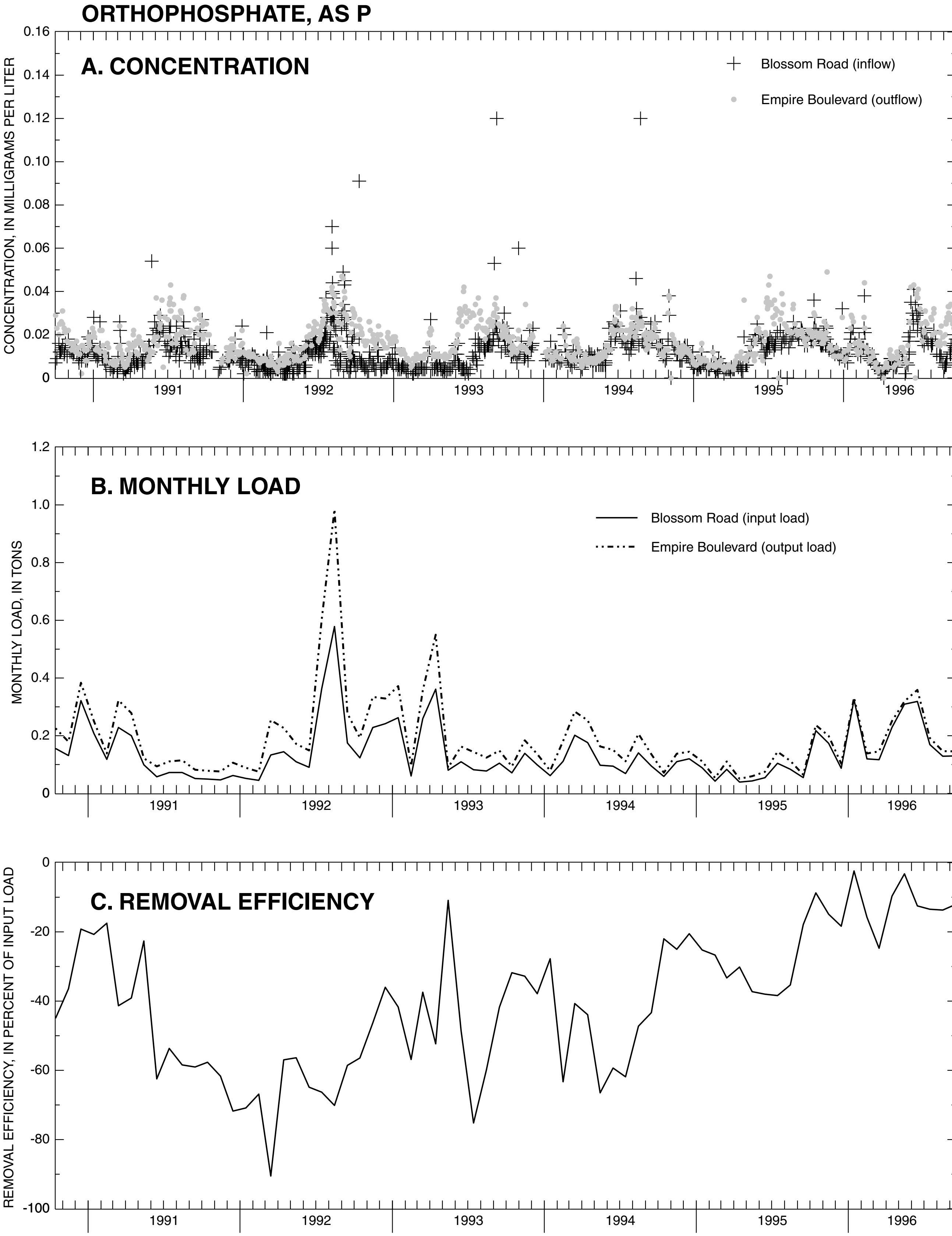

Figure 11. Concentration, monthly load, and wetland's removal efficiency for orthophosphate, Ellison Park wetland, Monroe County, N.Y., 1990-96

component of TSS, at the inflow and outflow were 21 and 16 mg/L, respectively. The interquartile ranges for both constituents at the inflow exceeded those at the outflow (table 7); thus, the wetland was a sink for suspended solids. The amounts of TSS entering the wetland during the study were large (fig. 12B); the average estimated annual input load was 28,500 tons, and the average output load was 15,200 tons (table 7). This difference, which is statistically significant (p-value = 0.0001; table 5), resulted in annual removal efficiencies that ranged from 31.9 to 58.6 percent and averaged 46.7 percent for the study period (table 7, fig. 12C). Volatile suspended solids constituted 12 to 14 percent of TSS; the average estimated annual input load of VSS was 3,540 tons, and the average output load was 2,080 tons (table 7, fig. 13B). Monthly VSS output loads were significantly lower (p-value = 0.0001) than input loads (table 5). Annual removal efficiency ranged from 28.1 to 55.4 percent and averaged 41.0 percent for the study period (table 7, fig. 13C).

Input loads of TSS and VSS were strongly correlated with discharge (Spearman correlation coefficients exceeded 0.93; table 6), and large loads coincided with periods of storm runoff. Although the removal efficiencies for TSS and VSS were not significantly correlated with discharge or season, nor with the duration or depth of wetland inundation (table 6), the removal-efficiency plots for TSS and VSS (figs. 12C and 13C) indicated a strong relation with discharge (fig. 3B). Except for the prolonged dry period of 1991, TSS-removal efficiency fluctuated between about 40 and 60 percent, and the greatest removal efficiencies corresponded to high-discharge periods. The primary factors in the removal of TSS were the low channel gradient and the dense vegetation of the wetland, both of which facilitated the wetland's sedimentation and filtration functions.

A TSS-removal efficiency of 49 percent reported for the Ellison Park wetland for the summer of 1972 by Harbison (1974) closely agrees with that computed from the 1991-96 data (table 7). In contrast, an average annual TSS-removal efficiency of only 12 percent, was measured between Blossom Road and the Narrows for 1980-81 by Kappel and others (1986). This low value probably reflects the removal efficiency for the southern wetland area alone, however.

Chloride and Sulfate

The primary source of chloride in the Irondequoit Creek basin is the road salts that are applied to highways during the winter (Diment and others, 1974). Chloride is a highly soluble, conservative substance in that it does not precipitate nor enter actively into biological and chemical processes (Kadlec, 1987); thus, its mass remains relatively constant among surface-water inflow and outflow, and wetland storages (Kadlec and Knight, 1996). Median concentrations of chloride at the inflow and outflow sites were 110 and 120 mg/L, respectively, and the interquartile ranges also were similar (table 7). The average estimated annual input load of chloride during the study was 16,800 tons, and the average output load was 17,500 tons (table 7). The differences among monthly loads were small but statistically significant (p-value = 0.0001; table 5). The annual removal efficiency ranged from -10.6 to 3.4 percent and averaged -3.9 percent for the study (table 7). Road salt from the land surrounding the wetland downstream from the inflow site probably is the reason why the output loads were slightly greater than the input loads.

Chloride concentrations and loads (fig. 14) were elevated during the winter and low at other times. Peak chloride input and output loads occurred during periods of high discharge (figs. 3 and 14B; Spearman correlation coefficients of 0.91 and 0.92, respectively, table 6) and reflect the washoff of chloride during the high flows that occurred during the winter and spring snowmelt; chloride loads during summer stormflows were lower. Removal efficiency (fig. 14C) was positive during the high-water periods of 1991 and 1993 (fig. 4), when the high water-surface elevations of Irondequoit Bay and Lake Ontario facilitated the dispersal and detention of flows, and was near-zero or negative during the prolonged low-water periods, when flows entering the wetland in the main channel of Irondequoit Creek had little opportunity for dispersal. Despite these observations, chloride-removal efficiency was not statistically correlated with discharge, nor with depth or duration of inundation in the wetland (figs. 4 and 14).

Sulfate is an airborne byproduct of fossil-fuel combustion and industrial processes, such as smelting of sulfide ores (Hem, 1989) and, thus, has a widespread distribution and settles to the earth as dryfall or is removed from the air by rain or snow. Sulfate is a soluble salt, and its concentrations and

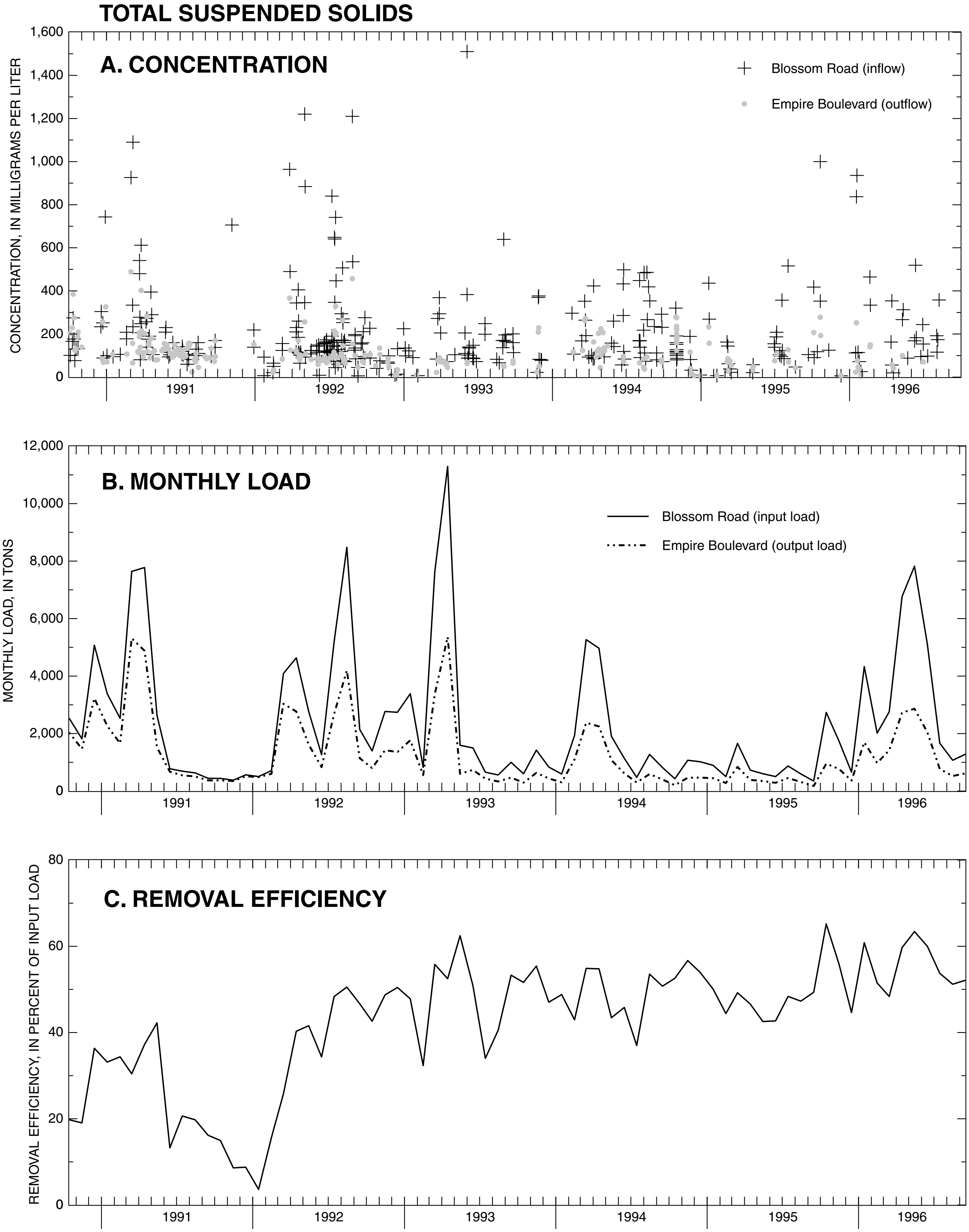

Figure 12. Concentration, monthly load, and wetland's removal efficiency for total suspended solids, Ellison Park wetland, Monroe County, N.Y., 1990-96

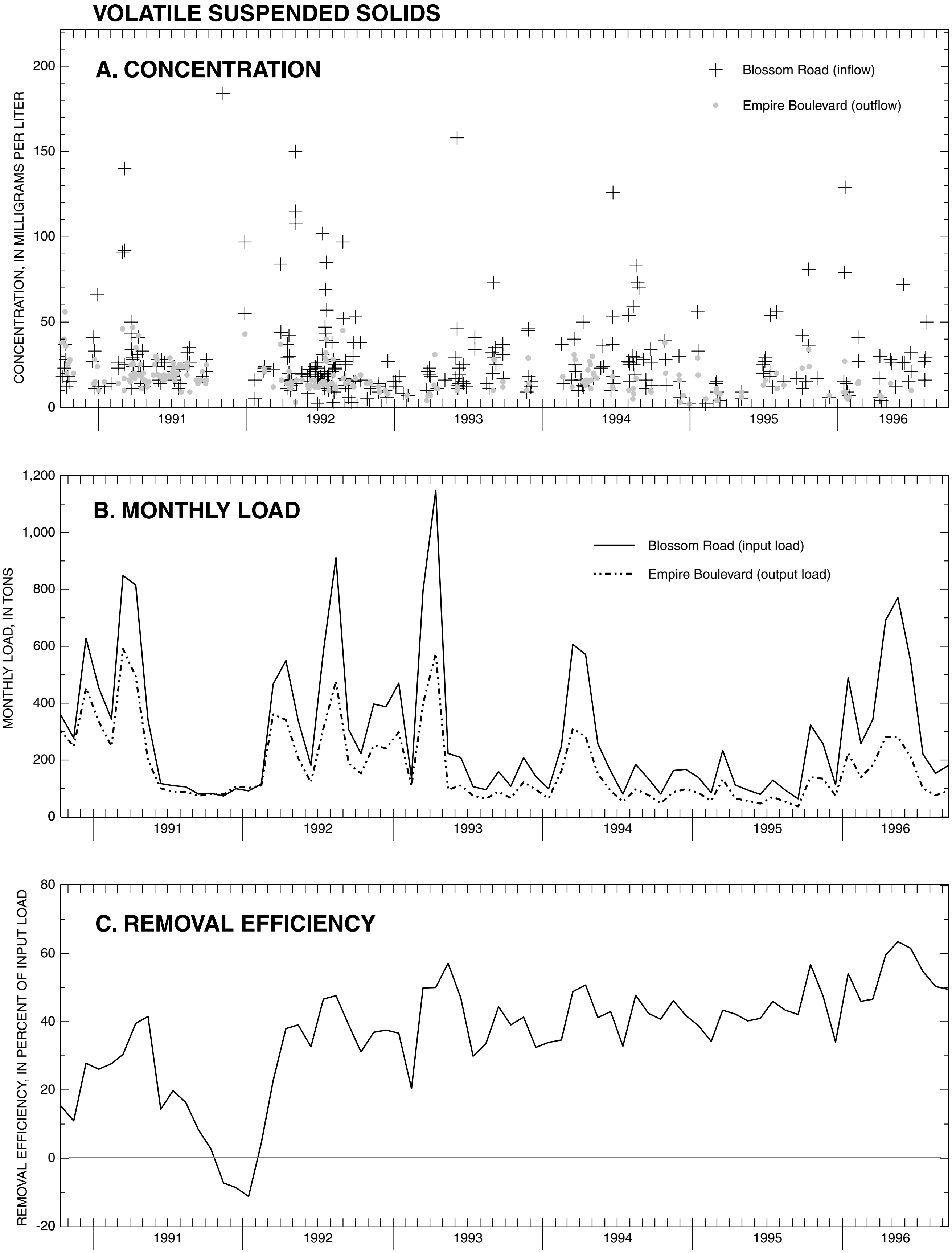

Figure 13. Concentration, monthly load, and wetland's removal efficiency for volatile suspended solids, Ellison Park wetland, Monroe County, N.Y., 1990-96

loads, like those of chloride, were not greatly affected by the wetland. Median sulfate concentrations were 140 mg/L at the inflow and outflow sites, and the interquartile ranges differed little between the two sites (table 7). The plot of sulfate concentrations (fig. 15A) indicates seasonally high concentrations from midsummer through autumn of most years and low concentrations from late winter through spring. The average estimated annual input and output loads of sulfate were 16,000 and 15,700 tons, respectively (table 7), but the monthly output loads were significantly different from (slightly less than) the input loads (p-value = 0.0024; table 5). This decrease within the wetland could result from sulfate reduction under anaerobic conditions. The annual removal efficiency ranged from -2.4 to 7.4 percent and averaged 2.0 percent for the study period (table 7). The temporal pattern of input and output loads and removal efficiency (fig. 15) was similar to that for chloride (fig. 14).

Trace Metals

Water samples were collected from Irondequoit Creek during stormflows, and less frequently during low-flow periods, and were analyzed for four trace metals—zinc, lead, copper, and cadmium (appendix 1). The range of inflow and outflow concentrations of zinc, lead, and copper are shown in boxplots in figure 16; cadmium concentrations were usually below the analytical detection limit and were excluded. Concentrations at the inflow were generally greater than at the outflow. The median concentrations of these metals in Irondequoit Creek were compared with (1) average concentrations found in rivers worldwide (Kadlec and Knight, 1996) and in the United States (Hem, 1989; Durum and others, 1971), and (2) a summary statistic derived from the nationwide data collected during the 1980-81 NURP studies (U.S. Environmental Protection Agency, 1983). Of the 13 metals for which urban-runoff samples from NURP study sites were analyzed, copper, lead and zinc were detected most frequently—in at least 91 percent of the samples, and in some samples at concentrations that exceeded U.S. Environmental Protection Agency water-quality standards (U.S. Environmental Protection Agency, 1983). The mean concentration of a given constituent during a specific stormflow (or event mean concentration, EMC) at a NURP site was computed as the total constituent mass divided by the total runoff volume (U.S. Environmental Protection Agency, 1983) and was used to normalize the data for differences in precipitation and runoff among the study sites. The median EMC for each constituent from each NURP site was computed, and the median value of the ranked medians from all NURP sites was used as a nationwide summary statistic for each constituent.

Zinc

Zinc, an essential micronutrient for plants and animals, is naturally occurring but becomes widely distributed in the environment through its many uses. It is used in dry-cell batteries, building materials, and alloys such as brass and bronze (Windholz, 1983); galvanized steel, paint pigment, and rubber (Hem, 1989). Median zinc concentrations in streams worldwide are reported to be between 5 and 45 µg/L (Hem, 1989), and the average concentration is estimated to be 10 µg/L (Kadlec and Knight, 1996). A median value of 20 µg/L has been reported for U.S. streams in 1970 by Durum and others (1971). The NURP median EMC concentration of zinc was 160 µg/L (U.S. Environmental Protection Agency, 1983), but this value represents zinc concentrations in urban stormwater, which do not reflect average conditions. Median concentrations of zinc in Irondequoit Creek at the wetland inflow and outflow during this study were 40 µg/L (fig. 16), but the outflow concentrations were significantly lower than the inflow concentrations (p-value = 0.0078; table 8). The maximum zinc concentrations at the inflow and outflow were 370 µg/L and 150 µg/L, respectively. The elevated zinc concentrations in the Irondequoit Creek basin are most likely a result of urbanization but also could be due partly to the dissociation of zinc sulfide from dolomite, which underlies part of the basin and is also within the overlying glacial deposits and local soils (Kappel and others, 1986). Removal of zinc by wetlands results from adsorption, sedimentation, ion exchange, formation of insoluble compounds such as zinc sulfide, which then precipitate, and through bioaccumulation, primarily in plant roots (Hem, 1989; Kadlec and Knight, 1996).

Lead

Lead has low solubility, adsorbs readily to organic and inorganic-sediment surfaces (Hem, 1989), and forms insoluble salts with sulfides, carbonates, sulfates, and chlorophosphates (Kadlec and Knight, 1996). Manmade sources of lead include pipes,

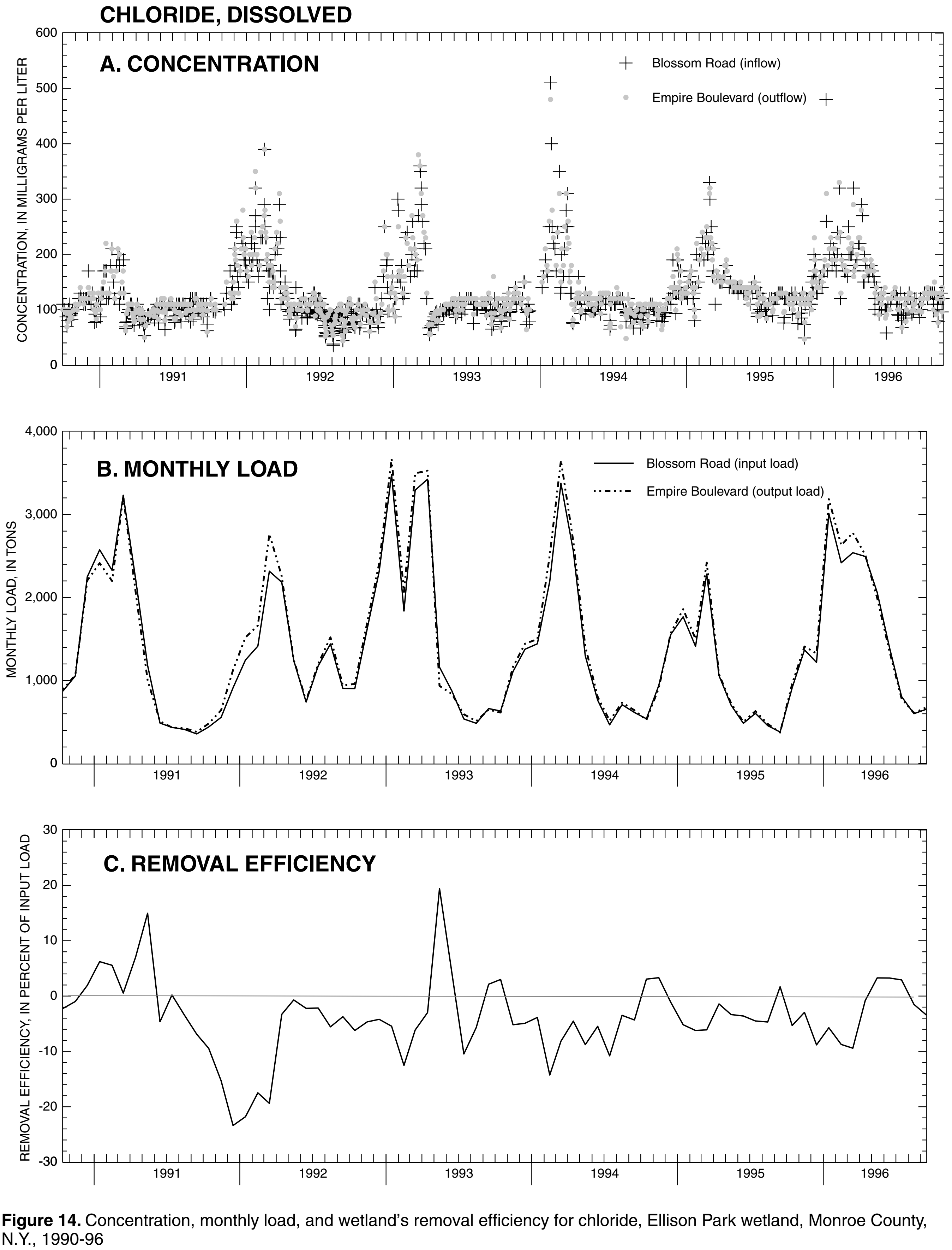

Figure 14. Concentration, monthly load, and wetland's removal efficiency for chloride, Ellison Park wetland, Monroe County, N.Y., 1990-96

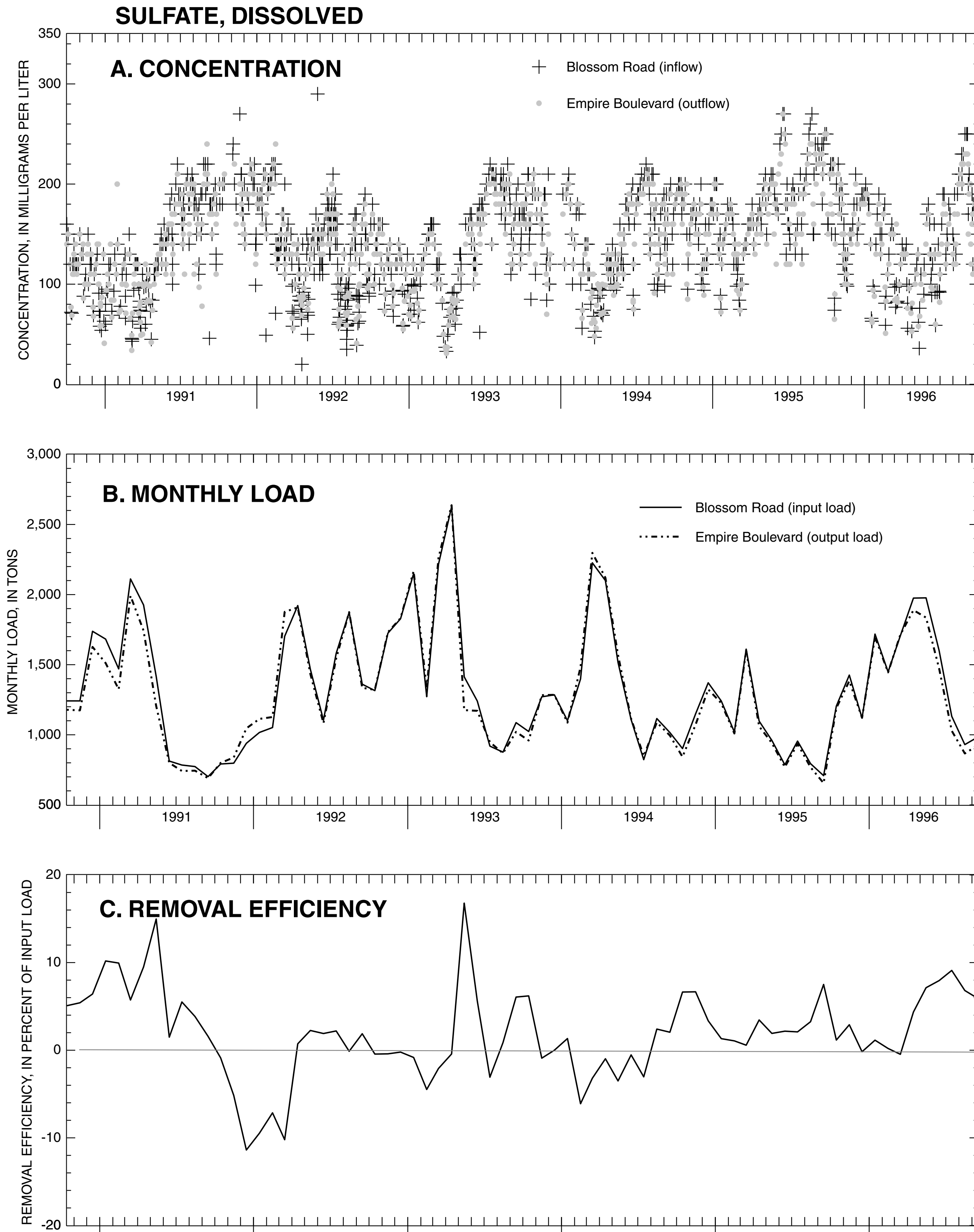

Figure 15. Concentration, monthly load, and wetland's removal efficiency for sulfate, Ellison Park wetland, Monroe County, N.Y., 1990-96

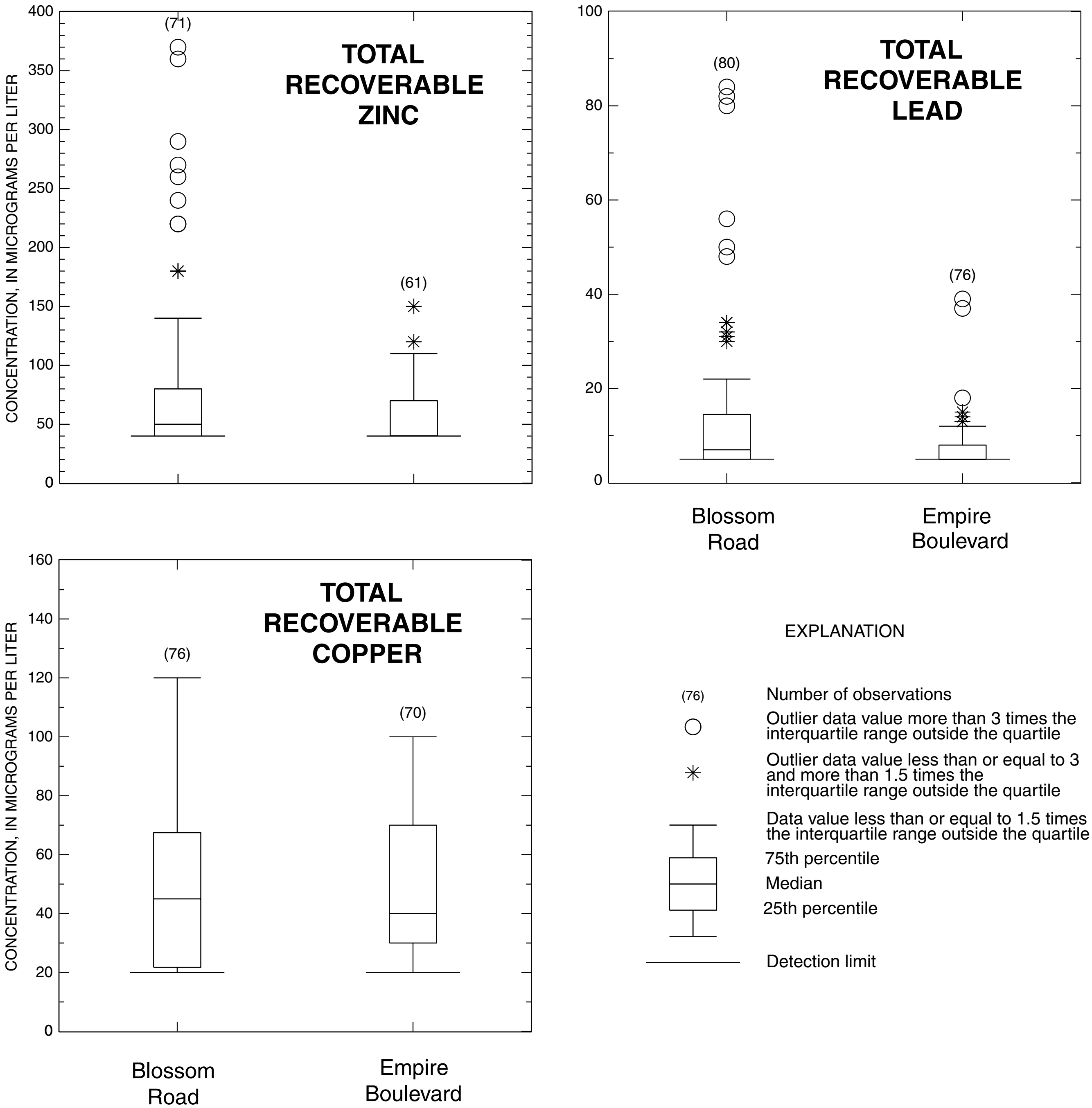

Figure 16. Concentrations of selected trace metals in stormwater samples from Irondequoit Creek above Blossom Road and at Empire Boulevard, Monroe County, N.Y., 1990-96

plastics, ceramics, paints, batteries, smelting of ores, and combustion of coal and leaded gasoline (Hem, 1989; Windholz, 1983). Lead concentration in the world's rivers averages about 0.2 µg/L (Kadlec and Knight, 1996), and that in U.S. streams ranges between 1 and 10 µg/L (Hem, 1989; Durum and others, 1971). The NURP median EMC concentration of lead in urban stormwater was 144 µg/L (U.S. Environmental Protection Agency, 1983). Median concentrations of lead in Irondequoit Creek during this study were 7 µg/L at the inflow and 5 µg/L at the outflow (fig. 16), a significant decrease (p-value =

Table 8. Selected statistics on trace-metal concentrations in Irondequoit Creek above Blossom Road (wetland inlet) and at Empire Boulevard (wetland outlet), Monroe County, N.Y., 1990-96

[mg/L, milligrams per liter; <, less than. Dash indicates no conclusion can be stated. Locations are shown in fig. 2.]

Metal	Number of observations: Inflow Total	Inflow Censored	Outflow Total	Outflow Censored	Censoring limit(s),[1] mg/L	Median concentration, mg/L: Inflow	Outflow	p-value Wilcoxon Rank Sum test[2]	Significant difference	Point of greater concentration
Zinc	783	220	659	192	40	40	40	0.0078	yes	inflow
Lead	79	21	76	25	2, 5	7	5	.0096	yes	inflow
Copper	77	7	73	6	10, 20, 50	50	40	.89	no	--
Cadmium	82	62	78	65	1, 5	< 1.0	< 1.0	.0265	yes	inflow

[1]Censoring limit varies with equipment used for analysis.
[2]Test of significant difference between median inflow and outflow concentrations.

0.0096; table 8). The maximum lead concentrations at the inflow and outflow were 84 µg/L and 39 µg/L, respectively. Lead removal in wetlands results from the formation of insoluble compounds and subsequent sedimentation; lead also can become biomagnified in aquatic biota (Kadlec and Knight, 1996).

Copper

Copper is an essential micronutrient for plants and animals and enters the environment from its use in water pipes and plumbing fixtures; it also is used in algicides and pesticides (Hem, 1989), in alloys such as bronze and brass, and in electrical conductors, ammunition, and wood preservatives (Windholz, 1983). Another source, particularly in urban settings, is the abrasion of vehicle brake pads (Woodward-Clyde Consultants, 1994; 1997). Of the 13 metals detected in NURP urban-runoff samples, copper was the most frequently detected (U.S. Environmental Protection Agency, 1983). The average copper concentration in the world's rivers is about 2 µg/L (Kadlec and Knight, 1996), and that in U.S. streams is about 10 µg/L (Hem, 1989; Durum and others, 1971). The NURP median EMC concentration was 34 µg/L (U.S. Environmental Protection Agency, 1983). Median concentrations at the wetland inflow and outflow during this study were 50 µg/L and 40 µg/L, respectively (fig. 16), but this apparent decrease was not statistically significant ($\alpha = 0.10$; table 8). The maximum copper concentrations at the inflow and outflow were 120 µg/L and 100 µg/L, respectively. The data indicate a decrease in concentrations from 1990 through 1996 (appendix 1). Wetlands can decrease copper loads through adsorption on mineral and organic surfaces, through the formation of complexes with hydroxides, sulfides, and carbonates, and through bioaccumulation in plant tissues (Kadlec and Knight, 1996).

Cadmium

Cadmium is a naturally occurring element that enters the environment through industrial uses, which include electroplating and photography; it also is used in paint pigment, printing ink, and plastics, and as a stabilizer in PVC products, in electrical batteries, and in fluorescent and video tubes (Hem, 1989; Windholz, 1983). The average concentration of cadmium in surface waters worldwide is about 0.07 µg/L (Kadlec and Knight, 1996) and about 1 µg/L in U.S. streams (Hem, 1989; Durum and others, 1971). Cadmium concentrations in 76 and 83 percent of the samples collected at the wetland inflow and outflow, respectively, were below the analytical detection limit of 1 µg/L. Nonetheless, the outflow concentrations, when detected, were significantly lower than the inflow concentrations (p-value = 0.0265; table 8). Maximum cadmium concentrations at the inflow and outflow during this study were 3 µg/L and 4 µg/L, respectively. The removal efficiency for cadmium in most wetlands is greater than 75 percent. Removal is achieved through adsorption on organic particles and the formation, and subsequent sedimentation, of sulfides (Kadlec and Knight, 1996).

Water Temperature

Surface-water temperature increased by passage through the wetland, especially during the summer (fig. 17A), through the slow movement of water, the shallow conditions, and the absence of shade. Winter water temperatures at the outflow site were similar to those at the inflow site; daily mean temperatures at the outflow usually differed from those at the inflow by less than 0.5 °C (fig. 17B), except in late spring and summer, when daily mean outflow temperatures were generally 1 to 2 °C higher than the inflow temperatures (fig. 17B). This difference narrowed during periods of storm runoff, as shown by the temperature record and storm hydrograph (fig. 17C) for June 18-28, 1996. The diurnal temperature pattern at the inflow site was not greatly affected by the runoff, except on June 19 and 20, when the runoff shifted the time of the peak temperatures. At the outflow site, the runoff lowered the water temperature to as low as the inflow temperature or lower. This cooling was enhanced by cloudy conditions on June 18-20, when less than 20 percent of possible sunshine was recorded (Northeast Regional Climate Center, 1996). Soon after the passage of the stormwater, temperatures at both sites increased, and the difference in the temperature records increased to prestorm values.

Characteristics of Wetland Sediments

The composition of channel-bottom material varies within the Ellison Park wetland according to the flow velocity. The predominant bed material in the main channel (Irondequoit Creek), in which high flow velocities occur, is sand, but the predominant bed materials in the open, backwater areas where velocities are slow are silt and clay. The four bottom-sediment samples collected for chemical analyses (fig. 2) were taken from backwater areas; more than 82 percent of the particles were silt sized and smaller (less than 4 mm in diameter). The high percentage of fine-grained mineral particles reflects the wetland's high removal efficiency for suspended solids that accumulate in these depositional environments. The sediment samples were 3.4 to 5.0 percent total organic carbon by weight and contained 0.13 percent phosphorus by weight. The relatively low concentrations of organic carbon in these samples reflects the low rate of biomass accumulation from small submergent aquatic macrophytes (such as *Myriophyllum sp.* and *Ceratophyllum demersum*). The organic content in the cattail-vegetated (*Typha glauca*) areas of the wetland is expected to be substantially greater than that indicated by these results.

Results of the sediment analyses are presented in appendix 4. The high percentage of silt and clay in the sediment, and the presence of organic matter, are conducive to adsorption of metals (Hem, 1989) and organic compounds (Smith and others, 1988). Metals found in elevated concentrations (greater than 200 ppm; see table 9) included barium, manganese, strontium, and zinc; these concentrations were within the range expected for water draining an urbanized watershed, however (E.C. Callender, U.S. Geological Survey, written commun., 1996). The elevated concentrations of these and other trace elements, including chromium, copper, lead, and vanadium, could be indicative of the effectiveness of the wetland's removal processes, as substantiated by the decrease in surface-water concentrations of lead and zinc between the inflow- and outflow-sampling sites, or the attainment of the wetland's maximum retention capacity. Another major mechanism for removal of metals is the uptake and possible bioaccumulation by plants, especially in roots and rhizomes, as discussed in the following section.

Some polycyclic aromatic hydrocarbons (PAH's), including chrysene, fluoranthene, phenanthrene, and pyrene, also were found in high concentrations in the wetland sediments, as were five persistent organochlorine pesticides (chlordane, dieldrin, DDT and its metabolic-degradation products, DDD and DDE) and polychlorinated biphenyls (PCB's) (table 9). The presence, and the magnitude of concentrations, of these compounds are fairly typical of a depositional environment in a highly urbanized watershed, and many of the pesticide and PCB concentrations are comparable to or lower than those measured in 14 studies in the United States during the 1970's and 1980's, as reported by Smith and others (1988, p. 33). Concentrations of cadmium, copper, mercury, silver, and all detected PAH's were noticeably higher in the sample from the northern (downstream) part of the wetland than in the three samples from the southern part, possibly as a result of current or past chemical inputs from the adjacent drainage area, but no definite conclusions can be drawn from these sparse data.

Wetland sediments can act as a sink for chemicals that (1) precipitate out of solution as

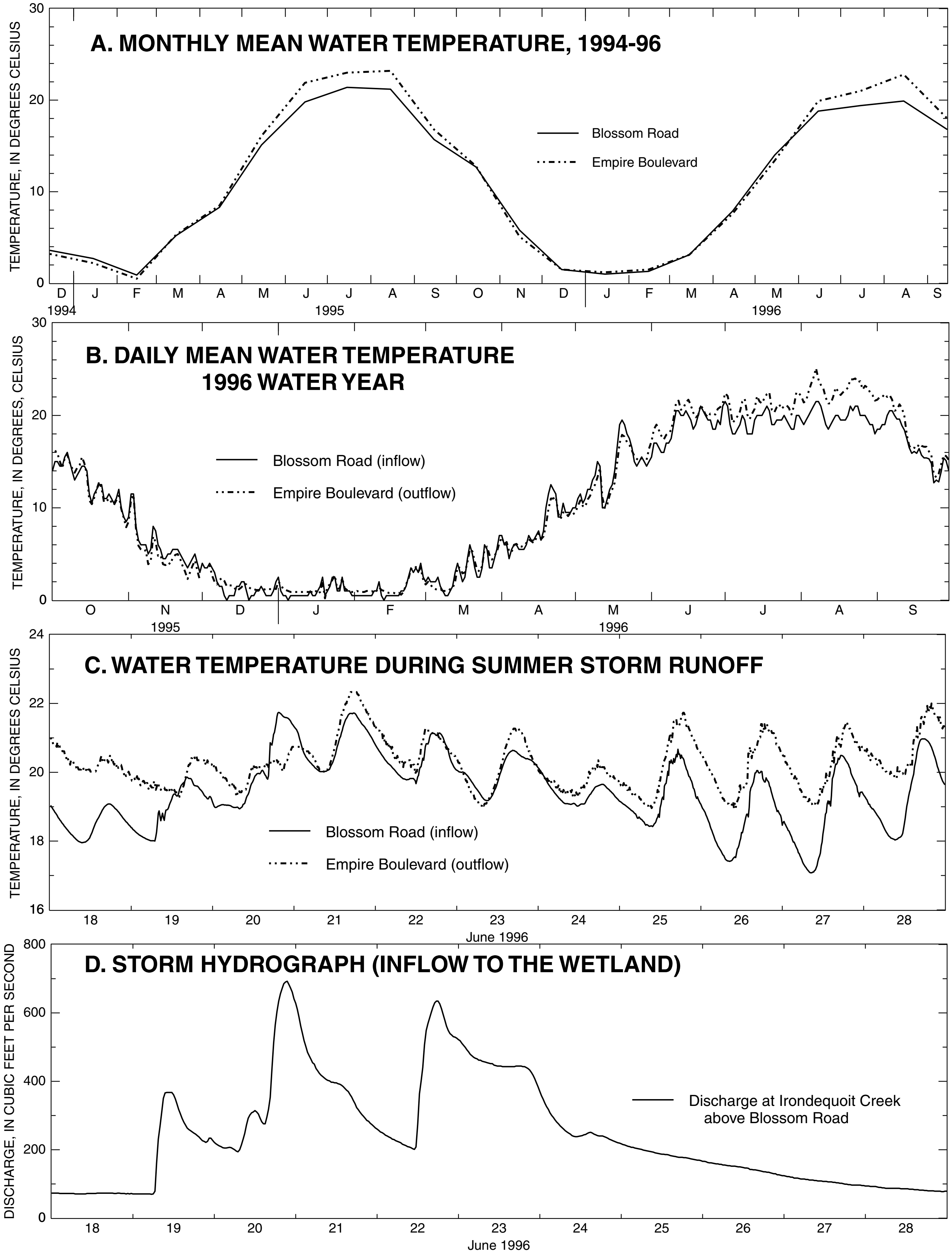

Figure 17. Water temperatures at Irondequoit Creek above Blossom Road and at Empire Boulevard, Monroe County, N.Y.: A. Monthly mean water temperature, 1994-96. B. Daily mean water temperature, 1996 water year. C. Water temperature and D. hydrograph during storm runoff period, June 18-28, 1996

insoluble salts, (2) are in particulate form, or (3) adsorb to mineral and organic particles (Kadlec and Knight, 1996). The storage potential of wetland soils for sorptive chemicals becomes limited, however, when the soil's capacity is reached (Mitsch and Gosselink, 1986; Gehrels and Mulamoottil, 1989; Kadlec and Knight, 1996). Thus, the only mechanism for increasing the capacity for long-term storage of chemicals is the accretion and subsequent burial of organic matter and the insoluble, particulate, and adsorbed chemicals

Characteristics of Wetland Vegetation (*Typha glauca)*

Vegetation plays an important role in the wetland's effectiveness in improving water quality. Plants provide filtration, nutrient assimilation and translocation, heavy-metal uptake, and surfaces for microbial growth and their subsequent utilization of nutrients (Kadlec and Knight, 1996). The Ellison Park wetland is an ideal environment for cattails, *Typha glauca*, which cover more than 60 percent of it. The cattails are extremely tall (more than 10 ft at the peak of the growing season) and have a high density, a large biomass, and a considerable capacity for taking up and utilizing nutrients during the growing season.

Density and Biomass

Characteristics of *Typha glauca* in the southern and northern parts of the wetland, including density, height, percentage of land surface covered, and biomass, for the two flora studies conducted during 1991 and 1996 are presented in table 10. About 63 percent, or 265 acres, of the wetland's land surface

Table 9. Concentrations of selected chemicals in sediment of Ellison Park wetland, Monroe County, N.Y., October 1994[1]

[Concentrations are average values from four samples. Percentages are by dry weight.]

Elements	Percent or concentration	Elements	Concentration	Organic compounds	Concentration
Percent by weight		**Parts per million** (cont.)		**Parts per billion**	
Aluminum	4.9	Gallium	12	Chlordane	22
Calcium	6.0	Lanthanum	24	DDD	4.8
Carbon, organic	4.0	Lead	65	DDE	7.5
Carbon, inorganic	1.7	Lithium	27	DDT	.8
Iron	2.6	Manganese	710	Dieldrin	2.2
Magnesium	1.3	Mercury	.19	PCB	40
Phosphorus	.13	Neodymium	24	Benzo *a* anthracene	850
Potassium	1.6	Nickel	20	Benzo *b* fluoranthene	1,000
Sodium	1.2	Niobium	11	Benzo *k* fluoranthene	1,040
Sulfur	.43	Scandium	8	Benzo *a* pyrene	800
Titanium	.26	Selenium	.7	Bis(2-ethyhexyl) phthalate	600
Parts per million		Silver	1.2	Chrysene	1,100
Antimony	0.4	Strontium	400	Fluoranthene	2,080
Arsenic	4.6	Thorium	6.2	Phenanthrene	920
Barium	460	Uranium	1.6	Pyrene	1720
Beryllium	1	Vanadium	48		
Cadmium	1.8	Yttrium	19		
Cerium	43	Ytterbium	2		
Chromium	49	Zinc	230		
Cobalt	11				
Copper	54				

[1] Values for other trace elements, organochlorine compounds, and polycyclic aromatic hydrocarbons that were not found in concentrations above the analytical detection limit are tabulated in Coon (1997).

was covered by cattails. Cattail density ranged from 31 to 38 shoots per 1-m^2 (3.3-ft^2) plot and averaged 34 shoots/m^2. These shoots averaged about 280 cm (9.2 ft) in height, and those in the northern part of the wetland averaged more than 300 cm (9.8 ft) in 1991 and attained maximum heights of 350 cm (11.5 ft). Cattail density and height varied with soil wetness; dry areas along streambanks and deep-water areas, where water depth exceeded about 40 cm (15 in.), yielded lower productivity than areas where the water level was between a few centimeters and about 30 cm (12 in.) above the top of the cattail mat.

The average weight of an individual shoot was 76 g; the maximum average was 90 g for plants in the northern part of the wetland during 1996. These long, dense shoots yielded a large biomass that averaged 2,608 g/m^2 above ground (46 percent of the total biomass) and 3,025 g/m^2 below ground. Maximum values were found in the northern wetland area during 1996. Above- and below-ground biomass exceeded most values reported by other researchers; reported measurements of peak above-ground biomass in *Typha glauca* range from 1,281 g/m^2 in an Iowa marsh (Van der Valk and Davis, 1978) to 1,361 g/m^2 in a central New York site (Bernard and Fitz, 1979) to 2,320 g/m^2 in a Minnesota marsh (Andrews and Pratt, 1978). Peak shoot biomass of other *Typha* species range from 1,118 to 2,338 g/m^2 (Whigham and others, 1978; Mason and Bryant, 1975; McNaughton, 1966; Van der Valk and Davis, 1978; Boyd and Hess, 1970; Boyd, 1971; Bray, Lawrence, and Pearson, 1959). Reported measurements of peak below-ground biomass in *Typha glauca* range from 1,450 g/m^2 in an Iowa marsh (Van der Valk and Davis, 1978) to 2,960 g/m^2 (Bray, 1960) and 3,100 g/m^2 (Andrews and Pratt, 1978) in two Minnesota sites. Peak below-ground biomass of other *Typha* species range from 2,646 to 5,053 g/m^2 (Whigham and others, 1978; McNaughton, 1966). Reported values for total biomass, which is infrequently measured, range from 3,405 g/m^2 in Oregon and 3,982 g/m^2 in Texas (McNaughton, 1966) to 4,230 and 4,720 g/m^2 in Minnesota (Andrews and Pratt, 1978; Bray, 1960). Total biomass measured in the Ellison Park wetland ranged from 4,801 g/m^2 in the southern area in 1991 to 7,085 g/m^2 in the northern area in 1996 and averaged 5,633 g/m^2 over the two study periods (table 10).

The values for all these characteristics, except cattail height in the northern area and below-ground biomass in the southern area, were lower in 1991 than in 1996, perhaps as a result of differences in sampling date, or chance variation in sampling resulting from differences in water depth, temperature, or other environmental factors. Seasonal variations in cattail biomass have been documented by many of the studies referenced above. Annual variation in wetland-plant biomass also has been reported: for example, a 37-percent difference in above-ground biomass of *Phragmites australis*, another emergent wetland plant, was found in Norfolk, England over a 3-yr period (Boar, 1996). Therefore, the mean values for both sampling periods (1991 and 1996) are considered reliable representations of the average values for cattails over the entire wetland (table 10).

Nutrients and Trace Metals

Results of the chemical analyses of cattail tissue are presented in table 11; the values represent above- and below-ground tissues collected from both parts of

Table 10. Characteristics of *Typha glauca* in Ellison Park wetland, Monroe County, N.Y., 1991 and 1996

[g/m^2, grams per square meter. Values are averages of samples collected along the specified transect. Data from Bernard and Seischab (1991, 1997).]

Characteristic	Transect location within wetland: 1991, Southern part	1991, Northern part	1996, Southern part	1996, Northern part	Overall mean
Number of 1-square-meter plots	31	26	31	20	27
Number of shoots per square meter	32	31	35	38	34
Height, centimeters	212	318	290	297	279
Percentage of land surface covered	68	79	88	97	83
Weight per shoot, grams	65	76	72	90	76
Above-ground biomass, g/m^2	2094	2368	2505	3466	2608
Below-ground biomass, g/m^2	2707	3291	2484	3619	3025
Total biomass, g/m^2	4801	5659	4989	7085	5633

the wetland during the two study periods (1991 and 1996). No striking differences are evident between the above-ground tissue data for 1991 and those for 1996, except possibly for aluminum and manganese concentrations, both of which were more than twice as great in 1991 as in 1996. The 1991 below-ground tissue data for most constituents also were similar to the 1996 data, except for boron concentrations, which were almost three times higher in 1991 than in 1996. Concentrations of sodium and lead were not measured in 1996.

Above-ground cattail tissues assimilated an average of 2.4 and 0.3 percent of their dry weight in nitrogen and phosphorus, respectively. Of the major macronutrients, nitrogen and potassium were found in higher concentrations in above-ground tissues (2.4 and 1.5 percent by dry weight, respectively) than in below-ground tissues; calcium and magnesium were found in higher concentrations in below-ground tissues. Above-ground concentrations of phosphorus, as well as molybdenum and manganese, were similar to those below ground; concentrations of all other chemicals were considerably higher in below-ground tissues. Concentrations of manganese (417 ppm) and sodium (3,600 ppm) in above-ground tissues were exceptionally high, as were those of aluminum (1,540 ppm), iron (15,400 ppm), manganese (433 ppm), and sodium (10,000 ppm) in below-ground tissues. These concentrations exceeded those typically found in a wide range of aquatic plants in natural wetlands (Hutchinson, 1975; Vitosh and others, 1973). The chemical composition of the Ellison Park cattails was generally within the range observed at two other cattail-study sites—a natural marsh in South Carolina (Boyd, 1970) and a constructed wetland in New York that receives landfill leachate (Bouldin and others, 1993). An exception was sodium, which was found in higher concentrations in the Ellison Park cattails than in those at the other sites, presumably as a result of winter road-salt application in the basin. Also, as in other studies, the highest concentration of micronutrients was found in below-ground tissues.

Chemical Standing Stocks

The standing stock of an element in an ecosystem is defined as the total mass of that element,

Table 11. Average dry-weight percentage or concentration of selected elements in above- and below-ground biomass of *Typha glauca* in Ellison Park wetland, Monroe County, N.Y., 1991 and 1996

[%, percent by weight; ppm, parts per million. Dash indicates no data.]

	Above-ground biomass			Below-ground biomass		
Element	1991	1996	Mean	1991	1996	Mean
Nitrogen, %	2.6	2.3	2.4	0.8	0.8	0.8
Phosphorus, %	.3	.3	.3	.2	.2	.2
Potassium, %	1.4	1.7	1.5	.4	.6	.5
Calcium, %	1.0	.8	.9	1.3	1.4	1.4
Magnesium, %	.2	.18	.19	.5	.5	.5
Copper, ppm	5.3	3.9	4.6	15.6	13.9	14.7
Nickel, ppm	1.6	1.1	1.4	9.6	11.7	10.6
Chromium, ppm	1.4	.12	.8	6.0	5.2	5.6
Cobalt, ppm	.1	.1	.1	.6	.6	.6
Molybdenum, ppm	.4	.5	.5	.6	.5	.5
Zinc, ppm	17.5	13.5	15.5	59.8	48.5	54.1
Aluminum, ppm	17.3	6.0	11.6	1,880	1,200	1,540
Iron, ppm	67.4	56.6	62.0	18,000	12,800	15,400
Boron, ppm	12.1	7.0	9.6	132	46.5	89.2
Manganese, ppm	598	236	417	458	408	433
Sodium, ppm	3,600	--	3,600	10,000	--	10,000
Lead, ppm	.6	--	.6	18.9	--	18.9

computed as the product of the element's concentration and the total biomass of the ecosystem. The total standing stocks of elements in above- and below-ground cattail tissues for 1991 and 1996, and the percentage of the total in the above-ground tissues, are presented in table 12. The above-ground tissue samples contained more than half of the total standing stocks of only three elements—nitrogen (73 percent), phosphorus (54 percent), and potassium (72 percent). Nitrogen had the largest above-ground standing stocks of any constituent measured, averaging almost 60 g/m^2; phosphorus, had just over 6 g/m^2 in above-ground tissues. Other elements with large above-ground standing stocks included potassium (37 g/m^2), calcium (23 g/m^2), and sodium (7 g/m^2). The other elements, especially the metals, tended to be concentrated in below-ground tissues; 98 percent of standing stocks of lead and more than 99 percent of standing stocks of iron and aluminum were found in below-ground tissues. Other elements with large below-ground standing stocks were iron (41 g/m^2), calcium (37 g/m^2), sodium (24 g/m^2), magnesium (14 g/m^2), and aluminum (4 g/m^2).

Water-Quality-Improvement Function of Ellison Park Wetland

A wetland's ability to improve water quality by the retention or removal of sediment and nutrients carried in stormwater, and the mechanisms by which this is achieved, are of special interest to water-resources managers, especially if the wetland is in an urban setting. The Ellison Park wetland is smaller than would be desired for a constructed wetland designed to effectively treat the volume and quality of stormwater that passes through it (the wetland covers 0.5 percent of Irondequoit Creek's drainage area). The water-quality, sediment, and biomass data obtained in this study indicate that the wetland provides effective stormwater treatment despite its small size and poor dispersal of all but the largest stormflows. The loads of particulate constituents (total phosphorus and suspended solids) and of constituents that form precipitates or that adsorb to, or chemically bind with, fine-grained sediment particles or organic matter (metals and organic chemicals) were significantly decreased by sedimentation and vegetative filtration. The loads of other constituents, such as organic

Table 12. Average standing stocks of selected elements in above- and below-ground biomass of *Typha glauca* in Ellison Park wetland, Monroe County, N.Y., 1991 and 1996

[g/m^2, grams per square meter; mg/m^2, milligrams per square meter. Dash indicates no data.]

Element	Above-ground standing stock			Below-ground standing stock			Total mean standing stock	Percent standing stock above ground
	1991	1996	Mean	1991	1996	Mean		
Nitrogen, g/m^2	50.1	68.1	59.1	19.1	23.8	21.4	80.5	73
Phosphorus, g/m^2	4.8	8.3	6.5	5.2	6.0	5.6	12.1	54
Potassium, g/m^2	27.0	47.8	37.4	9.6	19.6	14.6	52.0	72
Calcium, g/m^2	19.2	26.5	22.8	30.4	43.6	37.0	59.8	38
Magnesium, g/m^2	3.8	5.4	4.6	10.8	16.4	13.6	18.2	25
Iron, g/m^2	.13	.17	.15	43.4	39.4	41.4	41.6	.4
Manganese, g/m^2	1.2	.7	.9	1.0	1.2	1.1	2.0	45
Sodium, g/m^2	6.9	--	6.9	24.1	--	24.1	31.0	22
Copper, mg/m^2	10.2	11.8	11.0	37.6	41.8	39.7	50.7	22
Nickel, mg/m^2	3.0	3.0	3.0	23.1	35.4	29.2	32.2	9
Chromium, mg/m^2	2.6	.3	1.4	14.4	15.0	14.7	16.1	9
Cobalt, mg/m^2	.09	.20	.14	1.4	1.8	1.2	1.3	11
Molybdenum, mg/m^2	.8	1.5	1.1	1.4	1.5	1.4	2.5	44
Zinc, mg/m^2	33.6	40.2	36.9	144	149	146	183	20
Aluminum, mg/m^2	33.3	17.5	25.4	4,524	3,662	4,093	4,118	.6
Boron, mg/m^2	23.2	20.4	21.8	320	140	230	252	9
Lead, mg/m^2	1.1	--	1.1	45.6	--	45.6	46.7	2

nitrogen, nitrate plus nitrite, and sulfate, were moderately decreased, although the long-term (6-year) removal efficiencies were low, less than 8 percent.

The input-output relations and the chemical-removal efficiencies found in this study were determined mainly by: (1) inflow loading rates, (2) storage or release mechanisms in the sediments, and (3) accretion and burial of organic detritus. The chemical loads and removal efficiencies for most constituents were directly related to stream discharge; that is, high flows produced large chemical loads and resulted in high removal efficiencies for constituents that were affected by the wetland, and low flows generally resulted in low removal efficiencies (relative to a given constituent).

Many of the chemicals, such as the metals, for which the cattail-tissue samples were analyzed, were more abundant in below-ground tissue than in above-ground tissue, but even nitrogen, phosphorus, and potassium, whose above-ground standing stocks were large during the growing season, might have been translocated below ground prior to senescence and stored during the winter. Generally *T. glauca* retains less than half of the summer standing stocks of these nutrients at the time of senescence (Bernard and Fitz, 1979); the remainder may be released into the water, and large releases of elements during fall and winter have been documented in some studies (Mason and Bryant, 1975; Gehrels and Mulamoottil, 1989). The chemical concentrations of some constituents showed seasonal patterns in this study, but most of the patterns were evident in the inflow data as well as the outflow data and, therefore, cannot be attributed to wetland processes alone. The chemical load data also do not indicate a seasonal release of nutrients during senescence, except possibly for nitrate plus nitrite, but do indicate that large amounts of chemicals are stored in the sediments and below-ground biomass. In addition to this long-term retention of nutrients and trace elements, the above-ground biomass and the microbial community provide a seasonal storage of chemicals. This seasonal retention is not reflected by the surface-water output loads of most constituents, however, and indicates that most of the seasonal nutrient needs of flora and microbes are not met by surface-water inputs, but through internal cycling of chemicals from the sediments and detritus, and that vegetative assimilation generally did not measurably decrease the nutrient loads in surface water passing through the wetland. A similar conclusion was reached by Johnston (1991), who reviewed the results of many wetland studies and noted that, with the exception of floating plants, vegetative uptake often is less important in sediment and nutrient retention in wetlands than physical and microbial processes. In the Ellison Park wetland, physical processes are the primary mechanisms for the decrease in surface-water chemical loads, but the effect of microbial processes, although considered substantial, were not studied directly and, except for the generation of ammonia nitrogen, had no identifiable effect on surface-water chemical loads.

The two removal processes that can be considered ultimate sinks for nutrients retained in a *Typha sp.* wetland are denitrification and the permanent burial of nutrients in sediment (Prentki and others, 1978). The effectiveness of burial is dependent on the availability of buried nutrients in root-zone soils, and the susceptibility of these nutrients to reuptake by wetland plants and subsequent release back into surface waters. If the depth of burial is sufficient to inhibit the translocation of nutrients in this manner, accretion and burial of sediment and dead but undecomposed plant tissues will be an effective nutrient trap and would provide a long-term removal mechanism for some chemicals. The magnitude of this removal mechanism in the Ellison Park wetland has not been documented, however.

Progress Toward Water-Quality Improvement of Irondequoit Bay

Improvement of the ecological and recreational status of Irondequoit Bay through control of nutrient loads entering the bay have been management objectives of Monroe County since the 1970’s. Progress toward these objectives has been monitored by (1) evaluation of the bay’s trophic status through periodic sampling of summer phytoplankton chlorophyll_*a* concentrations and calculation of biologically available phosphorus concentrations in the bay, and (2) estimation of constituent loads entering the bay in surface-runoff.

Trophic Status

Two limnological measures of lake fertility are concentrations of phytoplankton chlorophyll, a measure of algal growth present, and phosphorus, a productivity-limiting nutrient. Chlorophyll_*a* concentrations have been measured in Irondequoit Bay since 1971 (MCEHL, written comm., 1997). Biweekly water samples are collected at a measuring site at the deepest point in the bay between May 1 and October 31 at about 3-ft intervals through about 20 ft of depth in the epilimnion. Concentrations of chlorophyll_*a* within the water column are averaged for a given day, and the mean of these daily values is used as the summer mean chlorophyll concentration. The potential, or biologically available, phosphorus concentration in the bay is computed from the annual total-phosphorus load and surface-water discharge to the system, and the bay's mean depth and surface area (Vollenweider, 1976). The chlorophyll_*a* and potential-phosphorus concentrations in the bay indicated the eutrophic conditions during the 1970's, when effluent from sewage-treatment plants was discharged into Irondequoit Creek (fig. 18). These concentrations have decreased in response to the cessation of effluent discharges in 1977 and, possibly, to erosion- and stormwater-control measures implemented by Monroe County to decrease chemical loads from nonpoint sources in the basin. The trophic state of Irondequoit Bay has improved during the last 20 years, but this improvement has not reached target levels nor returned the bay to mesotrophic conditions.

Temporal Trends in Chemical Loads

Data from this study indicate that the average annual loads of selected chemical constituents entering Irondequoit Bay, as measured at the Empire Boulevard monitoring site and adjusted for the intervening surface-drainage area, are: total nitrogen, 289 tons, which includes 130 tons of ammonia-plus-organic nitrogen and 159 tons of nitrate-plus-nitrite nitrogen; total phosphorus, 21 tons; total suspended solids, 16,700 tons; dissolved chloride, 19,200 tons; and sulfate, 17,200 tons (table 13). Corresponding

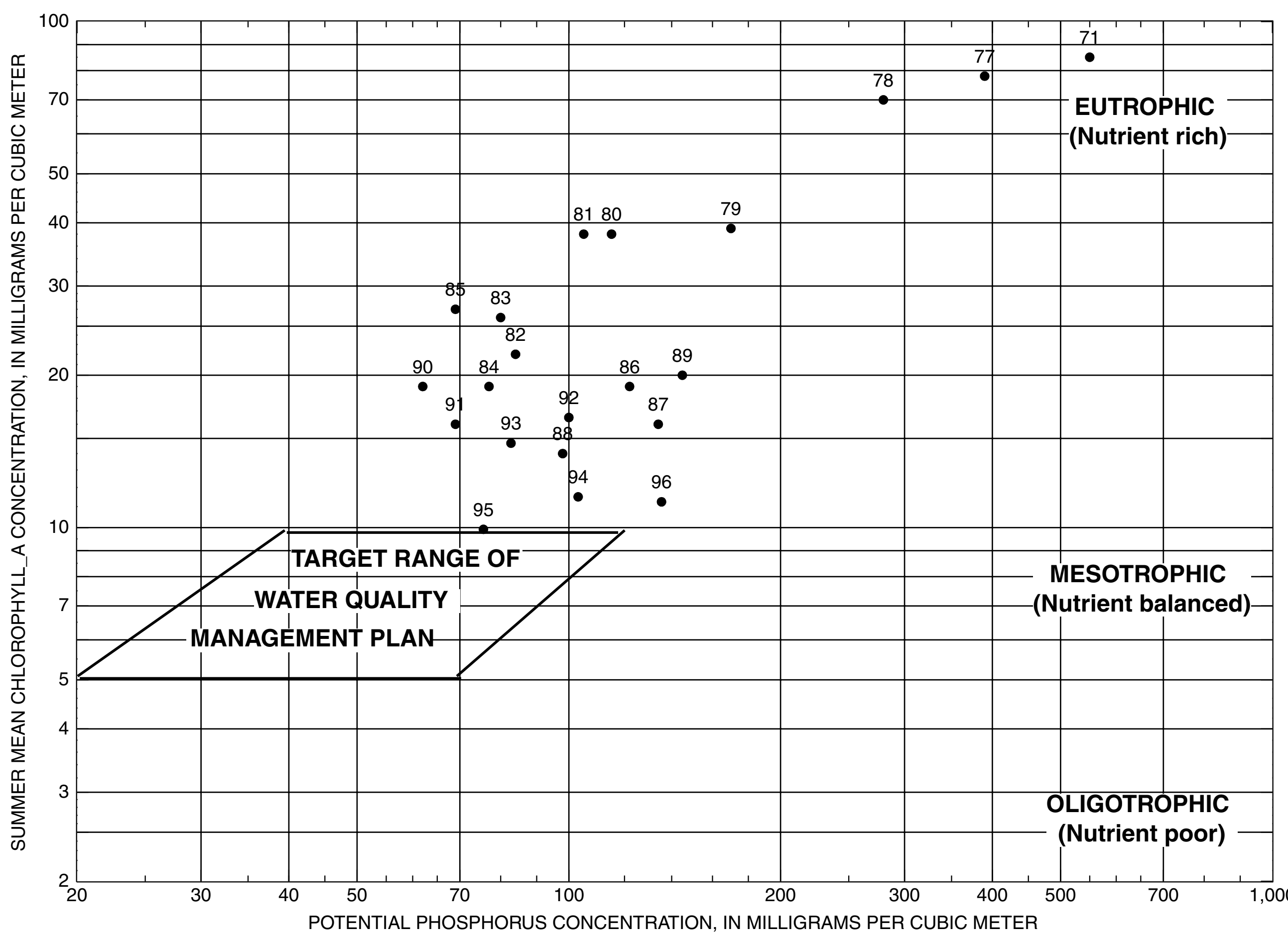

Figure 18. Trophic state of Irondequoit Bay, 1971-96, based on measured chlorophyll_*a* and computed potential-phosphorus concentrations (Source: Monroe County Environmental Health Laboratory.)

values calculated from data collected during 1980-81 and 1984-88 (Kappel and others, 1986; Johnston and Sherwood, 1996) should indicate whether decreasing trends are present, but these are difficult to evaluate because the earlier load calculations were based on data collected at the Blossom Road monitoring site (adjusted for intervening surface-drainage area by a multiplier of 1.17). This estimation technique assumed that loading rates from the intervening area (the Ellison Park wetland) were comparable to those from the rest of the basin, whereas the present study (1990-96) indicated that the wetland can have a significant effect on the loads of certain constituents. For example, loads of total phosphorus and total suspended solids were greatly decreased by passage through the wetland; therefore, the estimated loads of these constituents, which were based on the adjusted Blossom Road values, probably exceeded the loads actually entering Irondequoit Bay by about 30 percent for TP and about 50 percent for TSS (based on 1990-96 estimated loads, table 13). Loads of conservative constituents, such as chloride and sulfate, which did not appear to be strongly affected by the wetland, also might have been slightly overestimated, and the loads of ammonia nitrogen and orthophosphate, which increased during passage through the wetland, probably were underestimated by this calculation method.

Comparison of estimated annual loads transported by Irondequoit Creek to Irondequoit Bay during the 1980-81 study (Kappel and others, 1986) with those for 1984-88 (table 13), indicates a decrease in TKN loads (24 tons, 11 percent), and an increase in TP loads (2.9 tons, 14 percent) and TSS loads (9,300 tons, 49 percent); chloride loads to Irondequoit Bay did not change substantially. Some of the differences between the two periods might be attributed to the differing lengths of time spanned by each study—the 1980-81 data provide a 1-year “snapshot” of a dynamic system, whereas the 1984-88 values represent a 5-year period. A comparison of the 1984-88 data with those from this study, which covered a similar time span, should provide a more reliable basis

Table 13. Estimated average annual loads of selected chemical constituents entering Irondequoit Bay, Monroe County, N.Y.

[All values are in tons. Dash indicates no data available.]

Constituent	Values based on data from: Upstream end of wetland (Blossom Road)[1] 1980-81[3]	Upstream end of wetland (Blossom Road)[1] 1984-88[4]	Upstream end of wetland (Blossom Road)[1] 1990-96[5]	Downstream end of wetland (Empire Boulevard)[2] 1990-96[5]
Total nitrogen	--	383	322	289
Ammonia-plus-organic nitrogen	214	190	148	130
Ammonia nitrogen	--	6.33	3.03	5.24
Organic nitrogen	--	184	145	125
Nitrate plus nitrite	--	193	174	159
Total phosphorus	20.2	23.1	30.7	20.9
Orthophosphate	--	2.44	1.97	2.56
Total suspended solids	19,100	28,400	33,300	16,700
Volatile suspended solids	--	3,170	4,140	2,290
Nonvolatile suspended solids	--	25,200	29,200	14,400
Chloride	16,400	16,700	19,700	19,200
Sulfate	--	18,700	18,700	17,200

[1]Values are estimated loads computed for Irondequoit Creek at Blossom Road multiplied by 1.17 to account for the drainage area between Blossom Road and the mouth of Irondequoit Bay.

[2]Values are estimated loads computed for Irondequoit Creek at Empire Boulevard multiplied by 1.10 to account for the drainage area between Empire Boulevard and the mouth of Irondequoit Bay.

[3]Data from Kappel and others (1986).

[4]Data from Johnston and Sherwood (1996).

[5]Data from this study, 1990-96.

for discerning long-term temporal trends in constituent loads.

The chemical loads entering Irondequoit Bay as calculated from the 1990-96 data were computed two ways—the first calculation used the Blossom Road (wetland inflow) loads adjusted by the drainage-area multiplier of 1.17 (as was done for the earlier load estimates), and the second used the Empire Boulevard (wetland outflow) loads adjusted by a drainage-area multiplier of 1.10 (table 13). Comparison of these results confirms the potential error inherent in the use of the upstream (Blossom Road) data; that is, overestimation for constituents whose loads are significantly decreased by the wetland, especially total phosphorus, total nitrogen, and total suspended solids, and underestimation for those that are increased in the wetland, such as orthophosphate and ammonia nitrogen. The results indicate that (1) the loads of all major forms of nitrogen entering Irondequoit Bay have decreased since the 1980's, (2) the loads of chloride have increased, (3) the loads of sulfate have remained about the same, and (4) the loads of ammonia nitrogen and orthophosphate entering the Ellison Park wetland have decreased, and (5) the loads of total phosphorus and suspended solids entering the wetland have increased. This increase in TP and TSS loads is possibly a result of increased erosion potential and transport capability of stormflows from an increasingly developed watershed and is substantiated by Young (1996), who documented an increasing rate of sediment accumulation in the floodplain of the lower Irondequoit Creek during the 20th century. The trend in loads of TP, TSS, NH_3, and PO_4 entering Irondequoit Bay since the 1980's cannot be reliably defined because the removal of TP and TSS and generation of NH_3 and PO_4 in the wetland during the two earlier study periods are unknown.

SUMMARY

A 6-year (1990-96) study of the Ellison Park wetland in Monroe County, N.Y., was conducted by the USGS, in cooperation with the Monroe County Department of Health, to document the effect of this predominantly cattail marsh on the chemical quality of Irondequoit Creek, which flows through it. This stream drains 151 mi^2 of mostly residential and urban land and is the main tributary to Irondequoit Bay. The wetland covers 423 acres and is mostly a palustrine persistent emergent marsh that is divided topographically into a southern and a northern part. Water levels in the wetland are controlled by the water-surface elevation of Irondequoit Bay and Lake Ontario. The seasonal periods of inundation averaged 136 and 189 days in the southern and northern areas, respectively. The average maximum depth of inundation during these periods was 1.1 ft in the southern part and 1.5 ft in the northern part.

Stream-discharge and water-quality data were collected at the inlet and outlet of the wetland, and the chemical loads were computed. Results indicate that the wetland decreased loads of particulate constituents and those chemicals associated with fine-grained sediment and organic matter, presumably through vegetative filtration, precipitation, and sedimentation and removal of adsorbed chemicals. Total-phosphorus and suspended-solids loads were decreased by 28 and 47 percent, respectively, over the 6-year study period, and outflow concentrations of metals (zinc, lead, and cadmium) were significantly lower than inflow concentrations. Ammonia nitrogen and orthophosphate output loads exceeded their input loads (-38 and -84 percent removal efficiencies, respectively) but represented only 1 to 2 percent of total nitrogen loads and 6 to 12 percent of total phosphorus loads, respectively. The export of these constituents reflects generation through leaching and decomposition of organic matter and the diffusion of ammonia nitrogen from the reduced wetland soils. The loads of other constituents, such as organic nitrogen, nitrate plus nitrite, and sulfate, were decreased by the wetland, but the long-term (6-year) removal efficiencies were low (less than 8 percent). The wetland appeared to have little effect on conservative constituents, such as chloride and sulfate. Removal efficiencies for total phosphorus, orthophosphate, and, possibly, suspended solids, appeared to increase after a diversion- control modification in1994 that permitted additional stormwater to flow into the southeastern backwater area of the wetland to increase dispersal and detention time. Water temperatures were minimally affected by the wetland during winter, but the summer daily mean outflow temperatures were generally 1 to 2 °C warmer than the inflow temperatures. The summer differences between outflow and inflow temperatures usually decreased during the passage of storm runoff.

The wetland sediments in open-water areas are predominantly silt sized and smaller and contained relatively small amounts of organic matter. The high

percentage of fine-grained mineral particles and particulate forms of chemicals, such as suspended solids and phosphorus, that accumulated in these depositional areas are reflected in the wetland's high removal efficiency for these constituents. The relatively low concentrations of organic carbon in the sediments reflect the lower rate of biomass accumulation from small submergent aquatic macrophytes here than would be expected in the cattail-covered areas. The sediments also contained high concentrations of trace metals, including barium, manganese, strontium, and zinc (each of which exceeded 200 ppm during this study), chromium, copper, lead, and vanadium; some polycyclic aromatic hydrocarbons, including chrysene, fluoranthene, phenanthrene, and pyrene; and persistent organochlorine pesticides (chlordane, dieldrin, DDT and its metabolic-degradation products, DDD and DDE) and polychlorinated biphenyls (PCB's).

Cattails, primarily *Typha glauca*, covered about 63 percent of the wetland, attained a maximum height of 350 cm, a density of more than 30 shoots/m^2, and a total biomass of over 5,600 g/m^2, 46 percent of which was in above-ground tissues during the summer. Chemical analyses of cattail tissues indicated that the above-ground tissues contained greater concentrations of nitrogen and potassium (2.4 and 1.5 percent by dry weight, respectively) than the below-ground tissues and considerably lower concentrations of all other constituents than the below-ground tissues, except for phosphorus, molybdenum, and manganese, whose concentrations in above-ground tissue were similar to those in below-ground tissue. The concentrations of four elements exceeded those typically found in natural wetlands—manganese (417 ppm) and sodium (3,600 ppm) in above-ground tissues; and aluminum (1,540 ppm), iron (15,400 ppm), manganese (433 ppm), and sodium (10,000 ppm) in below-ground tissues.

The wetland vegetation undoubtedly assimilated large quantities of nutrients during the growing season as indicated by the large biomass, but neither tissue production nor microbial metabolic processes appeared to appreciably affect the seasonal removal-efficiency patterns of surface-water chemical loads. Presumably, internal cycling of nutrients in the sediments and organic detritus, combined with a summer increase in microbially mediated chemical transformations, obscured the effect of vegetative assimilation on surface-water loads. Additionally, confinement of most flows within the banks of Irondequoit Creek, which resulted in passage of storm water through the wetland with little dispersion or detention of water in the cattail and backwater areas of the wetland, diminished the wetland's capability for water-quality improvement. Anaerobic conditions in the wetland soils probably were the reason for generation of ammonia nitrogen (through microbially mediated reduction of nitrate) and orthophosphate (through dissolution of cation-phosphate precipitates). The dominant factors in the chemical-removal efficiency of the wetland are (1) inflow-loading rates, (2) storage and release mechanisms of the sediments (sedimentation, adsorption, filtration, precipitation, dissolution, and resuspension), and (3) accretion and burial of organic matter.

Measurements of chlorophyll_*a* concentrations and calculations of potential phosphorus concentrations made since the 1970's indicate an improvement in the trophic state of Irondequoit Bay. Estimated annual loads of selected constituents indicated a decrease in loadings of all major forms of nitrogen, an increase in chloride loads, and little change in sulfate loads since 1980. Loads of total phosphorus and suspended solids entering the wetland increased during this period, possibly in response to increased stormflow volume and erosion from increased development in the watershed, but the trends of these loads entering Irondequoit Bay cannot be reliably defined because their removal efficiencies during the 1980's are unknown. Loads of ammonia nitrogen and orthophosphate entering the wetland have decreased, but no trends on loads entering Irondequoit Bay can be stated because the generation of these constituents within the wetland was not taken into account by the earlier studies. Average annual loads (1990-96) of selected constituents entering Irondequoit Bay, as measured at the wetland outflow (Empire Boulevard) monitoring site and adjusted for the intervening surface-drainage area, were estimated to be 289 tons of total nitrogen (including 130 tons of ammonia-plus-organic nitrogen and 159 tons of nitrate-plus-nitrite nitrogen), 21 tons of total phosphorus, 16,700 tons of total suspended solids, 19,200 tons of dissolved chloride, and 17,200 tons of sulfate.

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Appendix 1. Selected chemical analyses of water samples from Irondequoit Creek above Blossom Road and at Empire Boulevard (Ellison Park wetland inflow and outflow sites), Monroe County, N.Y., 1990-96

[yr-mo-d, year, month, day; Q, mean discharge; ft^3/s, cubic feet per second; Cd, total cadmium; Cu, total recoverable copper; Pb, total recoverable lead; Zn, total recoverable zinc; TOC, total organic carbon; BOD_5, 5-day biochemical oxygen demand; COD, chemical oxygen demand; Alk, alkalinity as calcium carbonate; Spec. Cond., specific conductance; µS/cm, microsiemens per centimeter. Dash indicates no data; <, less than.]

Beginning of sampling period		End of sampling period		Q	Metals (micrograms per liter)				Physical properties (milligrams per liter)				Spec. Cond.
Yr-mo-d	Time	Yr-mo-d	Time	(ft^3/s)	Cd	Cu	Pb	Zn	TOC	BOD_5	COD	Alk	(µS/cm)
A. Irondequoit Creek above Blossom Road, Rochester, N.Y. (station 0423205010)													
1990-01-03	1915	90-01-05	0915	170	< 1	50	< 5	80	--	--	--	--	--
1990-01-18	0115	90-01-19	0915	350	< 1	60	82	180	--	--	--	--	--
1990-02-08	1015	90-02-09	0515	340	1	40	13	70	--	--	--	--	--
1990-02-09	0615	90-02-12	0915	540	< 1	50	32	120	--	--	--	--	825
1990-02-22	1535	90-02-23	0835	500	3	50	30	120	--	--	--	--	--
1991-03-02	1005	91-03-04	0305	440	2	90	50	240	--	--	--	--	890
1991-03-07	1105	91-03-08	1005	560	1	70	84	260	--	--	--	--	612
1991-03-08	1320	--	--	410	< 5	< 10	< 5	40	--	--	--	--	697
1991-03-11	1140	--	--	210	< 1	< 10	7	< 40	--	--	--	--	877
1992-02-18	1020	92-02-19	1320	140	< 1	120	6	60	--	--	--	--	1280
1992-02-18	1055	92-02-19	1355	144	< 1	60	< 5	40	--	--	--	--	1290
1992-02-19	1420	92-02-20	0820	190	< 1	50	20	40	--	--	--	--	1300
1992-02-19	1455	92-02-20	0855	186	< 1	30	9	40	--	--	--	--	1300
1992-02-20	0915	92-02-22	2015	160	< 1	60	5	40	--	--	--	--	1170
1992-02-20	0940	92-02-22	2040	160	< 1	20	--	50	--	--	--	--	1180
1992-02-22	2115	92-02-24	0815	190	< 1	60	6	40	--	--	--	--	1170
1992-02-22	2140	92-02-24	0840	188	< 1	< 20	< 5	60	--	--	--	--	1170
1992-03-26	0915	92-03-27	2015	610	1	90	56	290	--	--	--	--	--
1992-03-27	2115	92-03-30	0815	850	< 1	90	15	140	--	--	--	--	--
1992-10-09	1330	92-10-10	0430	299	1	70	16	110	--	--	--	--	708
1992-10-10	0530	92-10-13	1030	160	< 1	40	6	60	--	--	--	--	810
1992-11-02	1030	92-11-03	0930	312	1	50	7	50	--	--	--	--	813
1992-11-03	1030	92-11-05	0430	342	3	100	10	40	--	--	--	--	684
1992-12-10	1100	92-12-14	1000	120	< 1	60	< 5	< 40	--	--	--	--	1420
1992-12-14	1205	92-12-16	0505	140	< 1	80	< 5	40	--	--	--	--	1230
1992-12-16	0605	92-12-17	1005	286	< 1	70	6	60	--	--	--	--	1150
1992-12-17	1100	92-12-18	0200	498	< 1	60	--	80	--	--	--	--	931
1992-12-18	0300	92-12-21	1000	439	< 1	50	--	70	--	--	--	--	792

Appendix 1. Selected chemical analyses of water samples from Irondequoit Creek above Blossom Road and at Empire Boulevard (Ellison Park wetland inflow and outflow sites), Monroe County, N.Y., 1990-96 (continued)

Beginning of sampling period		End of sampling period		Q	Metals (micrograms per liter)				Physical properties (milligrams per liter)				Spec. Cond.
Yr-mo-d	Time	Yr-mo-d	Time	(ft^3/s)	Cd	Cu	Pb	Zn	TOC	BOD_5	COD	Alk	(µS/cm)
A. Irondequoit Creek above Blossom Road, Rochester, N.Y. (station 0423205010, cont.)													
1993-02-04	1215	--	--	147	< 1	< 50	< 5	< 40	--	--	--	--	--
1993-03-22	0920	93-03-25	0820	307	< 1	100	5	50	--	--	--	--	--
1993-03-25	0915	93-03-29	0815	721	< 1	70	6	60	--	--	--	--	--
1993-03-29	0925	93-03-30	0025	1270	< 1	120	20	80	--	< 2.00	--	159	575
1993-03-29	0925	93-03-31	0025	1360	--	120	--	80	--	--	--	--	--
1993-04-01	0945	--	--	1400	1	20	8	70	--	< 2.00	--	146	508
1993-04-05	0935	93-04-08	0835	482	< 1	40	12	60	4.60	< 2.00	--	198	698
1993-05-24	0900	93-05-28	0800	87	< 1	60	8	60	3.80	3.00	--	244	1060
1993-06-05	0525	93-06-05	2025	318	< 1	110	80	370	6.60	12.3	--	--	777
1993-06-05	2125	93-06-06	1225	238	2	90	18	180	5.90	9.70	--	--	792
1993-09-03	0035	93-09-04	0035	159	< 1	100	48	270	6.10	7.20	--	127	654
1993-09-04	0135	93-09-06	0735	71	< 1	70	22	130	4.60	< 4.00	--	388	910
1993-11-24	1005	93-11-27	0705	68	< 1	--	6	50	3.50	< 2.00	< 10	246	1160
1993-11-27	0805	93-11-28	1305	431	< 1	--	20	180	4.90	3.50	37	179	824
1993-11-28	1405	93-11-29	0905	580	< 1	--	16	110	6.70	4.50	33	158	633
1993-11-29	0905	93-12-02	0805	203	< 1	--	< 5	--	6.60	2.30	16	195	852
1994-01-14	0950	94-01-18	0850	58	< 1	--	< 5	--	--	2.00	--	262	1380
1994-02-18	0920	94-02-21	0820	320	< 1	--	11	--	--	2.30	35	196	1580
1994-02-21	0920	94-02-22	0820	818	< 1	--	7	--	--	3.30	--	138	801
1994-02-22	0905	94-02-24	0905	392	< 1	--	6	--	--	< 2.00	38	171	881
1994-03-21	0920	94-03-23	0220	735	1	50	15	--	--	2.20	53	184	830
1994-03-23	0320	94-03-24	0820	959	2	40	9	--	--	2.10	31	146	579
1994-03-24	0930	94-03-24	2030	724	1	30	5	--	--	--	22	141	600
1994-04-12	1820	94-04-14	0820	780	--	30	12	--	--	3.60	58	178	748
1994-04-14	0900	94-04-18	0800	383	2	20	11	--	--	2.30	18	190	771
1994-06-09	0920	94-06-13	0820	65	--	58	2	--	--	--	--	236	1110
1994-08-13	0925	94-08-14	1225	148	< 1	40	10	--	--	2.70	28	180	895
1994-08-14	1325	94-08-15	0825	168	< 1	50	13	--	--	3.60	60	148	615
1994-08-15	0900	94-08-18	0800	68	< 1	40	6	< 40	--	< 2.00	14	199	1170
1994-09-19	0915	94-09-22	0815	52	< 1	30	< 5	< 40	--	2.10	26	210	1030
1994-12-05	0940	94-12-06	0240	264	2	28	--	--	--	< 2.00	--	168	764

Appendix 1. Selected chemical analyses of water samples from Irondequoit Creek above Blossom Road and at Empire Boulevard (Ellison Park wetland inflow and outflow sites), Monroe County, N.Y., 1990-96 (continued)

Beginning of sampling period		End of sampling period		Q	Metals (micrograms per liter)				Physical properties (milligrams per liter)				Spec. Cond.
Yr-mo-d	Time	Yr-mo-d	Time	(ft^3/s)	Cd	Cu	Pb	Zn	TOC	BOD_5	COD	Alk	($\mu S/cm$)
A. Irondequoit Creek above Blossom Road, Rochester, N.Y. (station 0423205010, cont.)													
1994-12-06	0340	94-12-07	2040	190	2	27	--	--	--	< 2.00	--	199	962
1994-12-08	0915	94-12-09	1615	138	< 1	30	5	40	--	< 2.00	--	221	1200
1994-12-30	0745	94-12-31	1845	57	< 1	40	< 5	< 40	--	2.00	< 10	257	1170
1995-02-09	0930	95-02-13	0830	60	< 1	< 50	< 5	< 40	--	< 2.00	18	254	1450
1995-03-06	1645	95-03-08	1250	283	1	20	< 5	40	--	2.00	--	206	1070
1995-03-08	1350	95-03-09	0750	322	< 1	20	< 5	< 40	--	2.00	--	185	1060
1995-03-09	0815	95-03-13	0715	222	< 1	20	< 5	< 40	--	< 2.00	--	210	1210
1995-03-13	0930	95-03-16	0730	187	< 1	20	2	50	--	< 2.00	--	212	1050
1995-03-16	0805	95-03-20	0705	148	1	20	< 2	< 40	--	< 2.00	--	230	1170
1995-05-08	1125	95-05-09	2225	52	< 1	< 20	1.7	< 40	--	< 2.00	--	231	--
1995-05-09	2325	95-05-11	1025	94	< 1	< 20	3	< 40	--	< 2.00	--	231	--
1995-08-21	1245	95-08-24	1045	30	< 1	20	< 5	30	2.3	< 2.00	--	211	1260
1995-10-21	0315	95-10-21	1815	1030	< 1	30	34	220	--	< 4.00	--	137	526
1995-10-21	1915	95-10-23	1015	551	< 1	30	12	70	--	< 2.00	45	129	640
1995-12-11	1200	95-12-14	1100	58	< 1	20	< 5	20	6.3	< 2.00	11	280	1430
1996-01-16	1045	96-01-18	0945	189	< 1	20	7	55	7.20	< 2.00	33	232	1700
1996-01-18	1025	96-01-19	2125	933	1	70	31	220	7.10	8.20	186	215	1160
1996-01-19	2225	96-01-22	0525	777	2	80	34	360	10.1	14.0	255	327	792
1996-01-22	1125	96-01-25	1025	336	< 1	40	10	45	7.60	2.00	--	194	1150
1996-01-25	1040	96-01-29	0940	268	< 1	30	13	35	5.80	< 2.00	--	198	1100
1996-01-29	1100	96-02-01	1000	145	< 1	20	8	30	5.70	< 2.00	25	239	1250
1996-02-01	1045	96-02-05	0945	86	< 1	20	8	25	5.20	< 2.00	23	273	1340
1996-04-12	1440	96-04-14	0140	475	< 1	50	< 5	30	5.60	2.30	--	198	1020
1996-04-14	0240	96-04-15	0940	866	< 1	50	9	40	11.0	2.90	--	172	695
1996-04-14	1100	96-04-17	0820	287	< 1	30	< 5	20	6.20	< 2.00	--	200	930
1996-04-18	1045	96-04-22	0945	229	< 1	20	< 5	10	--	--	--	218	1040

Appendix 1. Selected chemical analyses of water samples from Irondequoit Creek above Blossom Road and at Empire Boulevard (Ellison Park wetland inflow and outflow sites), Monroe County, N.Y., 1990-96 (continued)

Beginning of sampling period		End of sampling period		Q	Metals (micrograms per liter)				Physical properties (milligrams per liter)				Spec. Cond.
Yr-mo-d	Time	Yr-mo-d	Time	(ft^3/s)	Cd	Cu	Pb	Zn	TOC	BOD_5	COD	Alk	(µS/cm)
B. Irondequoit Creek at Empire Boulevard, Rochester, N.Y. (station 0423205025)													
1991-03-02	1825	91-03-04	0925	438	1	80	39	150	--	--	--	--	832
1991-03-06	1110	91-03-08	1010	659	< 1	70	13	90	--	--	--	--	610
1991-03-08	1015	91-03-11	0915	291	< 1	50	8	60	--	--	--	--	772
1991-03-12	0955	--	--	175	< 1	< 10	< 5	< 40	--	--	--	--	--
1992-02-14	1015	92-02-15	1715	72	< 1	60	< 5	--	--	--	--	--	1610
1992-02-15	1815	92-02-16	1715	136	< 1	70	6	--	--	--	--	--	1800
1992-02-16	1815	92-02-17	1915	143	< 1	70	< 5	--	--	--	--	--	1400
1992-02-18	1130	92-02-19	1430	136	< 1	70	7	--	--	--	--	--	1310
1992-02-19	1530	92-02-20	0930	160	< 1	70	7	--	--	--	--	--	1320
1992-02-20	1015	92-02-22	2115	148	< 1	60	5	< 40	--	--	--	--	1200
1992-02-22	2215	92-02-24	0915	176	< 1	50	< 5	< 40	--	--	--	--	1230
1992-03-26	1000	92-03-28	0400	714	1	90	37	120	--	--	--	--	--
1992-03-28	0500	92-03-30	0900	1010	1	< 50	14	90	--	--	--	--	--
1992-10-09	0945	92-10-10	0845	256	< 1	40	8	70	--	--	--	--	880
1992-10-10	0945	92-10-13	0845	167	< 1	40	6	60	--	--	--	--	785
1992-11-02	1010	92-11-03	2110	316	1	40	9	70	--	--	--	--	816
1992-11-03	2210	92-11-05	0910	336	1	40	7	70	--	--	--	--	694
1992-12-10	1025	92-12-14	0925	134	< 1	60	< 5	40	--	--	--	--	1460
1992-12-14	1125	92-12-16	0725	147	< 1	80	< 5	30	--	--	--	--	1300
1992-12-16	0825	92-12-17	0925	276	< 1	90	< 5	50	--	--	--	--	1210
1992-12-17	1025	92-12-18	0125	437	< 1	70	--	110	--	--	--	--	1020
1992-12-18	0225	92-12-21	0925	461	< 1	70	--	80	--	--	--	--	809
1993-02-01	1100	93-02-04	1000	162	< 1	< 50	8	< 40	--	--	--	--	--
1993-03-22	0950	93-03-25	0850	325	< 1	70	< 5	40	--	--	--	--	--
1993-03-25	0950	93-03-29	0850	668	< 1	90	< 5	110	--	--	--	--	--
1993-03-29	1005	93-03-31	0405	1260	< 1	100	6	65	--	< 2.00	--	160	594
1993-03-29	1005	93-03-31	0605	1250	< 1	80	7	50	--	< 2.00	--	159	597
1993-03-31	0705	93-04-01	0905	1360	< 1	70	10	60	--	< 2.00	--	147	516
1993-04-01	1030	93-04-03	0130	1760	< 1	90	10	70	5.00	< 2.00	--	147	483
1993-04-03	0230	93-04-05	0830	1150	< 1	90	5	60	4.40	< 2.00	--	151	526
1993-04-06	1015	93-04-06	1045	496	< 1	70	5	70	4.40	< 2.00	--	197	698
1993-04-06	1045	93-04-08	0945	442	< 1	80	8	70	4.30	< 2.00	--	196	701

Appendix 1. Selected chemical analyses of water samples from Irondequoit Creek above Blossom Road and at Empire Boulevard (Ellison Park wetland inflow and outflow sites), Monroe County, N.Y., 1990-96 (continued)

Beginning of sampling period		End of sampling period		Q	Metals (micrograms per liter)				Physical properties (milligrams per liter)				Spec. Cond.
Yr-mo-d	Time	Yr-mo-d	Time	(ft^3/s)	Cd	Cu	Pb	Zn	TOC	BOD_5	COD	Alk	(µS/cm)
B. Irondequoit Creek at Empire Boulevard, Rochester, N.Y. (station 0423205025, cont.)													
1993-05-24	0925	93-05-28	0825	68	1	70	5	< 40	4.90	< 2.00	--	249	1050
1993-06-05	0545	93-06-06	0045	275	--	60	9	110	6.50	2.20	--	--	939
1993-06-06	0145	93-06-07	0845	174	< 1	60	12	90	5.60	5.30	--	--	764
1993-09-02	2015	93-09-04	0615	150	< 1	30	6	80	4.30	< 2.00	--	140	735
1993-09-04	0715	93-09-07	0915	106	< 1	40	12	60	4.50	< 2.00	--	155	790
1993-11-24	1030	93-11-27	1230	69	< 1	--	< 5	40	3.50	< 2.00	14	251	1170
1993-11-27	1330	93-11-28	1330	307	< 1	--	13	60	5.00	< 4.00	27	186	836
1993-11-28	1430	93-11-29	0930	591	< 1	--	11	80	7.40	< 4.00	28	144	589
1993-11-29	1000	93-12-02	0900	244	< 1	--	< 5	--	6.70	2.30	14	191	835
1994-01-14	1030	94-01-18	0930	64	< 1	--	< 5	--	--	< 2.00	--	260	1410
1994-02-18	1025	94-02-21	1325	362	< 1	--	9	--	--	4.90	29	186	1550
1994-02-21	1425	94-02-22	0925	976	< 1	--	6	--	--	2.90	29	126	827
1994-02-22	0945	94-02-24	0845	574	< 1	--	5	--	--	< 2.00	38	162	872
1994-03-21	0950	94-03-23	0550	582	1	40	12	--	--	2.60	46	159	818
1994-03-23	0650	94-03-24	0850	919	1	30	7	--	--	2.20	21	131	591
1994-03-24	1000	94-03-27	0500	580	1	30	5	--	--	--	20	159	676
1994-04-12	1555	94-04-14	0855	563	--	20	8	--	--	2.50	21	178	777
1994-04-14	0930	94-04-18	0830	438	< 1	30	--	--	--	2.70	22	191	803
1994-06-09	1035	94-06-13	0835	67	< 1	29	3	--	--	--	< 10	242	1130
1994-08-13	0955	94-08-14	1655	133	< 1	30	10	--	--	< 2.00	10	183	960
1994-08-14	1755	94-08-15	0855	180	< 1	40	5	--	--	< 2.00	22	120	593
1994-08-15	0930	94-08-18	0830	70	< 1	30	5	< 40	--	< 2.00	11	182	910
1994-12-05	1005	94-12-06	0305	259	1	21	--	--	--	< 2.00	--	182	832
1994-12-06	0405	94-12-08	0905	192	< 1	22	--	--	--	< 2.00	--	196	1000
1994-12-08	0945	94-12-09	2045	135	< 1	40	< 5	< 40	--	2.00	--	216	1250
1994-12-30	0815	94-12-31	1915	54	--	30	< 5	< 40	--	2.00	< 10	265	1190

Appendix 1. Selected chemical analyses of water samples from Irondequoit Creek above Blossom Road and at Empire Boulevard (Ellison Park wetland inflow and outflow sites), Monroe County, N.Y., 1990-96 (continued)

Beginning of sampling period		End of sampling period		Q	Metals (micrograms per liter)				Physical properties (milligrams per liter)				Spec. Cond.
Yr-mo-d	Time	Yr-mo-d	Time	(ft^3/s)	Cd	Cu	Pb	Zn	TOC	BOD_5	COD	Alk	(µS/cm)
B. Irondequoit Creek at Empire Boulevard, Rochester, N.Y. (station 0423205025, cont.)													
1995-02-09	1000	95-02-13	0900	60	< 1	< 50	< 5	< 40	--	< 2.00	11	258	1500
1995-03-06	1025	95-03-08	0815	273	< 1	20	< 5	< 40	--	< 2.00	--	206	1210
1995-03-08	0915	95-03-09	0815	348	< 1	20	< 5	< 40	--	< 2.00	--	182	1040
1995-03-09	0845	95-03-13	0745	237	< 1	20	< 5	< 40	--	< 2.00	--	210	1260
1995-03-13	0950	95-03-16	0750	198	< 1	20	2	< 40	--	< 2.00	--	213	1020
1995-03-16	0835	95-03-20	0735	147	1	20	3	40	--	< 2.00	--	232	1170
1995-05-08	1100	95-05-09	2200	52	< 1	< 20	3.3	< 40	--	< 2.00	--	232	--
1995-05-09	2300	95-05-11	1000	87	< 1	< 20	4	40	--	< 2.00	--	227	--
1995-08-21	1215	95-08-24	1015	32	< 1	20	< 5	40	3.6	< 2.00	--	210	1250
1995-10-21	0250	95-10-22	0550	664	< 1	30	15	65	--	< 2.00	39	105	526
1995-10-22	0650	95-10-23	0950	564	< 1	30	7	50	--	< 2.00	31	122	644
1995-12-11	1140	95-12-14	1040	60	< 1	20	< 5	10	5.60	< 2.00	10	286	1490
1996-01-16	1025	96-01-18	0925	178	< 1	40	5	30	6.10	< 2.00	33	232	1780
1996-01-18	1005	96-01-20	0105	708	4	50	5	35	6.90	4.00	68	161	1220
1996-01-20	0205	96-01-22	0905	848	4	40	9	40	6.90	2.40	43	139	822
1996-01-22	1055	96-01-25	0955	329	< 1	30	8	50	7.60	< 2.00	--	193	1170
1996-01-25	1015	96-01-29	0915	288	< 1	40	6	25	6.00	< 2.00	--	194	1120
1996-01-29	1025	96-02-01	0925	136	< 1	20	< 5	15	6.00	< 2.00	< 20	238	1260
1996-02-01	1020	96-02-05	0920	94	< 1	30	< 5	20	5.20	2.40	28	273	1360
1996-04-14	1035	96-04-17	0935	541	< 1	40	< 5	20	6.10	2.10	--	195	916
1996-04-18	1025	96-04-22	0925	222	< 1	30	< 5	20	--	--	--	219	1050
1996-10-20	1820	96-10-21	0920	--	< 1	50	18	50	--	3.00	--	--	524

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96

[Values are in tons. Input and output loads are based on data from Irondequoit Creek above Blossom Road and Irondequoit Creek at Empire Boulevard, respectively. Error is standard error of prediction, which, when multiplied by 1.96 and added to and subtracted from the estimated load, provides 95-percent confidence limits of the load estimate. WY, water year.]

A. Nitrogen Compounds

Month/ year	Total nitrogen[1]		Ammonia-plus-organic nitrogen				Ammonia nitrogen				Organic nitrogen[2]		Nitrate plus nitrite			
	Input	Output	Input		Output		Input		Output		Input	Output	Input		Output	
	Load	Load	Load	Error	Load	Error	Load	Error	Load	Error	Load	Load	Load	Error	Load	Error
10/90	19.24	20.01	10.82	0.99	10.91	0.76	0.18	0.04	0.18	0.03	10.63	10.72	8.42	0.43	9.10	0.41
11/90	20.05	20.82	10.40	0.87	10.57	0.69	0.19	0.04	0.23	0.04	10.21	10.34	9.64	0.46	10.26	0.43
12/90	49.19	44.53	25.05	2.82	20.06	1.63	0.62	0.19	0.58	0.12	24.43	19.48	24.14	1.39	24.47	1.23
1/91	45.24	39.17	19.59	1.86	15.07	1.17	0.68	0.16	0.57	0.11	18.92	14.51	25.64	1.27	24.09	1.10
2/91	36.82	31.52	14.33	1.31	11.05	0.78	0.59	0.14	0.42	0.08	13.75	10.63	22.48	1.12	20.46	0.90
3/91	66.69	61.58	30.08	2.96	25.58	1.99	0.99	0.26	0.64	0.13	29.09	24.95	36.61	1.89	35.99	1.73
4/91	53.98	46.39	28.03	3.01	23.94	2.08	0.62	0.16	0.43	0.09	27.40	23.51	25.95	1.34	22.45	1.09
5/91	25.85	19.92	13.47	1.07	11.00	0.69	0.27	0.06	0.23	0.04	13.21	10.77	12.38	0.56	8.92	0.36
6/91	9.55	9.58	5.13	0.45	5.62	0.36	0.10	0.02	0.16	0.03	5.02	5.46	4.43	0.21	3.96	0.16
7/91	8.38	7.70	4.57	0.38	4.45	0.28	0.10	0.02	0.15	0.02	4.46	4.30	3.82	0.18	3.26	0.13
8/91	7.28	7.12	3.91	0.32	3.95	0.25	0.09	0.02	0.12	0.02	3.83	3.83	3.37	0.15	3.16	0.13
9/91	5.50	6.05	2.89	0.25	3.33	0.22	0.06	0.01	0.09	0.01	2.83	3.25	2.62	0.12	2.71	0.12
WY91 total	**347.78**	**314.38**	**168.27**	**16.27**	**145.54**	**10.92**	**4.49**	**1.14**	**3.80**	**0.72**	**163.78**	**141.74**	**179.50**	**9.11**	**168.84**	**7.79**
10/91	6.32	7.50	3.23	0.26	4.08	0.25	0.05	0.01	0.10	0.02	3.17	3.98	3.09	0.14	3.42	0.13
11/91	7.33	9.28	3.48	0.30	4.67	0.31	0.06	0.01	0.14	0.02	3.42	4.53	3.85	0.18	4.61	0.19
12/91	11.85	15.24	5.14	0.51	6.64	0.46	0.13	0.03	0.27	0.05	5.01	6.37	6.72	0.35	8.60	0.38
1/92	13.98	17.25	5.07	0.42	6.25	0.40	0.18	0.04	0.34	0.06	4.89	5.91	8.91	0.40	11.00	0.44
2/92	16.44	18.80	5.70	0.51	6.49	0.44	0.22	0.05	0.31	0.05	5.47	6.17	10.74	0.52	12.32	0.52
3/92	40.42	46.78	17.94	2.15	20.26	1.80	0.49	0.14	0.56	0.11	17.45	19.69	22.48	1.24	26.52	1.28
4/92	43.90	42.59	21.30	1.90	20.95	1.42	0.45	0.10	0.48	0.08	20.86	20.47	22.60	1.06	21.64	0.89
5/92	26.34	24.82	13.86	1.43	13.76	1.03	0.24	0.06	0.33	0.06	13.62	13.43	12.48	0.64	11.06	0.51
6/92	14.93	14.19	8.07	0.66	8.21	0.53	0.14	0.03	0.26	0.04	7.93	7.95	6.85	0.31	5.98	0.24
7/92	33.71	28.91	20.58	2.34	16.85	1.43	0.35	0.10	0.52	0.11	20.23	16.33	13.13	0.72	12.06	0.60
8/92	44.06	39.35	27.61	3.11	22.66	1.95	0.45	0.13	0.60	0.12	27.16	22.06	16.45	0.91	16.69	0.85
9/92	18.03	17.57	10.06	0.87	9.49	0.63	0.16	0.04	0.25	0.04	9.90	9.24	7.97	0.37	8.08	0.34
WY92 total	**277.33**	**282.29**	**142.04**	**14.44**	**140.29**	**10.66**	**2.92**	**0.75**	**4.16**	**0.77**	**139.12**	**136.13**	**135.29**	**6.85**	**142.00**	**6.37**

[1]Loads of total nitrogen are computed as the sum of ammonia-plus-organic and nitrate-plus-nitrite nitrogen loads. No associated errors of prediction are available.

[2]Loads of organic nitrogen are computed as the difference between ammonia-plus-organic and ammonia nitrogen loads. No associated errors of prediction are available.

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

A. Nitrogen Compounds (continued)

	Total nitrogen		Ammonia-plus-organic nitrogen				Ammonia nitrogen				Organic nitrogen		Nitrate plus nitrite			
	Input	Output	Input		Output		Input		Output		Input	Output	Input		Output	
Month/ water year	Load	Load	Load	Error	Load	Error	Load	Error	Load	Error	Load	Load	Load	Error	Load	Error
10/92	15.29	16.50	8.13	0.67	8.79	0.56	0.11	0.02	0.22	0.04	8.01	8.57	7.16	0.32	7.71	0.31
11/92	30.35	31.38	16.10	1.47	15.94	1.10	0.23	0.06	0.46	0.08	15.87	15.48	14.26	0.69	15.44	0.66
12/92	38.69	37.92	18.26	1.78	16.46	1.17	0.37	0.10	0.71	0.13	17.89	15.75	20.43	1.05	21.46	0.95
1/93	53.94	52.63	22.63	1.93	19.72	1.31	0.62	0.14	1.04	0.18	22.00	18.68	31.31	1.44	32.91	1.33
2/93	20.46	22.01	6.90	0.55	7.32	0.46	0.24	0.05	0.43	0.07	6.66	6.89	13.56	0.61	14.69	0.58
3/93	62.43	58.18	29.05	3.49	25.15	2.16	0.67	0.19	0.80	0.16	28.38	24.34	33.38	1.89	33.03	1.57
4/93	79.64	74.61	40.93	4.29	37.33	3.02	0.76	0.22	0.94	0.19	40.16	36.38	38.72	2.14	37.28	1.89
5/93	19.96	14.09	9.71	0.76	7.51	0.46	0.16	0.03	0.24	0.04	9.55	7.27	10.25	0.45	6.58	0.26
6/93	16.98	14.51	9.03	0.76	8.23	0.53	0.14	0.03	0.31	0.05	8.90	7.92	7.95	0.37	6.29	0.26
7/93	8.79	8.98	4.56	0.36	4.97	0.30	0.08	0.02	0.23	0.04	4.48	4.74	4.23	0.18	4.01	0.16
8/93	7.20	7.09	3.66	0.28	3.78	0.23	0.07	0.01	0.17	0.03	3.59	3.61	3.54	0.15	3.31	0.13
9/93	10.38	9.59	5.38	0.46	5.03	0.33	0.08	0.02	0.18	0.03	5.30	4.85	5.01	0.23	4.57	0.19
WY93 total	**364.12**	**347.49**	**174.32**	**16.80**	**160.21**	**11.62**	**3.54**	**0.89**	**5.72**	**1.03**	**170.79**	**154.48**	**189.80**	**9.53**	**187.28**	**8.28**
10/93	8.33	8.17	4.08	0.32	4.24	0.26	0.05	0.01	0.14	0.02	4.03	4.09	4.25	0.19	3.93	0.15
11/93	17.05	17.52	8.49	1.09	8.54	0.70	0.11	0.04	0.32	0.07	8.37	8.21	8.56	0.53	8.99	0.46
12/93	16.60	17.21	6.93	0.61	7.23	0.49	0.13	0.03	0.40	0.07	6.81	6.83	9.66	0.45	9.98	0.41
1/94	14.81	14.28	5.05	0.53	4.82	0.36	0.15	0.04	0.38	0.07	4.90	4.44	9.76	0.53	9.46	0.45
2/94	28.08	30.53	10.28	1.36	10.58	1.04	0.30	0.10	0.63	0.14	9.98	9.95	17.80	1.10	19.95	1.12
3/94	53.38	52.02	21.97	2.20	20.43	1.47	0.49	0.12	0.85	0.15	21.47	19.58	31.41	1.58	31.59	1.34
4/94	44.97	42.93	20.33	1.95	19.71	1.39	0.35	0.09	0.66	0.12	19.98	19.05	24.63	1.22	23.22	0.99
5/94	21.51	22.36	10.17	0.81	11.63	0.72	0.14	0.03	0.42	0.07	10.02	11.21	11.34	0.51	10.73	0.42
6/94	12.93	12.51	6.51	0.58	6.86	0.46	0.09	0.02	0.31	0.05	6.42	6.55	6.41	0.30	5.65	0.24
7/94	6.64	6.79	3.24	0.25	3.65	0.22	0.05	0.01	0.21	0.03	3.19	3.43	3.40	0.15	3.14	0.12
8/94	11.54	10.61	5.88	0.55	5.43	0.38	0.09	0.02	0.27	0.05	5.79	5.16	5.66	0.28	5.18	0.23
9/94	8.51	8.55	4.14	0.35	4.31	0.28	0.06	0.01	0.18	0.03	4.09	4.12	4.36	0.20	4.25	0.18
WY94 total	**244.33**	**243.49**	**107.07**	**10.60**	**107.42**	**7.76**	**2.01**	**0.52**	**4.78**	**0.87**	**105.05**	**102.64**	**137.26**	**7.03**	**136.07**	**6.11**

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

A. Nitrogen Compounds (continued)

Month/ water year	Total nitrogen		Ammonia-plus-organic nitrogen				Ammonia nitrogen				Organic nitrogen		Nitrate plus nitrite			
	Input	Output	Input		Output		Input		Output		Input	Output	Input		Output	
	Load	Load	Load	Error	Load	Error	Load	Error	Load	Error	Load	Load	Load	Error	Load	Error
10/94	6.14	6.02	2.80	0.22	3.01	0.18	0.03	0.01	0.13	0.02	2.77	2.88	3.34	0.15	3.01	0.12
11/94	12.38	12.09	5.77	0.65	5.79	0.50	0.07	0.02	0.25	0.05	5.70	5.54	6.61	0.35	6.30	0.32
12/94	18.10	17.63	7.16	0.62	6.98	0.47	0.12	0.03	0.47	0.08	7.05	6.51	10.93	0.51	10.65	0.44
1/95	18.41	18.09	6.06	0.64	5.80	0.46	0.15	0.04	0.52	0.10	5.91	5.28	12.35	0.66	12.29	0.60
2/95	12.68	12.50	3.61	0.32	3.74	0.26	0.10	0.02	0.34	0.06	3.51	3.41	9.06	0.44	8.76	0.38
3/95	25.83	25.36	8.38	0.71	8.48	0.55	0.20	0.04	0.52	0.09	8.18	7.95	17.45	0.81	16.89	0.69
4/95	11.58	11.06	4.10	0.34	4.60	0.30	0.07	0.02	0.23	0.04	4.03	4.37	7.48	0.34	6.45	0.26
5/95	8.60	8.51	3.54	0.29	4.21	0.27	0.05	0.01	0.21	0.04	3.49	4.00	5.06	0.23	4.29	0.17
6/95	6.48	6.27	2.93	0.26	3.30	0.23	0.04	0.01	0.20	0.04	2.89	3.10	3.55	0.17	2.96	0.13
7/95	8.92	8.24	4.22	0.37	4.20	0.27	0.06	0.01	0.28	0.05	4.16	3.91	4.70	0.22	4.04	0.16
8/95	5.96	5.70	2.74	0.26	2.80	0.20	0.04	0.01	0.19	0.03	2.70	2.61	3.21	0.16	2.90	0.13
9/95	4.10	3.92	1.79	0.15	1.90	0.12	0.02	0.01	0.11	0.02	1.76	1.79	2.32	0.11	2.02	0.08
WY95 total	**139.17**	**135.39**	**53.11**	**4.82**	**54.82**	**3.82**	**0.96**	**0.23**	**3.47**	**0.61**	**52.16**	**51.36**	**86.05**	**4.14**	**80.57**	**3.48**
10/95	15.00	14.63	7.65	1.26	7.14	0.72	0.07	0.03	0.29	0.07	7.58	6.84	7.35	0.53	7.49	0.44
11/95	18.04	18.28	7.77	0.72	7.89	0.55	0.08	0.02	0.43	0.08	7.68	7.46	10.27	0.51	10.38	0.45
12/95	12.01	12.90	4.17	0.35	4.70	0.31	0.06	0.01	0.41	0.07	4.11	4.30	7.84	0.36	8.20	0.33
1/96	41.21	38.58	14.99	2.07	12.20	1.16	0.31	0.11	1.13	0.26	14.69	11.07	26.21	1.70	26.38	1.47
2/96	26.38	26.19	7.84	0.89	7.45	0.60	0.19	0.05	0.69	0.14	7.65	6.76	18.55	1.03	18.73	0.90
3/96	29.89	30.21	9.41	0.86	9.76	0.68	0.18	0.04	0.66	0.12	9.22	9.10	20.49	1.00	20.45	0.88
4/96	40.74	36.36	16.71	1.80	15.29	1.19	0.22	0.06	0.73	0.14	16.49	14.56	24.03	1.29	21.07	0.98
5/96	39.65	32.88	18.52	2.08	15.82	1.23	0.19	0.06	0.74	0.14	18.32	15.07	21.13	1.15	17.07	0.80
6/96	27.32	22.22	13.31	1.31	11.08	0.82	0.14	0.04	0.67	0.13	13.17	10.41	14.01	0.73	11.14	0.52
7/96	12.23	10.19	5.48	0.46	4.83	0.32	0.07	0.01	0.38	0.06	5.41	4.45	6.76	0.32	5.36	0.23
8/96	7.92	7.10	3.42	0.31	3.21	0.22	0.04	0.01	0.25	0.04	3.37	2.96	4.51	0.23	3.89	0.17
9/96	8.33	8.16	3.57	0.35	3.62	0.26	0.04	0.01	0.22	0.04	3.53	3.39	4.76	0.26	4.54	0.22
WY96 total	**278.72**	**257.69**	**112.81**	**12.46**	**102.99**	**8.07**	**1.59**	**0.45**	**6.62**	**1.28**	**111.22**	**96.37**	**165.90**	**9.12**	**154.70**	**7.40**
Period of record 1990-96	**1,651**	**1,581**	**757.64**	**75.39**	**711.27**	**52.84**	**15.52**	**3.98**	**28.55**	**5.29**	**742.12**	**682.73**	**893.80**	**45.79**	**869.45**	**39.43**

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

[Values are in tons. Input and output loads are based on data from Irondequoit Creek above Blossom Road and Irondequoit Creek at Empire Boulevard, respectively. Error is standard error of prediction, which, when multiplied by 1.96 and added to and subtracted from the estimated load, provides 95-percent confidence limits of the load estimate. WY, water year.]

B. Phosphorus Compounds

Month/ year	Total phosphorus, as P				Orthophosphate, as P			
	Input		Output		Input		Output	
	Load	Error	Load	Error	Load	Error	Load	Error
10/90	2.36	0.47	2.39	0.28	0.16	0.02	0.23	0.02
11/90	1.49	0.25	1.54	0.16	0.13	0.01	0.18	0.01
12/90	4.53	1.33	3.10	0.48	0.32	0.05	0.38	0.04
1/91	2.53	0.56	2.05	0.29	0.21	0.03	0.25	0.03
2/91	1.72	0.32	1.46	0.16	0.12	0.01	0.14	0.01
3/91	6.29	1.46	5.14	0.72	0.23	0.03	0.32	0.03
4/91	7.20	2.11	5.48	0.94	0.20	0.03	0.28	0.03
5/91	2.09	0.31	1.85	0.18	0.10	0.01	0.12	0.01
6/91	0.75	0.14	1.00	0.10	0.06	0.01	0.09	0.01
7/91	0.75	0.12	0.92	0.09	0.07	0.01	0.11	0.01
8/91	0.73	0.12	0.89	0.09	0.07	0.01	0.11	0.01
9/91	0.52	0.09	0.64	0.07	0.05	0.01	0.08	0.01
WY91 total	**30.94**	**7.27**	**26.44**	**3.55**	**1.72**	**0.23**	**2.30**	**0.21**
10/91	0.47	0.07	0.58	0.05	0.05	0.01	0.08	0.01
11/91	0.36	0.06	0.47	0.05	0.05	0.01	0.08	0.01
12/91	0.46	0.10	0.60	0.07	0.06	0.01	0.11	0.01
1/92	0.37	0.06	0.53	0.05	0.05	0.01	0.09	0.01
2/92	0.49	0.09	0.64	0.07	0.05	0.01	0.08	0.01
3/92	3.73	1.16	3.64	0.65	0.13	0.02	0.25	0.03
4/92	3.89	0.77	3.41	0.37	0.14	0.02	0.23	0.02
5/92	2.52	0.69	2.25	0.30	0.11	0.02	0.17	0.01
6/92	1.20	0.19	1.35	0.13	0.09	0.01	0.15	0.01
7/92	6.40	1.89	4.84	0.76	0.36	0.06	0.60	0.06
8/92	11.76	3.23	7.88	1.21	0.58	0.09	0.98	0.10
9/92	2.33	0.40	1.99	0.21	0.17	0.02	0.28	0.02
WY92 total	**33.96**	**8.70**	**28.17**	**3.91**	**1.85**	**0.26**	**3.09**	**0.29**
10/92	1.40	0.23	1.27	0.13	0.12	0.01	0.19	0.01
11/92	2.65	0.51	1.98	0.22	0.23	0.03	0.33	0.03
12/92	2.42	0.54	1.68	0.19	0.24	0.03	0.33	0.03
1/93	2.72	0.48	2.04	0.21	0.26	0.03	0.37	0.03
2/93	0.57	0.09	0.63	0.06	0.06	0.01	0.09	0.01
3/93	8.26	2.60	4.38	0.73	0.26	0.05	0.36	0.04
4/93	12.48	3.56	7.44	1.19	0.36	0.06	0.55	0.06
5/93	1.33	0.20	0.89	0.08	0.08	0.01	0.09	0.01
6/93	1.42	0.24	1.25	0.12	0.11	0.01	0.16	0.01
7/93	0.72	0.11	0.83	0.08	0.08	0.01	0.14	0.01
8/93	0.65	0.10	0.67	0.06	0.08	0.01	0.12	0.01
9/93	1.08	0.18	0.86	0.09	0.10	0.01	0.15	0.01
WY93 total	**35.70**	**8.83**	**23.92**	**3.17**	**1.99**	**0.26**	**2.90**	**0.25**

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

B. Phosphorus Compounds (continued)

Month/ year	Total phosphorus, as P				Orthophosphate, as P			
	Input		Output		Input		Output	
	Load	Error	Load	Error	Load	Error	Load	Error
10/93	0.61	0.09	0.49	0.05	0.07	0.01	0.09	0.01
11/93	1.41	0.48	0.89	0.13	0.14	0.03	0.18	0.02
12/93	0.67	0.13	0.56	0.06	0.10	0.01	0.14	0.01
1/94	0.44	0.11	0.35	0.05	0.06	0.01	0.08	0.01
2/94	1.62	0.58	1.28	0.25	0.11	0.02	0.18	0.02
3/94	4.57	1.13	2.81	0.35	0.20	0.03	0.28	0.02
4/94	4.28	1.01	2.82	0.34	0.18	0.02	0.25	0.02
5/94	1.54	0.24	1.50	0.14	0.10	0.01	0.16	0.01
6/94	1.06	0.20	1.00	0.11	0.09	0.01	0.15	0.01
7/94	0.52	0.08	0.56	0.05	0.07	0.01	0.11	0.01
8/94	1.35	0.28	1.05	0.12	0.14	0.02	0.21	0.02
9/94	0.85	0.14	0.69	0.07	0.09	0.01	0.14	0.01
WY94 total	**18.92**	**4.45**	**14.00**	**1.71**	**1.36**	**0.18**	**1.98**	**0.17**
10/94	0.43	0.06	0.33	0.03	0.06	0.01	0.07	0.00
11/94	0.99	0.29	0.63	0.11	0.11	0.02	0.14	0.01
12/94	0.76	0.13	0.53	0.06	0.12	0.01	0.14	0.01
1/95	0.62	0.16	0.46	0.06	0.09	0.01	0.11	0.01
2/95	0.32	0.06	0.28	0.03	0.04	0.00	0.05	0.00
3/95	1.07	0.18	0.84	0.08	0.08	0.01	0.11	0.01
4/95	0.50	0.08	0.44	0.04	0.04	0.00	0.05	0.00
5/95	0.48	0.07	0.45	0.04	0.04	0.00	0.06	0.00
6/95	0.46	0.08	0.43	0.05	0.05	0.01	0.07	0.01
7/95	0.82	0.14	0.69	0.07	0.10	0.01	0.14	0.01
8/95	0.61	0.12	0.50	0.06	0.08	0.01	0.11	0.01
9/95	0.37	0.06	0.28	0.03	0.05	0.01	0.06	0.00
WY95 total	**7.43**	**1.43**	**5.86**	**0.66**	**0.88**	**0.11**	**1.14**	**0.09**
10/95	3.00	1.37	1.19	0.23	0.22	0.05	0.24	0.03
11/95	1.32	0.25	0.80	0.09	0.17	0.02	0.20	0.02
12/95	0.44	0.07	0.34	0.03	0.09	0.01	0.10	0.01
1/96	3.55	1.30	1.45	0.26	0.32	0.07	0.33	0.04
2/96	1.28	0.39	0.78	0.11	0.12	0.02	0.14	0.01
3/96	1.65	0.32	1.15	0.13	0.12	0.01	0.15	0.01
4/96	5.07	1.36	2.45	0.33	0.23	0.04	0.25	0.02
5/96	6.52	2.06	2.81	0.39	0.31	0.05	0.32	0.03
6/96	4.09	0.88	2.21	0.28	0.32	0.04	0.36	0.03
7/96	1.34	0.22	0.90	0.09	0.17	0.02	0.19	0.01
8/96	0.93	0.17	0.63	0.07	0.13	0.02	0.15	0.01
9/96	1.07	0.24	0.67	0.08	0.13	0.02	0.15	0.01
WY96 total	**30.25**	**8.62**	**15.41**	**2.10**	**2.32**	**0.37**	**2.57**	**0.24**
Period of record 1990-96	**157.19**	**39.30**	**113.81**	**15.11**	**10.12**	**1.42**	**13.97**	**1.25**

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

[Values are in tons. Input and output loads are based on data from Irondequoit Creek above Blossom Road and Irondequoit Creek at Empire Boulevard, respectively. Error is standard error of prediction, which, when multiplied by 1.96 and added to and subtracted from the estimated load, provides 95-percent confidence limits of the load estimate. WY, water year.]

C. Selected Anions (chloride and sulfate)

	Chloride				Sulfate			
	Input		Output		Input		Output	
Month/year	Load	Error	Load	Error	Load	Error	Load	Error
10/90	874	36	893	38	1242	46	1179	40
11/90	1056	43	1067	44	1242	45	1174	39
12/90	2249	101	2206	101	1739	65	1627	56
1/91	2575	105	2416	103	1683	61	1512	50
2/91	2328	97	2199	95	1470	54	1324	45
3/91	3232	136	3215	144	2112	77	1991	68
4/91	2222	92	2065	91	1926	70	1743	59
5/91	1183	46	1006	41	1417	48	1205	38
6/91	488	20	511	21	813	29	800	26
7/91	436	17	435	18	785	27	741	24
8/91	412	16	426	17	774	27	744	24
9/91	357	15	382	16	702	25	691	23
WY91 total	**17,414**	**725**	**16,821**	**729**	**15,903**	**575**	**14,731**	**490**
10/91	441	17	483	19	792	27	799	25
11/91	557	23	642	27	797	28	838	27
12/91	914	39	1128	48	939	33	1046	33
1/92	1248	49	1520	61	1017	34	1113	34
2/92	1415	59	1663	71	1051	37	1127	36
3/92	2317	100	2766	121	1703	61	1877	62
4/92	2184	87	2257	93	1922	66	1908	60
5/92	1244	52	1252	54	1466	50	1433	45
6/92	741	29	757	31	1104	37	1083	34
7/92	1176	51	1201	55	1581	56	1546	50
8/92	1441	64	1521	71	1873	67	1875	63
9/92	906	36	940	39	1361	46	1335	42
WY92 total	**14,584**	**608**	**16,130**	**690**	**15,606**	**543**	**15,981**	**510**
10/92	904	35	961	38	1315	44	1321	40
11/92	1624	67	1699	72	1725	60	1732	55
12/92	2315	98	2413	103	1828	63	1832	58
1/93	3482	137	3672	149	2150	73	2168	67
2/93	1838	73	2068	84	1272	44	1329	42
3/93	3294	143	3496	151	2217	83	2263	77
4/93	3426	152	3528	165	2627	98	2638	92
5/93	1161	45	936	37	1413	47	1176	36
6/93	875	34	839	34	1241	42	1171	37
7/93	537	20	593	23	920	31	948	29
8/93	485	18	513	20	876	30	868	27
9/93	663	26	649	27	1087	37	1021	32
WY93 total	**20,605**	**849**	**21,366**	**903**	**18,670**	**651**	**18,467**	**592**

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

C. Selected Anions (chloride and sulfate) (continued)

	Chloride				Sulfate			
	Input		Output		Input		Output	
Month/year	Load	Error	Load	Error	Load	Error	Load	Error
10/93	633	24	615	24	1023	34	960	29
11/93	1108	51	1165	54	1271	46	1283	42
12/93	1377	54	1445	58	1285	43	1285	40
1/94	1443	62	1499	66	1101	38	1086	34
2/94	2197	104	2510	123	1398	54	1484	53
3/94	3376	138	3652	150	2227	79	2298	74
4/94	2558	105	2674	112	2100	74	2120	68
5/94	1298	50	1412	56	1516	51	1569	48
6/94	762	30	804	33	1108	38	1114	35
7/94	467	18	517	20	823	28	848	26
8/94	710	29	734	31	1116	38	1089	34
9/94	616	24	643	26	1016	35	995	31
WY94 total	**16,545**	**690**	**17,670**	**753**	**15,983**	**559**	**16,131**	**516**
10/94	540	21	524	21	902	30	842	26
11/94	941	40	910	41	1149	41	1073	36
12/94	1555	62	1573	64	1371	46	1325	41
1/95	1769	77	1860	84	1241	43	1225	39
2/95	1412	59	1500	64	1020	36	1009	32
3/95	2282	91	2422	100	1611	54	1602	50
4/95	1061	43	1076	44	1098	37	1060	33
5/95	704	28	727	30	960	32	942	29
6/95	486	20	503	22	786	28	769	25
7/95	605	24	632	26	955	32	935	29
8/95	457	19	479	21	794	28	768	25
9/95	380	15	374	16	709	25	655	22
WY95 total	**12,193**	**498**	**12,580**	**532**	**12,595**	**434**	**12,204**	**386**
10/95	913	47	962	49	1205	47	1191	41
11/95	1370	58	1410	61	1426	50	1385	45
12/95	1219	48	1327	54	1119	38	1121	35
1/96	3014	150	3186	160	1718	67	1698	61
2/96	2419	108	2630	119	1448	54	1445	49
3/96	2540	104	2780	116	1706	61	1714	56
4/96	2495	108	2515	110	1975	74	1889	65
5/96	2061	89	1994	87	1977	73	1836	62
6/96	1394	60	1348	60	1600	60	1473	51
7/96	809	32	785	32	1132	41	1028	34
8/96	601	24	610	25	930	34	867	29
9/96	655	28	678	30	984	37	926	32
WY96 total	**19,491**	**857**	**20,226**	**904**	**17,220**	**638**	**16,574**	**561**
Period of record 1990-96	**100,832**	**4,226**	**104,793**	**4,512**	**95,978**	**3,400**	**94,087**	**3,055**

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

[Values are in tons. Input and output loads are based on data from Irondequoit Creek above Blossom Road and Irondequoit Creek at Empire Boulevard, respectively. Error is standard error of prediction, which, when multiplied by 1.96 and added to and subtracted from the estimated load, provides 95-percent confidence limits of the load estimate. WY, water year.]

D. Suspended Solids

Month/ year	Total suspended solids				Volatile suspended solids				Nonvolatile suspended solids[1]	
	Input		Output		Input		Output		Input	Output
	Load	Error	Load	Error	Load	Error	Load	Error	Load	Load
10/90	2541	719	2038	411	357	85	303	46	2184	1736
11/90	1815	453	1470	270	278	60	247	35	1537	1222
12/90	5072	1755	3229	791	628	171	453	76	4444	2776
1/91	3390	957	2267	512	454	105	336	53	2936	1931
2/91	2529	651	1660	310	343	75	248	35	2186	1412
3/91	7640	2151	5317	1151	848	196	590	91	6792	4726
4/91	7778	2547	4882	1219	816	207	494	82	6962	4388
5/91	2631	553	1520	234	341	62	199	23	2291	1321
6/91	775	200	672	107	117	25	100	12	657	572
7/91	693	157	550	87	110	21	88	11	583	462
8/91	633	144	508	81	105	20	88	11	528	420
9/91	446	109	374	65	80	17	74	10	365	300
WY91 total	**35,944**	**10,396**	**24,486**	**5,239**	**4,479**	**1,044**	**3,221**	**483**	**31,465**	**21,265**
10/91	439	97	374	61	83	16	81	10	356	293
11/91	382	93	349	63	74	15	79	11	308	270
12/91	565	166	516	103	99	24	108	16	466	408
1/92	502	122	484	88	92	19	102	14	411	382
2/92	712	179	601	110	116	25	111	16	596	490
3/92	4088	1480	3035	773	467	131	361	61	3621	2674
4/92	4637	1139	2769	478	550	111	341	43	4088	2428
5/92	2767	888	1617	334	339	82	207	29	2428	1410
6/92	1265	272	831	131	181	33	122	15	1084	708
7/92	5190	1774	2681	638	580	152	310	49	4610	2371
8/92	8481	2782	4195	994	912	239	478	79	7569	3718
9/92	2146	494	1144	195	308	60	188	24	1838	957
WY92 total	**31,175**	**9,487**	**18,595**	**3,967**	**3,800**	**908**	**2,486**	**367**	**27,374**	**16,109**
10/92	1395	317	801	136	222	43	153	20	1173	648
11/92	2770	700	1421	265	397	84	251	35	2373	1170
12/92	2741	767	1358	267	387	88	242	35	2354	1116
1/93	3389	789	1769	317	470	94	298	41	2918	1471
2/93	825	185	558	97	136	27	109	15	688	449
3/93	7624	2728	3369	813	795	225	398	66	6829	2971
4/93	11292	3500	5366	1228	1148	284	574	92	10143	4792
5/93	1593	329	598	95	223	40	96	12	1370	503
6/93	1501	343	737	122	209	40	111	14	1292	627
7/93	657	138	433	70	106	19	75	9	550	359
8/93	558	115	332	54	96	17	64	8	463	268
9/93	998	233	466	82	159	31	89	12	839	378
WY93 total	**35,343**	**10,144**	**17,209**	**3,547**	**4,350**	**991**	**2,458**	**359**	**30,993**	**14,751**

[1] Loads of nonvolatile suspended solids are computed as the difference between total suspended solids and volatile suspended solids. No associated errors of prediction are available.

Appendix 2. Monthly and annual constituent input and output loads and associated errors for Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

D. Suspended Solids (continued)

Month/ year	Total suspended solids				Volatile suspended solids				Nonvolatile suspended solids[1]	
	Input		Output		Input		Output		Input	Output
	Load	Error	Load	Error	Load	Error	Load	Error	Load	Load
10/93	600	130	290	50	108	20	66	9	492	224
11/93	1422	579	634	148	208	63	122	20	1214	512
12/93	835	217	442	86	142	31	96	14	693	346
1/94	591	199	303	69	99	26	65	11	492	237
2/94	1931	805	1102	315	247	79	162	31	1684	940
3/94	5271	1542	2378	457	607	143	311	43	4664	2067
4/94	4969	1389	2247	423	571	128	281	38	4398	1966
5/94	1905	407	1078	170	257	47	151	18	1649	927
6/94	1139	286	617	112	161	33	92	12	977	525
7/94	475	98	299	48	80	14	54	7	395	246
8/94	1275	345	592	112	185	40	97	13	1090	496
9/94	822	191	405	72	134	26	77	10	688	328
WY94 total	**21,236**	**6,188**	**10,388**	**2,062**	**2,800**	**651**	**1,574**	**227**	**18,436**	**8,814**
10/94	428	91	203	34	80	15	48	6	348	155
11/94	1072	391	464	122	163	45	88	15	909	376
12/94	1021	246	470	85	167	35	97	14	854	373
1/95	895	293	446	104	139	36	85	14	756	361
2/95	504	138	280	56	85	19	56	8	419	224
3/95	1658	386	842	145	234	47	132	17	1425	710
4/95	729	167	389	68	112	22	65	9	617	325
5/95	605	138	347	62	94	19	56	8	510	291
6/95	506	128	290	58	79	17	47	7	427	243
7/95	873	213	451	85	129	26	70	10	743	381
8/95	596	167	314	68	94	21	53	8	502	261
9/95	348	81	177	34	63	13	37	6	285	140
WY95 total	**9,235**	**2,438**	**4,674**	**920**	**1,440**	**314**	**833**	**122**	**7,795**	**3,841**
10/95	2738	1455	953	291	323	128	140	28	2415	813
11/95	1741	452	768	153	256	56	135	20	1485	633
12/95	655	161	363	70	113	24	74	11	542	288
1/96	4330	1809	1697	472	489	160	225	43	3841	1472
2/96	2016	733	978	240	258	73	139	24	1757	838
3/96	2755	733	1422	302	343	77	183	30	2412	1239
4/96	6767	2215	2728	674	692	183	280	51	6076	2447
5/96	7824	2839	2863	742	770	218	282	54	7053	2581
6/96	5110	1514	2044	526	547	137	211	42	4563	1833
7/96	1663	425	769	187	221	49	100	19	1443	669
8/96	1072	302	523	132	153	37	76	15	919	447
9/96	1284	421	615	168	181	49	92	19	1102	523
WY96 total	**37,955**	**13,059**	**15,721**	**3,959**	**4,347**	**1,190**	**1,936**	**358**	**33,608**	**13,785**
Period of record 1990-96	**170,888**	**51,712**	**91,074**	**19,693**	**21,215**	**5,097**	**12,508**	**1,915**	**149,673**	**78,565**

Appendix 3. Monthly removal efficiencies for selected constituents as percentage of input load retained in Ellison Park wetland, Monroe County, N.Y., 1990-96

[Values are in percent. Positive and negative values indicate net constituent retention in or export from wetland, respectively. WY, water year. Water year values are based on total annual loads and are not mean monthly values.]

Month/ year	Percent removal											
	Total nitrogen	Ammonia plus organic nitrogen	Ammonia nitrogen	Organic nitrogen	Nitrate plus nitrite	Total phosphorus	Ortho-phosphate	Chloride	Sulfate	Total suspended solids	Volatile suspended solids	Nonvolatile suspended solids
10/90	-4.0	-0.9	-1.1	-0.8	-8.0	-1.0	-45.0	-2.3	5.1	19.8	15.3	20.5
11/90	-3.9	-1.6	-17.6	-1.3	-6.3	-3.8	-36.5	-1.0	5.4	19.0	10.9	20.5
12/90	9.5	19.9	6.9	20.3	-1.4	31.7	-19.2	1.9	6.4	36.3	27.8	37.5
1/91	13.4	23.1	16.0	23.3	6.0	19.0	-20.7	6.2	10.2	33.1	26.0	34.2
2/91	14.4	22.9	28.8	22.6	9.0	15.2	-17.5	5.6	9.9	34.4	27.7	35.4
3/91	7.7	15.0	35.8	14.2	1.7	18.3	-41.3	0.5	5.7	30.4	30.4	30.4
4/91	14.1	14.6	30.1	14.2	13.5	23.8	-39.1	7.1	9.5	37.2	39.5	37.0
5/91	22.9	18.3	11.6	18.5	27.9	11.6	-22.6	15.0	15.0	42.2	41.5	42.3
6/91	-0.3	-9.7	-50.9	-8.8	10.5	-33.7	-62.5	-4.6	1.5	13.3	14.3	13.1
7/91	8.1	2.6	-46.3	3.7	14.7	-23.1	-53.7	0.2	5.5	20.6	19.8	20.8
8/91	2.3	-1.1	-43.2	-0.1	6.2	-22.0	-58.4	-3.4	3.9	19.8	16.3	20.4
9/91	-9.9	-15.5	-56.0	-14.7	-3.6	-23.3	-59.0	-6.9	1.6	16.2	8.2	17.9
WY91	**9.6**	**13.5**	**15.3**	**13.4**	**5.9**	**14.5**	**-34.1**	**3.4**	**7.4**	**31.9**	**28.1**	**32.4**
10/91	-18.7	-26.4	-79.9	-25.5	-10.6	-23.9	-57.7	-9.5	-0.9	14.9	2.8	17.8
11/91	-26.5	-34.2	-117	-32.6	-19.6	-31.4	-61.7	-15.3	-5.2	8.6	-7.3	12.4
12/91	-28.6	-29.2	-114	-27.1	-28.0	-31.2	-71.8	-23.4	-11.4	8.8	-8.6	12.5
1/92	-23.4	-23.1	-85.2	-20.8	-23.5	-42.9	-70.9	-21.8	-9.5	3.6	-11.2	6.9
2/92	-14.4	-13.9	-39.1	-12.9	-14.7	-29.3	-66.9	-17.5	-7.1	15.7	4.5	17.9
3/92	-15.7	-12.9	-14.3	-12.8	-18.0	2.5	-90.5	-19.4	-10.2	25.8	22.7	26.1
4/92	3.0	1.7	-8.1	1.9	4.2	12.2	-57.0	-3.3	0.7	40.3	38.0	40.6
5/92	5.8	0.7	-36.5	1.4	11.3	10.5	-56.4	-0.7	2.3	41.6	39.1	41.9
6/92	4.9	-1.7	-81.4	-0.3	12.7	-12.3	-64.9	-2.2	1.9	34.3	32.6	34.6
7/92	14.2	18.1	-48.0	19.3	8.1	24.4	-66.3	-2.2	2.2	48.3	46.6	48.6
8/92	10.7	17.9	-35.4	18.8	-1.5	33.0	-70.1	-5.6	-0.1	50.5	47.6	50.9
9/92	2.6	5.7	-59.4	6.7	-1.3	14.5	-58.6	-3.7	1.9	46.7	39.0	48.0
WY92	**-1.8**	**1.2**	**-42.2**	**2.2**	**-5.0**	**17.1**	**-67.1**	**-10.6**	**-2.4**	**40.4**	**34.6**	**41.2**

Appendix 3. Monthly removal efficiencies for selected constituents as percentage of input load retained in Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

Month/ year	Percent removal											
	Total nitrogen	Ammonia plus organic nitrogen	Ammonia nitrogen	Organic nitrogen	Nitrate plus nitrite	Total phosphorus	Ortho-phosphate	Chloride	Sulfate	Total suspended solids	Volatile suspended solids	Nonvolatile suspended solids
10/92	-8.0	-8.2	-97.4	-6.9	-7.7	8.9	-56.4	-6.2	-0.4	42.6	31.1	44.8
11/92	-3.4	1.0	-98.5	2.4	-8.3	25.3	-46.3	-4.7	-0.4	48.7	36.9	50.7
12/92	2.0	9.9	-90.4	11.9	-5.1	30.6	-36.0	-4.2	-0.2	50.4	37.5	52.6
1/93	2.4	12.9	-66.2	15.1	-5.1	25.0	-41.7	-5.4	-0.8	47.8	36.6	49.6
2/93	-7.6	-6.0	-76.7	-3.5	-8.3	-10.3	-56.9	-12.5	-4.5	32.4	20.3	34.7
3/93	6.8	13.4	-19.3	14.2	1.1	47.0	-37.4	-6.1	-2.1	55.8	49.9	56.5
4/93	6.3	8.8	-23.6	9.4	3.7	40.4	-52.4	-3.0	-0.4	52.5	50.0	52.8
5/93	29.4	22.6	-54.1	23.9	35.8	32.5	-10.9	19.4	16.8	62.4	57.1	63.3
6/93	14.5	8.9	-120	11.0	20.9	12.3	-48.5	4.2	5.6	50.9	47.0	51.5
7/93	-2.2	-9.0	-187	-5.8	5.2	-15.4	-75.2	-10.5	-3.1	34.0	29.9	34.8
8/93	1.6	-3.3	-163	-0.4	6.7	-2.3	-59.8	-5.7	0.9	40.5	33.5	42.0
9/93	7.6	6.5	-122	8.4	8.8	20.8	-41.8	2.1	6.1	53.3	44.4	55.0
WY93	**4.6**	**8.1**	**-61.8**	**9.5**	**1.3**	**33.0**	**-45.5**	**-3.7**	**1.1**	**51.3**	**43.5**	**52.4**
10/93	2.0	-3.8	-167	-1.6	7.5	19.5	-31.8	3.0	6.2	51.6	39.1	54.4
11/93	-2.8	-0.6	-181	1.9	-4.9	36.6	-32.8	-5.2	-0.9	55.4	41.3	57.8
12/93	-3.7	-4.3	-214	-0.4	-3.3	16.5	-37.9	-4.9	-0.0	47.0	32.5	50.0
1/94	3.5	4.5	-160	9.4	3.1	19.6	-27.8	-3.9	1.3	48.8	33.9	51.8
2/94	-8.7	-2.9	-112	0.3	-12.1	21.1	-63.3	-14.3	-6.1	43.0	34.6	44.2
3/94	2.5	7.0	-72.0	8.8	-0.6	38.5	-40.7	-8.2	-3.2	54.9	48.8	55.7
4/94	4.5	3.1	-88.2	4.6	5.8	34.1	-44.0	-4.5	-1.0	54.8	50.7	55.3
5/94	-4.0	-14.4	-187	-11.9	5.4	2.4	-66.5	-8.8	-3.5	43.4	41.2	43.8
6/94	3.2	-5.4	-241	-2.0	12.0	5.5	-59.3	-5.5	-0.5	45.8	43.0	46.3
7/94	-2.2	-12.5	-306	-7.6	7.5	-7.4	-61.9	-10.8	-3.0	37.0	32.8	37.8
8/94	8.0	7.7	-206	10.9	8.4	22.4	-47.2	-3.5	2.4	53.5	47.7	54.5
9/94	-0.5	-3.9	-231	-0.8	2.7	19.1	-43.3	-4.3	2.0	50.8	42.5	52.4
WY94	**0.3**	**0.0**	**-137**	**2.3**	**0.1**	**26.0**	**-46.0**	**-6.8**	**-0.9**	**51.1**	**43.8**	**52.2**

Appendix 3. Monthly removal efficiencies for selected constituents as percentage of input load retained in Ellison Park wetland, Monroe County, N.Y., 1990-96 (continued)

	Percent removal											
Month/ year	Total nitrogen	Ammonia plus organic nitrogen	Ammonia nitrogen	Organic nitrogen	Nitrate plus nitrite	Total phosphorus	Ortho- phosphate	Chloride	Sulfate	Total suspended solids	Volatile suspended solids	Nonvolatile suspended solids
10/94	1.9	-7.6	-280	-4.3	9.8	23.7	-22.0	3.0	6.6	52.6	40.7	55.3
11/94	2.4	-0.3	-275	2.9	4.7	36.2	-25.1	3.3	6.7	56.7	46.2	58.6
12/94	2.6	2.6	-297	7.6	2.6	30.0	-20.5	-1.1	3.4	53.9	41.8	56.3
1/95	1.7	4.3	-244	10.7	0.5	26.6	-25.2	-5.2	1.3	50.1	38.9	52.2
2/95	1.4	-3.7	-220	2.8	3.3	12.8	-26.7	-6.2	1.1	44.4	34.2	46.5
3/95	1.8	-1.1	-165	2.9	3.2	21.4	-33.3	-6.1	0.6	49.2	43.4	50.2
4/95	4.5	-12.3	-226	-8.5	13.7	12.1	-30.2	-1.4	3.5	46.6	42.2	47.4
5/95	1.1	-18.9	-334	-14.5	15.1	5.1	-37.3	-3.3	1.9	42.6	40.2	43.0
6/95	3.3	-12.6	-411	-7.2	16.5	6.6	-38.0	-3.6	2.2	42.7	41.0	43.0
7/95	7.6	0.5	-379	5.9	14.0	16.1	-38.4	-4.5	2.1	48.4	46.0	48.8
8/95	4.3	-2.1	-375	3.3	9.7	17.8	-35.3	-4.7	3.3	47.3	43.4	48.0
9/95	4.5	-6.4	-385	-1.5	13.0	23.9	-17.9	1.7	7.5	49.3	42.1	50.9
WY95	**2.7**	**-3.2**	**-262**	**1.5**	**6.4**	**21.1**	**-28.8**	**-3.2**	**3.1**	**49.4**	**42.1**	**50.7**
10/95	2.5	6.7	-320	9.7	-1.9	60.3	-8.7	-5.3	1.2	65.2	56.7	66.3
11/95	-1.3	-1.6	-415	2.9	-1.1	39.2	-14.9	-2.9	2.9	55.9	47.4	57.4
12/95	-7.4	-12.7	-527	-4.6	-4.6	22.3	-18.4	-8.8	-0.2	44.6	34.1	46.8
1/96	6.4	18.6	-270	24.6	-0.6	59.1	-2.4	-5.7	1.1	60.8	54.1	61.7
2/96	0.7	4.9	-271	11.6	-1.0	38.9	-15.8	-8.7	0.2	51.5	46.0	52.3
3/96	-1.1	-3.7	-259	1.4	0.2	30.1	-24.7	-9.4	-0.5	48.4	46.6	48.6
4/96	10.8	8.5	-236	11.7	12.3	51.6	-9.7	-0.8	4.4	59.7	59.5	59.7
5/96	17.1	14.6	-284	17.7	19.2	56.9	-3.2	3.3	7.1	63.4	63.4	63.4
6/96	18.7	16.7	-379	21.0	20.5	45.8	-12.5	3.3	7.9	60.0	61.5	59.8
7/96	16.7	11.8	-465	17.8	20.7	32.6	-13.5	2.9	9.1	53.7	54.7	53.6
8/96	10.4	5.9	-484	12.2	13.8	31.5	-13.7	-1.5	6.8	51.2	50.3	51.4
9/96	2.0	-1.4	-486	3.8	4.6	36.9	-12.1	-3.4	5.9	52.1	49.5	52.6
WY96	**7.6**	**8.7**	**-315**	**13.4**	**6.8**	**49.0**	**-10.5**	**-3.8**	**3.8**	**58.6**	**55.4**	**59.0**
Period of record 1990-96	**4.3**	**6.1**	**-84.0**	**8.0**	**2.7**	**27.6**	**-38.1**	**-3.9**	**2.0**	**46.7**	**41.0**	**47.5**

Appendix 4. Chemical analyses of four sediment samples collected in Ellison Park wetland,Monroe County, N.Y., October 1994.

[µg/g, microgram per gram; <63U or <180U WS, material passing through a 63- or 180-micrometer wet sieve, respectively; DW REC, dry weight recoverable; < , less than. SQ1 = Station 430951077312801. SQ2 = Station 430952077314001. SQ3 = Station 431021077315901. Locations are shown in fig. 2.]

A. Major Elements, Trace Elements, and Carbon

LOCAL SITE ID	ALUMINUM <63U WS (PERCENT)	ANTIMONY <63U WS (µg/g)	ARSENIC <63U WS (µg/g)	BARIUM <63U WS (µg/g)	BERYLLIUM <63U WS (µg/g)	BISMUTH <180U WS (µg/g)	CADMIUM <63U WS (µg/g)	CALCIUM <63U WS (PERCENT)
SQ1	5.0	0.4	4.9	460	1	<10	0.9	6.4
	5.0	.5	5.1	460	1	<10	.7	6.6
SQ2	4.9	.2	5.0	450	1	<10	.9	6.7
SQ3	4.8	.6	3.9	470	1	<10	3.8	4.7

LOCAL SITE ID	CERIUM <63U WS (µg/g)	CHROMIUM <63U WS (µg/g)	COBALT <63U WS (µg/g)	COPPER <63U WS (µg/g)	EUROPIUM <63U WS (µg/g)	GALLIUM <63U WS (µg/g)	GOLD <63U WS (µg/g)	HOLMIUM <63U WS (µg/g)	IRON <63U WS (PERCENT)	LANTHANUM <63U WS (µg/g)
SQ1	45	43	11	41	<2	11	<8	<4	2.7	25
	44	43	10	38	<2	12	<8	<4	2.7	25
SQ2	45	46	12	49	<2	12	<8	<4	2.8	25
SQ3	39	59	10	72	<2	11	<8	<4	2.4	23

LOCAL SITE ID	LEAD <63U WS (µg/g)	LITHIUM <63U WS (µg/g)	MAGNESIUM <63U WS (PERCENT)	MANGANESE <63U WS (µg/g)	MERCURY <63U WS (µg/g)	MOLYBDENUM <63U WS (µg/g)	NEODYMIUM <63U WS (µg/g)	NICKEL <63U WS (µg/g)	NIOBIUM <63U WS (µg/g)	PHOSPHORUS <63U WS (PERCENT)
SQ1	44	30	1.4	880	0.11	<2	25	19	12	0.13
	46	30	1.4	890	.10	<2	26	18	12	.13
SQ2	62	30	1.2	720	.14	<2	24	20	11	.15
SQ3	89	20	1.3	530	.33	<2	23	20	11	.12

LOCAL SITE ID	POTASSIUM <63U WS (PERCENT)	SCANDIUM <63U WS (µg/g)	SELENIUM <63U WS (µg/g)	SILVER <63U WS (µg/g)	SODIUM <63U WS (PERCENT)	STRONTIUM <63U WS (µg/g)	SULFUR <63U WS (PERCENT)	TANTALUM <63U WS (µg/g)	THORIUM <63U WS (µg/g)	TIN <63U WS (µg/g)
SQ1	1.7	8	0.5	0.5	1.2	420	0.34	<40	4.7	<10
	1.7	8	.6	.5	1.2	420	.33	<40	7.8	<10
SQ2	1.6	8	.8	.7	1.1	440	.60	<40	6.5	<10
SQ3	1.6	7	.8	2.3	1.3	340	.35	<40	5.7	<10

LOCAL SITE ID	TITANIUM, <63U WS DW REC (PERCENT)	URANIUM <63U WS (µg/g)	VANADIUM <63U WS (µg/g)	YTTRIUM <63U WS (µg/g)	YTTERBIUM <63U WS (µg/g)	ZINC <63U WS (µg/g)	CARBON, ORGANIC <63U WS DW REC (PERCENT)	CARBON, ORG + INORG, <63U WS DW REC (PERCENT)	CARBON, INORGANIC, <63U WS DW REC (PERCENT)
SQ1	0.26	1.6	50	20	2	210	3.4	5.4	1.9
	0.26	1.6	49	20	2	220	3.5	5.4	1.9
SQ2	0.25	1.6	50	19	2	230	5.0	6.9	1.9
SQ3	0.27	1.7	45	19	2	250	3.7	5.1	1.4

Appendix 4. Analyses of sediment samples collected in the Ellison Park wetland, Monroe County, N.Y., October 1994 (continued)

B. Polycyclic aromatic hydrocarbons

LOCAL SITE ID	PARA-CHLORO-META CRESOL (µg/kg)	2-CHLORO-PHENOL (µg/kg)	2,4-DI-CHLORO-PHENOL (µg/kg)	2,4-DP (µg/kg)	4,6-DINITRO-ORTHO-CRESOL (µg/kg)	2,4-DI-NITRO-PHENOL (µg/kg)	2-NITRO-PHENOL (µg/kg)	4-NITRO-PHENOL (µg/kg)	PENTA-CHLORO-PHENOL (µg/kg)	PHENOL (C_6H_5-OH) (µg/kg)
SQ1	<600	<200	<200	<200	<600	<600	<200	<600	<600	<200
	<600	<200	<200	<200	<600	<600	<200	<600	<600	<200
SQ2	<600	<200	<200	<200	<600	<600	<200	<600	<600	<200
SQ3	<600	<200	<200	<200	<600	<600	<200	<600	<600	<200

LOCAL SITE ID	2,4,6-TRI-CHLORO-PHENOL (µg/kg)	ACE-NAPHTH-ENE (µg/kg)	ACE-NAPHTH-YLENE (µg/kg)	ANTHRA-CENE (µg/kg)	BENZO A ANTHRA-CENE (µg/kg)	BENZO B FLUOR-AN-THENE (µg/kg)	BENZO K FLUOR-AN-THENE (µg/kg)	BENZO-A-PYRENE (µg/kg)	BENZO (G,H,I) PERY-LENE (µg/kg)	N-BUTYL BENZYL PHTHAL-ATE (µg/kg)	BIS (2-CHLORO-ETHOXY) METHANE (µg/kg)
SQ1	<600	<200	<200	<200	500	1,100	1,100	640	<400	<200	<200
	<600	<200	<200	<200	500	780	830	590	<400	<200	<200
SQ2	<600	<200	<200	<200	<400	750	740	500	<400	<200	<200
SQ3	<600	<200	<200	<200	1,200	1,300	1,400	1,300	780	<200	<200

LOCAL SITE ID	BIS (2-CHLORO-ETHYL) ETHER (µg/kg)	BIS (2-CHLORO-ISO-PROPYL) ETHER (µg/kg)	4-BROMO-PHENYL PHENYL ETHER (µg/kg)	2-CHLORO-NAPH-THALENE (µg/kg)	4-CHLORO-PHENYL PHENYL ETHER (µg/kg)	CHRY-SENE (µg/kg)	1,2,5,6-DIBENZ-ANTHRA-CENE (µg/kg)	DI-N-BUTYL PHTHAL-ATE (µg/kg)	1,2-DI-CHLORO-BENZENE (µg/kg)	1,3-DI-CHLORO-BENZENE (µg/kg)	1,4-DI-CHLORO-BENZENE (µg/kg)
SQ1	<200	<200	<200	<200	<200	900	<400	<200	<200	<200	<200
	<200	<200	<200	<200	<200	930	<400	<200	<200	<200	<200
SQ2	<200	<200	<200	<200	<200	670	<400	<200	<200	<200	<200
SQ3	<200	<200	<200	<200	<200	1,700	440	<200	<200	<200	<200

LOCAL SITE ID	DIETHYL PHTHAL-ATE (µg/kg)	DI-METHYL PHTHAL-ATE (µg/kg)	2,4-DI-NITRO-TOLUENE (µg/kg)	2,6-DI-NITRO-TOLUENE (µg/kg)	DI-N-OCTYL PHTHAL-ATE (µg/kg)	BIS(2-ETHYL HEXYL) PHTHAL-ATE (µg/kg)	FLUOR-ENE (µg/kg)	FLUOR-ANTHENE (µg/kg)	HEXA-CHLORO-BENZENE TOTAL (µg/kg)	HEXA-CHLORO-BUT-ADIENCE (µg/kg)	HEXA-CHLORO-CYCLO-PENT-ADIENE (µg/kg)
SQ1	<200	<200	<200	<200	<400	750	<200	1,700	<200	<200	<200
	<200	<200	<200	<200	<400	330	<200	2,000	<200	<200	<200
SQ2	<200	<200	<200	<200	<400	510	<200	1,100	<200	<200	<200
SQ3	<200	<200	<200	<200	<400	750	<200	3,300	<200	<200	<200

LOCAL SITE ID	HEXA-CHLORO-ETHANE (µg/kg)	INDENO (1,2,3-CD) PYRENE (µg/kg)	ISO-PHORONE (µg/kg)	NAPHTH-ALENE (µg/kg)	NITRO-BENZENE (µg/kg)	N-NITRO-SODI-METHY-LAMINE (µg/kg)	N-NITRO-SODI-PHENY-LAMINE (µg/kg)	N-NITRO-SODI-N-PROPYL-AMINE (µg/kg)	PHENAN-THRENE (µg/kg)	PYRENE (µg/kg)	1,2,4-TRI-CHLORO-BENZENE (µg/kg)
SQ1	<200	<400	<200	<200	<200	<200	<200	<200	580	1,300	<200
	<200	<400	<200	<200	<200	<200	<200	<200	880	1,500	<200
SQ2	<200	<400	<200	<200	<200	<200	<200	<200	320	850	<200
SQ3	<200	720	<200	<200	<200	<200	<200	<200	1,700	2,900	<200

Appendix 4. Analyses of sediment samples collected in the Ellison Park wetland, Monroe County, N.Y., October 1994 (continued).

C. Organochlorine compounds

LOCAL SITE ID	ALDRIN, TOTAL (µg/kg)	CHLORDANE, TOTAL (µg/kg)	P,P'-DDD, RECOVER (µg/kg)	P,P'-DDE, RECOVER (µg/kg)	P,P'-DDT, RECOVER (µg/kg)	DIELDRIN, TOTAL (µg/kg)	ENDOSULFAN, TOTAL (µg/kg)	ENDRIN, TOTAL (µg/kg)
SQ1	<0.1	22	3.8	7.1	1.0	2.3	<0.1	<0.8
	<0.1	19	3.1	6.2	.9	1.8	<0.1	<0.8
SQ2	<0.2	18	4.5	8.4	.6	1.2	<0.2	<1.6
SQ3	<0.1	26	6.5	7.4	.8	3.5	<0.1	<0.8

LOCAL SITE ID	HEPTACHLOR EPOXIDE, TOTAL (µg/kg)	HEPTACHLOR, TOTAL (µg/kg)	LINDANE, TOTAL (µg/kg)	METHOXYCHLOR, TOTAL (µg/kg)	MIREX, TOTAL (µg/kg)	PERTHANE, TOTAL (µg/kg)	TOXAPHENE, TOTAL (µg/kg)	PCB, TOTAL (µg/kg)	PCN, TOTAL (µg/kg)
SQ1	<0.8	<0.1	<0.1	<32	<0.1	<1	<10	28	<1.0
	<0.8	<0.1	<0.1	<26	<0.1	<1	<10	25	<1.0
SQ2	<1.6	<0.2	<0.2	<24	<0.2	<2	<20	43	<2.0
SQ3	<0.8	<0.1	<0.1	<38	<0.1	<1	<10	52	<1.0