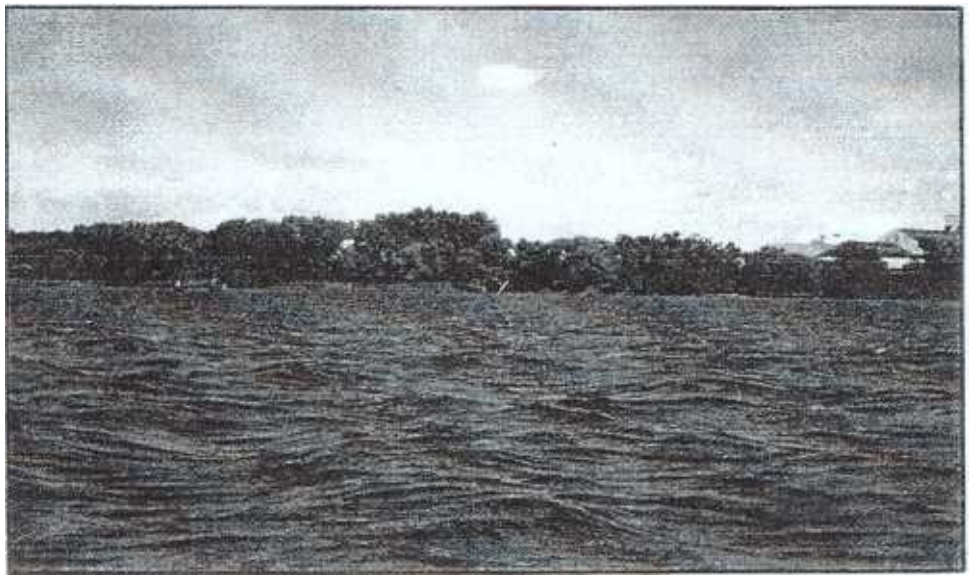

Onondaga Lake
Ambien Monitoring Program
999 Annua Report

Report and Appendix A

November 2000

ONONDAGA LAKE AMBIENT MONITORING PROGRAM

1999 ANNUAL REPORT

REPORT AND APPENDIX A

ONONDAGA COUNTY, NEW YORK

November 2000

Prepared for

ONONDAGA COUNTY, NEW YORK

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CHAPTER 1
INTRODUCTION

1.1 AMBIENT MONITORING PROGRAM

A. Overview

This report presents results of Onondaga County Department of Drainage and Sanitation's (OCDDS) 1999 water quality monitoring program of Onondaga Lake, its tributary streams, permitted discharges to the Lake, and segments of the Three Rivers system (the Seneca, Oneida, and Oswego Rivers). Extensive data were collected in 1999 to evaluate physical, chemical, and biological conditions of this surface water system. Onondaga County is required to monitor water quality and biological conditions as part of its New York State Pollution Discharge Elimination System (SPDES) permit to discharge treated wastewater to Onondaga Lake.

Since 1970, OCDDS has conducted an annual monitoring program. Employees of the Department of Drainage and Sanitation sample Onondaga Lake and its tributaries, analyze samples in the County's state-certified environmental laboratory, calculate loading of materials to the lake, and produce annual reports. Data collected each year are added to a database, which enables an examination of trends in water quality and loading over time and in response to pollution abatement activities. The data are also compared with ambient water quality standards and guidance values.

In January 1998, Onondaga County signed an Amended Consent Judgement (ACJ), committing to a phased 15-year program of upgrades and improvements to the County's wastewater collection and treatment system. The ACJ requires Onondaga County to continue and expand its annual monitoring program, with a specific focus on the effectiveness of alterations in the operation of METRO and the CSOs in reducing pollutant loads and improving water quality. As part of the ACJ, the County is required to conduct an extensive monitoring program of physical, chemical, and biological conditions in the surface water resources. Self-monitoring is a central element of the federal Clean Water Act.

The revised monitoring program, called the Ambient Monitoring Program (AMP) began on August 1, 1998. In most cases, the AMP was designed to supplement, not replace, the historical program. This1999 annual report reflects the first full year of AMP activities.

B. Objectives

The objectives of the historical monitoring program (in place through July 31, 1998) were as follows:

1. Estimate the annual external loading of constituents (chemicals, sediment, and bacteria) to Onondaga Lake through its tributary streams.

2. Assess compliance of lake and tributary waters with New York's ambient water quality standards and guidance values.

3. Evaluate the lake's trophic status as indicated by nutrient concentrations, chlorophyll *a*, algal density and community structure, dissolved oxygen status, transparency, and zooplankton density and community structure.

4. Analyze trends in lake water quality in response to point and nonpoint sources of constituents and in response to pollution abatement efforts.

As part of the ACJ requirements, the County's annual monitoring effort was redesigned to focus specifically on the water quality and ecological improvements to the aquatic system brought about by the planned improvements to METRO and the CSOs. The data collected through the AMP will help New York State and the federal Environmental Protection Agency determine whether further reductions in wastewater load are needed for the lake to meet ambient water quality standards.

Improvements to METRO and the CSOs are being implemented in a phased program, with final completion dates in the year 2012. Loading reductions of wastewater related pollutants (ammonia, phosphorus, solids, floatables and bacteria) will be accomplished as discrete step improvements, not gradual reductions in loading. The ACJ includes specific milestone dates for assessment of progress and evaluation of the need for additional treatment or controls. The County's AMP includes both annual elements, designed to recur each year to evaluate compliance and establish trends, and special elements, timed to follow these construction-related milestones.

The objectives of the AMP include additional detail, due to the program's specific focus on evaluating the effectiveness of improvements to the wastewater collection and treatment system. The program also includes a greatly expanded focus on the biology of the system. Objectives of the AMP may be summarized as follows:

1. Quantify external loading of phosphorus, nitrogen, suspended solids, indicator bacteria, and salts. Design program to include stations upstream and downstream of potential sources in the watershed.

   Utilize the software program FLUX to quantify external pollutant loading, calculate the standard error of loading estimates, and continually refine the allocation of sampling resources to best estimate loads.

   Shift monitoring efforts from a scheduled to an event-based program to minimize the standard error of external load calculations (i.e. collect more samples during high flow conditions).

   Conduct wet weather monitoring upstream and downstream of the CSO discharges in order to assess the loading reductions achieved by CSO improvements. Schedule these wet weather sampling events around milestones in the 15-year program.

   Design the monitoring program for total phosphorus (TP) to enable a reliable partitioning of point and non-point sources of TP to Onondaga Lake for use in TMDL revisions.

   Consider the requirements of tributary, lake, and river water quality models when determining spatial and temporal scales for load estimates.

2. Assess the tributaries' physical habitat and macroinvertebrate community.
   Measure attributes of the physical environment in the lake tributaries, including velocity and cross-sectional area, to map erosional and depositional sections.

   Conduct field surveys for the presence and character of sludge deposits in depositional areas from above the CSO discharges to the tributary mouths.

   Map the physical characteristics of the streambed that could affect spawning habitat from the tributary mouths upstream until a barrier to fish passage is encountered.

   Sample the streams' macroinvertebrate communities and calculate the NYSDEC's biotic indices throughout the tributaries' length.

3. Gather data on an adequate temporal and spatial scale to assess compliance with ambient water quality standards.
   - Compare results with applicable standards and guidance values.

   Examine data for patterns and trends indicating additional sources.

4. Evaluate the lake's response to reductions in external loading achieved by the planned improvements to

METRO and the CSOs.

Assess compliance with ambient water quality standards and guidance values on an annual basis.

- Assess the trophic status of the lake through measuring indicator parameters (phosphorus, chlorophyll *a*, and Secchi disk transparency).

5. Expand the chemical monitoring program to include other indices of ecological integrity: biological data, contaminant burden, and physical habitat.

   Assess the abundance and species composition of communities of phytoplankton, zooplankton, macrophytes, macrobenthos, and fish.

   Evaluate the success of walleye, bass, and sunfish propagation in the lake.

   Establish data sharing protocols with NYSDEC and NYSDOH to enable the County to track contaminant burden in fish flesh.

   - Acquire and track data by others regarding the nature of the littoral (shallow area) sediments in Onondaga Lake.

6. Through interaction with NYSDEC and appropriate peer reviewers, coordinate data collection and analysis to provide data at an adequate spatial and temporal scale to use in existing or revised lake models.

7. Define ambient water quality conditions in the Seneca River between Cross Lake and Three Rivers.
   - Evaluate the longitudinal variation of concentrations of Dissolved Oxygen, Ammonia, Nitrite, Total Phosphorus, Soluble Reactive Phosphorus, Chlorophyll *a* and Turbidity

   Design monitoring program to test temporal and spatial variability (for example, diurnal variations in river water quality presence and extent of chemical stratification).

   Assess compliance with NYS ambient water quality standards.

8. Evaluate and quantify the assimilative capacity of the Seneca River and quantify effects of zebra mussels.
   - Update the dissolved oxygen model of the river.

   Concentrate river monitoring during critical conditions of warm weather and low stream flows

   Determine the abundance/biomass and size frequency of zebra mussels at sites from Jack's Reef to Three Rivers.

Because the AMP will continue over an extended time period, the parties designing and approving the program consider flexibility to be an important consideration. Monitoring results are continually reviewed by engineers and scientists associated with NYSDEC, Atlantic States Legal Foundation, and other interested parties. The County has convened a Technical Advisory Committee (TAC) to provide expert advice and oversight. Current members of the Onondaga Lake TAC and their expertise are listed below.

Dr. Raymond Canale (water quality modeling, Seneca River)
Dr. Charles Driscoll (aquatic chemistry, mercury)
Dr. Edward Mills (phytoplankton and zooplankton)
Dr. Elizabeth Moran (limnology, monitoring program)

Dr. Lars Rudstam (fish ecology)
Dr. Ken Stewart (physical limnology)
Dr. William Walker, Jr. (statistics, loading estimates, mass balance)

.2 THE ONONDAGA LAKE WATERSHED

A. **Physical Features.** Onondaga Lake is located immediately northwest of the City of Syracuse in Onondaga County, New York, USA (43° 6' 54" N, 76° 14' 34" W). The outlet of Onondaga Lake flows into the Seneca River, which joins with the Oswego River and flows north and east into Lake Ontario.

The Onondaga Lake drainage basin encompasses approximately 642 km^2, and with the exception of 2 km^2 in Cortland County, lies almost entirely in Onondaga County (Figure 1-1). The drainage basin includes six natural subbasins: Nine Mile Creek, Harbor Brook, Onondaga Creek, Ley Creek, Bloody Brook, and Saw Mill Creek.

The climate of the Onondaga Lake basin is continental humid and is strongly influenced by proximity to Lake Ontario and the presence of the Appalachian upland in the southern part of the drainage basin. Lake Ontario moderates the temperature extremes. The warmest month is July with a mean daily maximum temperature of 81.9 °F. January is the coldest month; mean daily minimum temperature is 14.9 °F. Based on the 1951 – 1980 period the average frost-free period is April 29 through October 15. Lake effect contributes high amounts of cloudiness and snowfall. The summer months are drier on average, but high year-to-year variation is typical. In 1999, the annual precipitation was 30.88 inches. This is well below the long-term average of 38.93 inches for the 30-year period of record.

Onondaga Lake is relatively small, with 7.6 km maximum length, 2 km maximum width, 11.7 km^2 surface area, 131 x 10^6 m^3 volume, 10.9 m mean depth, and 19.5 m maximum depth. A bathymetric map (Figure 1-2) shows two minor depressions in a fairly uniform profile. The Onondaga Lake shoreline is very regular, with few embayments. More than 75 percent of the shoreline is owned by Onondaga County and is maintained as part of a popular park and trail system. The lakeside park is currently used for recreation (hiking, biking, jogging, roller-blading, etc.), fishing, and cultural entertainment. The lake is used for secondary water contact recreation such as boating and water skiing.

Fishing was prohibited in the lake in 1972 due to mercury contamination. The prohibition was lifted in 1986 and modified into a catch and release fishery, i.e. recreational fishing was permitted but possession of lake fishes was not. In 1999 the New York State Department of Health revised its advisory regarding consumption of gamefish from Onondaga Lake. The current recommendation is to eat no walleye from Onondaga Lake, and restrict consumption of all other species to no more than one meal per month. The fish advisory continues to be based on mercury levels in fish flesh. As in all New York waters with health advisories, the Health Department advises that women of childbearing age, infants, and children under the age of 15 eat no fish from these waters.

Onondaga Lake has a rapid flushing rate; the average rate for the 1971 to 1999 period was 3.7 flushes/year (Figure 1-3). From 1995-1999, the lake residence time was 0.32 years. In 1999, the calculated flushing rate was approximately 2.3 water exchanges. Flushing rate is estimated by summing the water that flows into the lake and dividing inflow by lake volume. This simple calculation assumes that the water column of lake is consistently well mixed. However, Onondaga Lake is dimictic, with two periods of complete mixing separated by periods of thermal stratification. During stratified periods, upper waters are replaced by tributary and effluent inflows, while lower waters are not. The flushing rate of the upper waters during summer stratification is rapid. Based on a detailed analysis of epilimnetic volume and tributary inflows over the three year period from 1987 – 1989, Effler and Whitehead (1996) concluded that the water in the epilimnion is replaced about three times between May and September of an average hydrologic year.

At temperate latitudes, lakes and reservoirs with a maximum depth greater than about 10 meters develop relatively predictable annual patterns of water temperature with depth. In spring, lakes begin to gain heat and the upper waters begin to warm. Heating causes water to expand; warmer less dense water floats on top of the cooler water. More work is needed for winds to overcome the developing density gradient. Depending on solar radiation and wind, Onondaga Lake alternates between isothermal and weakly stratified conditions in April through early May.

By late May of a typical year, Onondaga Lake waters stratify into the three layers associated with classic thermal stratification: warm upper waters (epilimnion), cool lower waters (hypolimnion) and a transition layer between the two (metalimnion, which includes the thermocline). The thermocline is defined as the plane in the metalimnion exhibiting maximum rate of change in temperature with depth. Density differences during stratification are strong enough to impede wind-induced mixing between the epilimnion and hypolimnion; the hypolimnion remains isolated from the atmosphere. The extent of mixing in the spring influences the temperature of the hypolimnion for the rest of the year. In some years, the lake warms quickly and lower waters are isolated relatively early, leading to colder temperature in the hypolimnion. In years with cool, windy springs the lake stratifies later and temperature of the bottom waters is warmer.

By August, Onondaga Lake ceases to gain heat and the waters begin to cool. The cooling process is manifested in a steady deepening of the epilimnion and gradual decrease in its temperature. As the epilimnion cools, the metalimnion warms due to wind-induced mixing of warmer surface waters deeper into the lake. Heat loss continues through the fall. Eventually, the temperature of the upper water cools to the temperature of the hypolimnion, and thermal stratification breaks down. There is no density impediment to complete mixing of the lake by winds. There is variability in the timing of fall mixing based on specific meteorological conditions; generally, Onondaga Lake is completely mixed by late October.

Development of thermal stratification in winter is variable, depending on the extent and persistence of ice cover. Onondaga County has maintained an ice diary each year since the winter of 1987 – 1988, noting dates of ice cover and sketching surface area affected. Limited measurements of ice thickness, mostly in the southern basin, have been made. Observations are summarized in Table 1-1. Note the interannual variability in the extent of ice cover on the lake. Ice cover in the north basin tends to develop in January and persist through mid March, although ice thickness varies greatly as well. Limited winter sampling has been conducted through the ice. Temperature profiles indicate that weak inverse stratification develops under the ice.

B. Tributaries. Five natural tributaries, three effluent discharges, and the lake outlet were monitored in 1999. Figure 1-4 depicts the long-term average hydrologic contributions of tributaries to Onondaga Lake.

1. **Nine Mile Creek.** The Nine Mile Creek watershed drains approximately 298 km^2 of land southwest of Onondaga Lake. The creek originates at the outlet of Otisco Lake, flows north and enters Onondaga Lake at Lakeland adjacent to the New York State Fairgrounds. Streamflow is gauged at the USGS station located at Route 48. This is also a water quality monitoring station. The main stem length is 55.2 km. Nine Mile Creek receives treated municipal wastewater from the Village of Marcellus, as well as overflow and infiltration from the AlliedSignal waste beds in the lowest 3 km of the stream. Nine Mile Creek is the second largest natural tributary to Onondaga Lake.

From 1996 - 1998, the U. S. Geological Survey, in cooperation with the Town of Camillus, developed and verified a precipitation-runoff model to simulate the impacts of urbanization on streamflow in a 108 km^2 portion of the watershed (Zarriello 1999). The model selected for the study was the EPA model HSPF (Hydrologic Simulation Program FORTRAN) which factors land use, slope, infiltration rate, and water storage characteristics of the watershed to simulate streamflow response to precipitation. The model projections indicate that peak discharge and runoff volume of Nine Mile Creek are likely to increase as the watershed develops. Future development is not projected to cause significant increases in flooding during large storms. Rather, the frequency and magnitude of flows resulting from small storms are expected to increase. A slight decrease in streamflow during dry periods is also projected.

2. **Harbor Brook.** The Harbor Brook watershed drains a long and narrow area of 29.3 km^2 southwest of the lake and enters the lake approximately 1 km southwest of Onondaga Creek. The main stem length is 12.1 km. Land use in the headwater segment of the Harbor Brook watershed is a mixture of agriculture and residential. As the Brook flows through the City of Syracuse, land use becomes increasingly urban; the lower reaches of the watershed include areas of high density residential, commercial, and industrial land uses. Twenty combined sewer overflows (CSOs) discharge to the lower reaches of Harbor Brook. On rare occasion, sanitary overflows from the

Hillcrest and Brookside pump stations enter the Brook as well. Harbor Brook is monitored for streamflow and water quality conditions at two sites, Velasko Rd. and Hiawatha Boulevard.

In 1999 Onondaga County completed a sampling and assessment program of the macroinvertebrate community tributaries to Onondaga Lake, including Harbor Brook. The results are discussed in Chapter 9.

3. **Onondaga Creek.** The Onondaga Creek watershed drains an area of 282 km^2. The Creek originates in the Tully Valley, flows north and enters the lake as the Barge Canal along the southern shore. The main stem length is 44.2 km. About one-third of the Creek is located in the City of Syracuse. The Creek receives urban runoff, including approximately 50 CSOs. Various construction projects are underway to reduce the CSOs. Groundwater contamination in the "Oil City" region of the lower watershed may impact Onondaga Creek's water quality. Onondaga Creek represents the largest source of water to Onondaga Lake.

A unique feature of Onondaga Creek is the discharge of sediment-laden (turbid) groundwater from mudboils in the Tully Valley in the Creek's headwaters segment. The Tully Valley mudboils are volcano-like cones of fine sand and silt that have been a landscape feature since the late 1890's (Kappel and McPherson 1998). According to these USGS investigators, flow from a mudboil is driven by artesian pressure that forces water and sediment upward from sand and gravel aquifers through a 60-foot layer of dense silt and clay. The artesian pressure within the aquifer can lift water 20-30 feet above land surface. The source of the water is surface water that infiltrates to groundwater along the valley walls.

USGS has implemented three remedial actions in the mudboil area to reduce loading of suspended solids to Onondaga Creek and ultimately Onondaga Lake. The first is diverting surface water from the tributary feeding the mudboil area to a nearby tributary. This diversion reduced the water flow to the mudboil area by about two-thirds, which has resulted in a reduction in sediment loading to the creek from 30 to 15 tons per day (Kappel et al. 1996).

The second remedial action is installation of aquifer depressurizing wells to reduce artesian pressure in the upper aquifer and slow mudboil activity. Total groundwater discharge from the wells averages around 350 gallons per minute (gpm). Chemical quality of the water discharged from these wells is variable. Wells south (upgradient) of the mudboil area discharge generally fresh water while wells north (downgradient) discharge water that is slightly brackish to salty (Kappel and McPherson 1998).

Finally, USGS constructed a temporary dam at the outlet of the mudboil area, creating an impoundment designed to settle silts and sands before discharge to Onondaga Creek. The impoundment has reduced suspended sediment loading from 15 tons per day in 1992 to 1.5 tons per day in 1993 – 1994. As the impoundment has filled with silts and sands removal efficiency has decreased. The dam was reconstructed in 1996 to raise the water level and recover settling efficiency.

Macroinvertebrate sampling was conducted at six sites along Onondaga Creek in 1999. These results are discussed in Chapter 9.

Routine monitoring stations include Dorwin Avenue and Spencer/Kirkpatrick Street. As part of the storm event monitoring program Onondaga Creek is also monitored at Rt. 20 (upstream of all urban areas but downstream of mudboils) and downstream of Spencer St. (just prior to flowing into the Inner Harbor, close to the confluence with Onondaga Lake).

4. **Ley Creek.** Water quality and streamflow of Ley Creek are monitored at Park Street, close to the confluence with Onondaga Lake. The Ley Creek watershed extends eastward from the southern end of Onondaga Lake and covers an area of approximately 77.4 km^2. The headwaters drain mainly wetlands but the majority of the drainage flows through residential and industrial sites. Two CSOs discharge to Ley Creek. Within the basin are a number of large commercial and industrial sites, dredge spoil disposal areas, and several closed landfills that

received both sanitary and industrial waste. Macroinvertebrate sampling was completed along Ley Creek in 1999 as part of the AMP biological sampling efforts (see Chapter 9).

5. **Tributary 5A.** Tributary 5A receives treated wastewater from Crucible Specialty Metals, a steel manufacturing facility. The total flow into Onondaga Lake from this source is low. Historically, Tributary 5A contributed significant amounts of iron, chromium and copper to the lake, but these loads decreased with construction of an industrial wastewater reuse and treatment system in 1974. Since the loading of chemicals and solids from this source is not significant, monitoring data are best used as an additional check on performance of the industrial wastewater treatment facility. Beginning in August 1998, flow in Tributary 5A has been measured using a Sigma flow meter during each sampling event.

6. **METRO Effluent.** Treated effluent from METRO enters the lake at the southeastern end. In 1999, the METRO effluent represented the third largest source of water to Onondaga Lake. Most of the water treated at METRO originates in Skaneateles Lake and Lake Ontario, which are situated outside of the Onondaga Lake drainage basin. A small percent of the public water supply is drawn from Otisco Lake, which is within the Nine Mile Creek and Onondaga Lake watersheds.

The METRO facility was designed to provide advanced secondary treatment for biochemical oxygen demanding-material (BOD) and phosphorus removal for sewage flows of up to 120 mgd. Discharge to Onondaga Lake is through a surface outfall (Outfall 001). Flows between 120 mgd and 220 mgd undergo primary treatment and chlorination prior to discharge to Onondaga Lake via a separate outfall (Outfall 002). Additional information describing current effluent loads and planned reduction based on implementation of the ACJ is presented in Section 1.3.

7. **East Flume.** This tributary channels noncontact cooling water and site drainage from the former AlliedSignal Chemical Corporation industrial complex to the lake. The East Flume flow is difficult to gauge because there is no permanent fixed channel. In previous years, we coupled discharge reported on the biweekly sampling date with the measured concentration to estimate load. Beginning in 1999, the field sampling team measured stream discharge during each monitoring event.

C. Land Use

The Onondaga Lake watershed is highly urbanized, compared with other lakes in the Seneca-Oswego river basin. Based on the USGS 1:250,000 (large scale) GIRAS land use and land cover files, approximately 27% of the basin is categorized as urban, 34% as forest and 36% as agricultural.

The Syracuse Onondaga County Planning Agency (SOCPA) has mapped land use and other attributes of the Onondaga Lake watershed with their GIS. Land use varies by subwatershed. Examples of the land use breakdown for the major tributary streams are provided in Table 1-2, which is based on a September 1994 Technical Memorandum on Watershed Modeling prepared by Moffa & Associates for the Onondaga County Draft Municipal Compliance Plan/Draft Environmental Impact Statement. Data sources for the Technical Memorandum include SOCPA and the Onondaga County Natural Resources Conservation Service.

1.3 Point Source Discharges

A. **Historical perspective** Near the turn of the century, Onondaga Lake was the focus of a flourishing resort industry. The lake became increasingly degraded as the population grew and industries developed, and its uses became impaired. Completion of the Onondaga County METRO plant in the late 1960s and the banning of phosphorus detergents in the early 1970s marked the beginning of significant efforts to bring about lake recovery.

Improved technology and more stringent regulations led to the reduction or elimination of some point sources of pollution. The level of treatment provided for municipal and industrial waste discharges has increased over the past

decades. The METRO treatment plant was upgraded to secondary treatment in 1978 and advanced secondary in 1981. In 1993, the METRO plant underwent structural modifications to its aeration tanks, clarifiers, and anaerobic digesters to improve performance. The treatment plant is currently being upgraded and expanded to provide year-round nitrification and enhanced phosphorus removal.

Portions of the City of Syracuse have combined sewers, single pipes that convey both wastewater and storm water to the METRO facility. When pipe capacity is exceeded during rainstorms and snowmelt, a mixture of stormwater and untreated wastewater discharges to Harbor Brook or Onondaga Creek through overflow points in the sewer system (called combined sewer overflows or CSOs). The frequency and volume of discharge from the CSO network was reduced in 1984 with implementation of a Best Management Practices (BMP) program. However, overflows continue to occur multiple times each year, and have an adverse impact on water quality and aesthetics of the streams and lake. Under typical rainfall conditions, CSOs are projected to occur over 50 times each year (Moffa & Associates 1994). The engineering improvements now underway are designed to mitigate these overflows, and bring the County's wastewater collection and treatment system into compliance with state and federal regulations. Additional discussion of the improvements to METRO and the CSOs is included in Section 1.3 C.

Significant reductions in the mass of materials directed to the treatment plant from local industries have been achieved with implementation and enforcement of a comprehensive industrial waste pretreatment program.

- In 1974, Crucible Specialty Metals completed construction of a wastewater recycle and treatment plant designed to reduce iron and chromium releases. The Crucible wastewater treatment facility was upgraded in 1981 and again in 1986.
- In 1986 the AlliedSignal chloralkali plant closed after 100 years of operation, thus reducing the biggest source of sodium, calcium, and chloride to the lake.
- In 1988, the Linden Chemicals and Plastics (LCP) plant was closed. This facility, which had previously been owned and operated by AlliedSignal, discharged mercury to Onondaga Lake. Based on EPA estimates, approximately 75,000 kg of mercury were discharged from this facility between 1946 and 1975. An unknown amount of mercury was released from the facility from 1976 until its closure in 1988. A remedial investigation/feasibility study (RI/FS) of the AlliedSignal complex is underway. As of the date of this report, the RI portion is close to completion.
- In 1997, the pharmaceutical company Bristol Myers Squibb began full-scale operation of a pretreatment facility designed to nitrify their wastewater prior to discharge to the municipal collection system.
- In 1999, Onondaga County reached a settlement agreement on a lawsuit brought by EPA in 1991. The agreement focuses on the County's pretreatment program and requires the County to report to EPA and NYSDEC on a quarterly basis, undertake a review of local limits, and conduct an industrial user survey. In addition, the County has agreed to undertake a supplemental environmental project as an offset to monetary penalties. The project selected by the County will address nonpoint source pollution from agricultural lands in the Onondaga Creek watershed.

B. **Significant Discharges to Onondaga Lake:** As of 1999, remaining point source discharges to Onondaga Lake include treated effluent and partially-treated bypass flows from METRO, treated wastewater from Crucible Specialty metals, and noncontact cooling water from several industries at the AlliedSignal complex. The treatment plant receives wastewater from industrial, commercial, and residential sources.

Bristol Myers Squibb remains a significant industrial source of influent wastewater to the METRO facility. As noted above, a pretreatment facility for the pharmaceutical industry has been constructed. Ammonia removal (oxidation to nitrate) at the pretreatment facility has been inconsistent. The ammonia load from the facility is plotted in Figure 1-5. The average ammonia load from this facility in 1999 was the lowest reported. However, the standard deviation remained high indicating that ammonia conversion was highly variable in the facility during 1999. The 1999 data reflect continued operational difficulties with the biological treatment system. Some fluctuation in performance can be attributed to the nature of this industry (large-scale cultivation of microorganisms to harvest pharmaceuticals).

Nonpoint sources of nutrients, sediment, and bacteria enter the lake through the tributaries and the CSOs. Industrial residuals in the watersheds of individual tributaries, such as PCBs in the Ley Creek basin and the AlliedSignal waste beds in the Nine Mile Creek basin, continue to flow to the lake through surface runoff and infiltrating groundwater. Lake sediments contain elevated concentrations of mercury and organic chemicals.

C. **Planned Improvements to the Onondaga County Wastewater Collection and Treatment System.** The Amended Consent Judgment (ACJ), signed in January 1998, commits the County to implementing a phased 15-year program of upgrades and improvements to METRO and the CSOs. The ACJ specifies a compliance schedule for METRO to meet staged effluent limits for ammonia and phosphorus (Table 1-3). Note that the compliance date for ammonia effluent limits of 1.2/2.4 mg/l (summer/winter limits) have been revised since the ACJ was signed in 1998. Stage III ammonia limits will now be met by May 1, 2004 eight years ahead of the original schedule. These effluent limits may be revised again once NYSDEC promulgates revised Total Maximum Daily Loads (TMDLs) for Onondaga Lake and the Seneca River.

In order to comply with the effluent limits, Onondaga County is required to design, test and construct modifications and additions to the METRO facility that enable year-round nitrification of ammonia and filtration for phosphorus removal. The ACJ includes language that requires the County to modify the METRO discharge so that compliance with ambient water quality standards in the Lake is achieved, even if diversion of METRO effluent to the Seneca River is necessary to achieve these standards. The decision whether additional measures are required to bring the lake into compliance is scheduled for the year 2009. Engineering alternatives that fully comply with water quality standards must be implemented by December 1, 2012.

For the combined sewers, the ACJ requires the County to design, construct, maintain, and modify and/or supplement as necessary, a CSO control and upgrade program. The program must meet requirements established in State and federal policy and guidance. Specifically, the County's CSO control and upgrade program must achieve three criteria:

(1) Elimination or capture for treatment of no less than 85% by volume of the combined sewage collected on a system-wide annual average basis,
(2) Elimination or minimization of floating substances in Onondaga Lake attributed to the County's CSOs, and
(3) Achievement of water quality standards for bacteria in all Class B portions of Onondaga Lake.

1.4 PRIORITY WATERBODIES WITHIN THE ONONDAGA LAKE WATERSHED

New York State Department of Environmental Conservation (NYSDEC) is responsible for managing the State's surface water resources. Lakes and streams are classified according to their designated best use (for example, water supply, swimming, fish propagation, aesthetic enjoyment, and fish survival). The State has an extensive program of monitoring and reporting to assess the extent to which the designated uses are being met. Water bodies that may not consistently meet their designated best use, or for which changes in land use may threaten water quality, are placed on a Priority Waterbodies List (PWL) that is updated every two years. Other agencies such as the County Water Quality Coordinating Committees provide input into the PWL.

The PWL ranks waterbodies on a scale of increasing severity:

Threatened: Water quality supports the waterbody's designated use and the ecosystem exhibits no obvious signs of stress. However, existing or changing land use may result in restricted use or ecosystem disruption. Or, water quality monitoring reveals a declining trend which, if it continues, may result in restricted use or ecosystem disruption.

Stressed. Waterbody use is not significantly limited or restricted, but occasional conditions discourage use.

Impaired. Occasional water quality conditions periodically prevent use.

Precluded: Frequent, persistent water quality conditions prevent all aspects of the designated use.

A subset of the PWL list is the 303(d) list, named for the section of the federal Clean Water Act that requires states to report to EPA those waterbodies requiring a watershed approach to water quality protection or restoration. A watershed approach examines all point and nonpoint sources of nutrients and other contaminants and develops an integrated strategy for improvements. The 303(d) list includes those waterbodies for which technology-based effluent limits will not achieve desired water quality and ecosystem protection. Water quality based effluent limits are required and should be developed within the TMDL (Total Maximum Daily Load) framework.

Various stream and lake segments in the Onondaga Lake watershed are included on the PWL and the 1998 303(d) list (Table 1-4). No changes to listings for the Onondaga County waterbodies have been issued. The Lake remains one of the State's top priorities for TMDL development and ultimate water quality restoration.

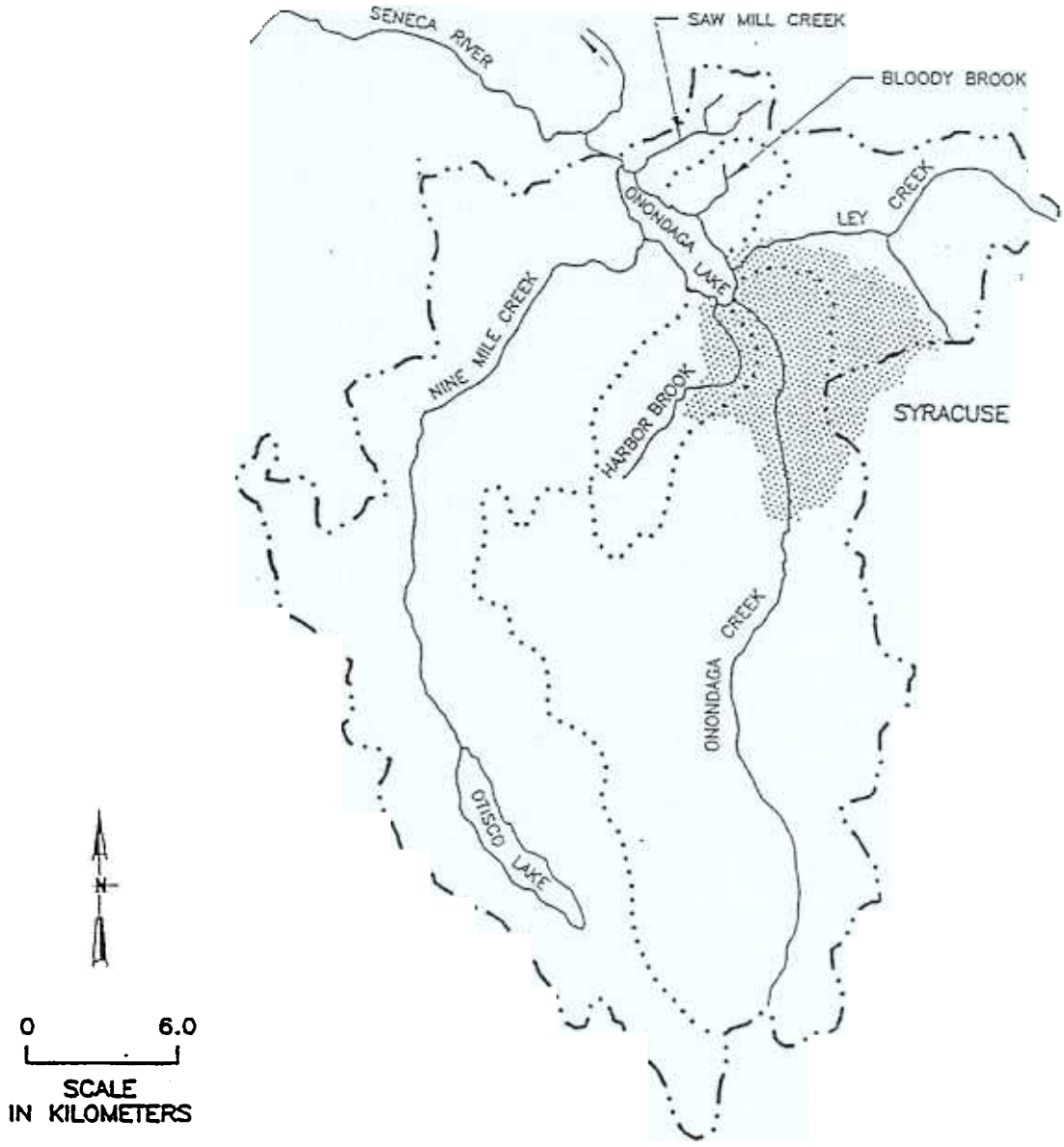
1.5 REPORT OVERVIEW

Chapter 1 has presented a historical perspective of the monitoring program, the objectives of the program, and a description of the Onondaga Lake drainage basin. In Chapter 2, field methods, analytical methods, strategies for quality assurance and quality control, statistical methods, and assessment of compliance procedures are outlined. Chapter 3 presents results of the quality assurance/quality control components of the program. In Chapter 4 we present results of the 1999 tributary monitoring program, including hydrological data, total loading and concentrations of chemical and microbiological constituents, seasonal patterns of constituent concentrations and flow, and an evaluation of compliance with New York State ambient water quality standards. Following the tributary chapter is a report on the results of storm event monitoring completed on three streams in 1999. The storm event monitoring is presented as Chapter 5.

Chapter 6 presents results of the 1999 Onondaga Lake monitoring effort. Data for temperature, dissolved oxygen, nitrogen, phosphorus, major ions, fecal coliforms, trophic status and compliance with standards are included. Chapter 7 focuses on trophic state assessment, the special topic of the 1999 annual report. Chapter 8 was prepared by Dr. Edward Mills and his associates to present the results of the 1999 plankton monitoring program. Chapter 9 is a summary of the EcoLogic report of macroinvertebrate monitoring conducted on the three tributaries and the lake's littoral zone. A summary of the report prepared by Beak Consultants of the zebra mussel community in the Seneca River is presented as Chapter 10. In Chapter 11, results of the 1999 Seneca River water quality monitoring program are presented and interpreted by Dr. Ray Canale.

Dr. William Walker has prepared Chapter 12 to present his continued progress on mass balance modeling for the lake. Chapter 13 is a summary of the water quality status of the lake with respect to its restoration goals. Each water quality issue is presented as a hypothesis, and the monitoring programs are summarized as means to test the hypothesis and assess progress towards meeting restoration goals. The final chapter, Chapter 14, is a summary of findings and recommendations.

Appendix A includes copies of the 1999 Onondaga Lake historic data plots and volume-weighted data for the 1999 Onondaga Lake Monitoring program that were provided by OCDDS. Also included are the electronic analytical data files for the Onondaga Lake, Onondaga Lake Tributary, and River Monitoring Programs. Because of the volume of data generated by the AMP, hard copies of the data files are not issued with this report, and are available upon request.



ONONDAGA LAKE 1999 ANNUAL REPORT
ONONDAGA COUNTY DEPARTMENT OF
DRAINAGE AND SANITATION

FIGURE 1–1
ONONDAGA LAKE DRAINAGE BASIN
AND 6 SUBBASINS

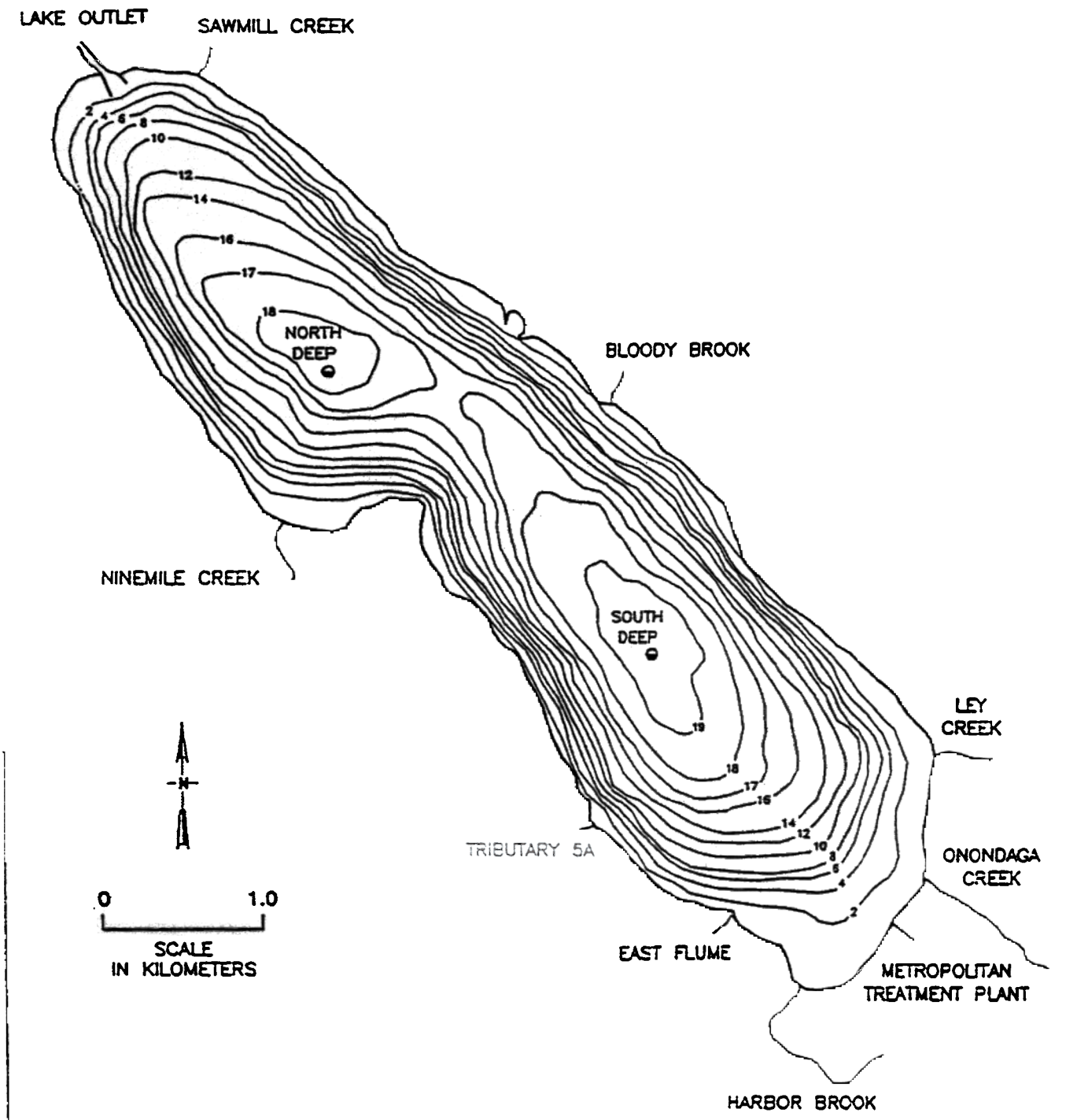


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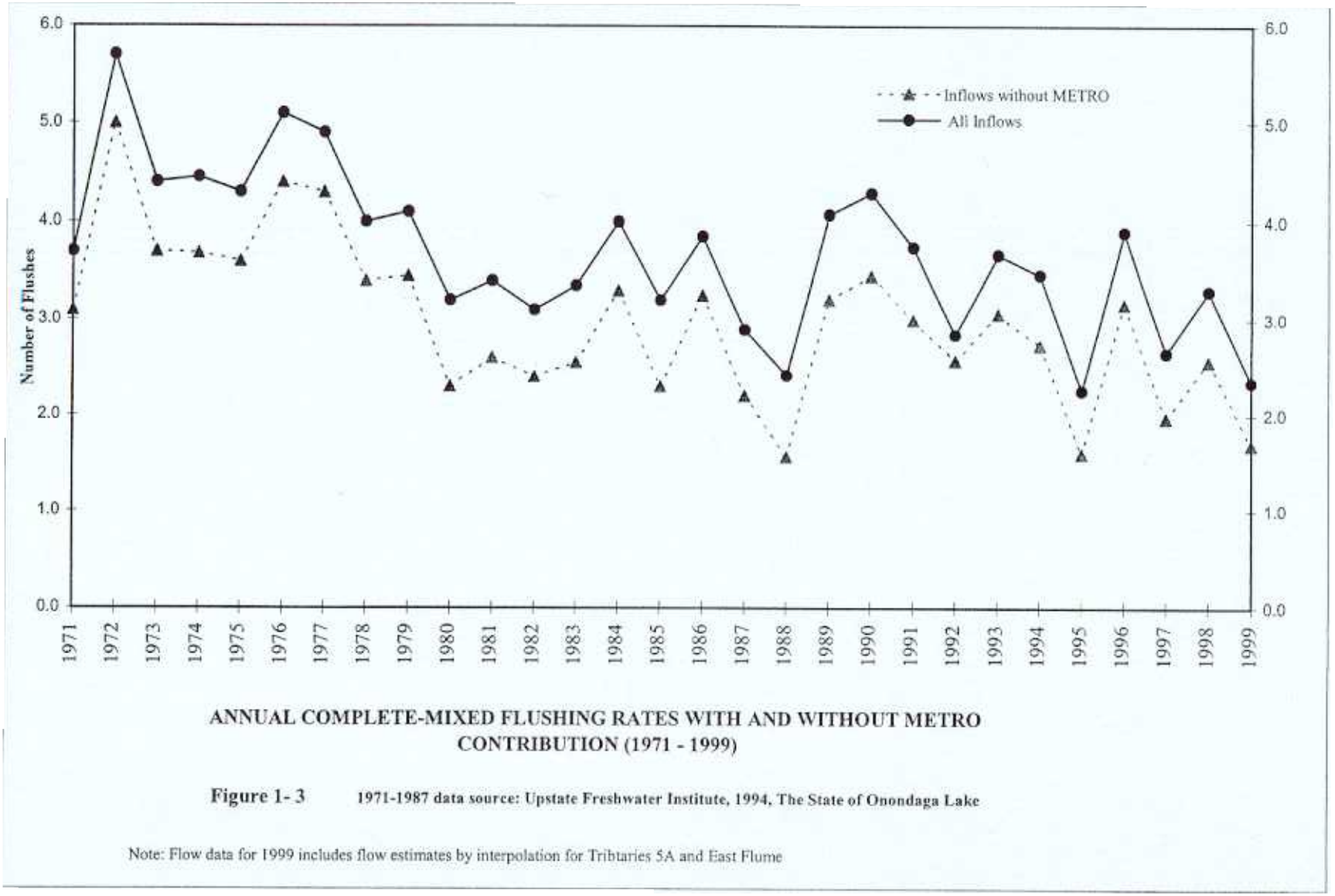
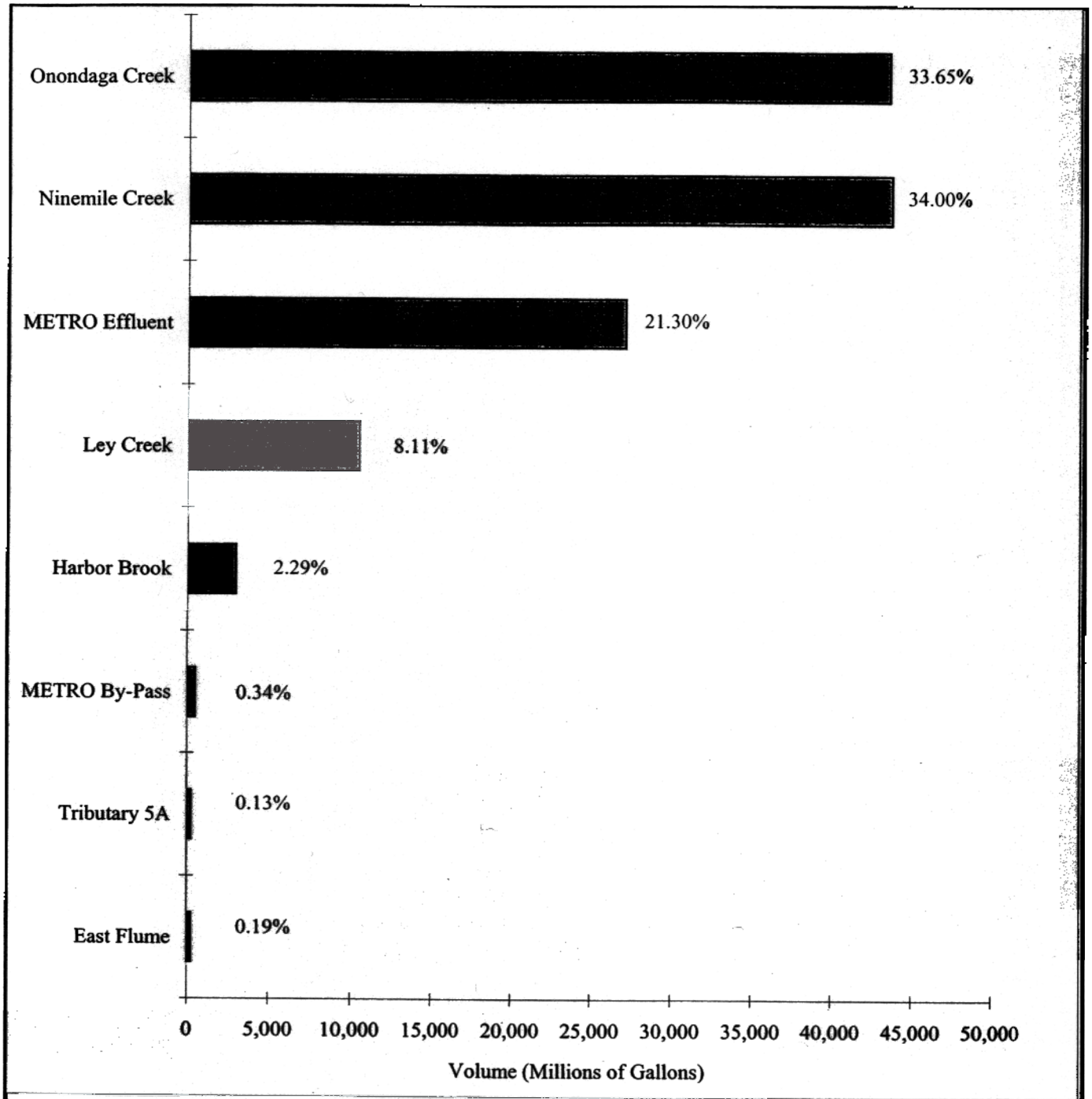
FIGURE 1-2
BATHYMETRIC MAP OF ONONDAGA LAKE



ANNUAL COMPLETE-MIXED FLUSHING RATES WITH AND WITHOUT METRO CONTRIBUTION (1971 - 1999)

Figure 1- 3 **1971-1987 data source: Upstate Freshwater Institute, 1994, The State of Onondaga Lake**

Note: Flow data for 1999 includes flow estimates by interpolation for Tributaries 5A and East Flume



Flow records for METRO are from Jan. 1987 - Dec. 1999. METRO data from 11/92 to 9/93 are not used due to construction-related bypasses during that period. Flow records for Onondaga Creek are from Oct. 1970 - Dec. 1999, records for Harbor Brook and Nine Mile Creek are from Jan 1971 - Dec. 1999, and records for Ley Creek are from Jan. 1973 - Dec. 1999. Tributary 5A and East Flume flows are provided for sampling dates by Crucible and Allied Signal, respectively; percentages for these tributaries are derived from 1993 - 1999 records.

FIGURE 1-4 LONG-TERM YEARLY HYDROLOGIC CONTRIBUTIONS OF TRIBUTARIES AND METRO TO ONONDAGA LAKE

2%CONTRI99.xls

Figure 1-5
Mean and Standard Deviation of Ammonia Load from Bristol Myers Squibb

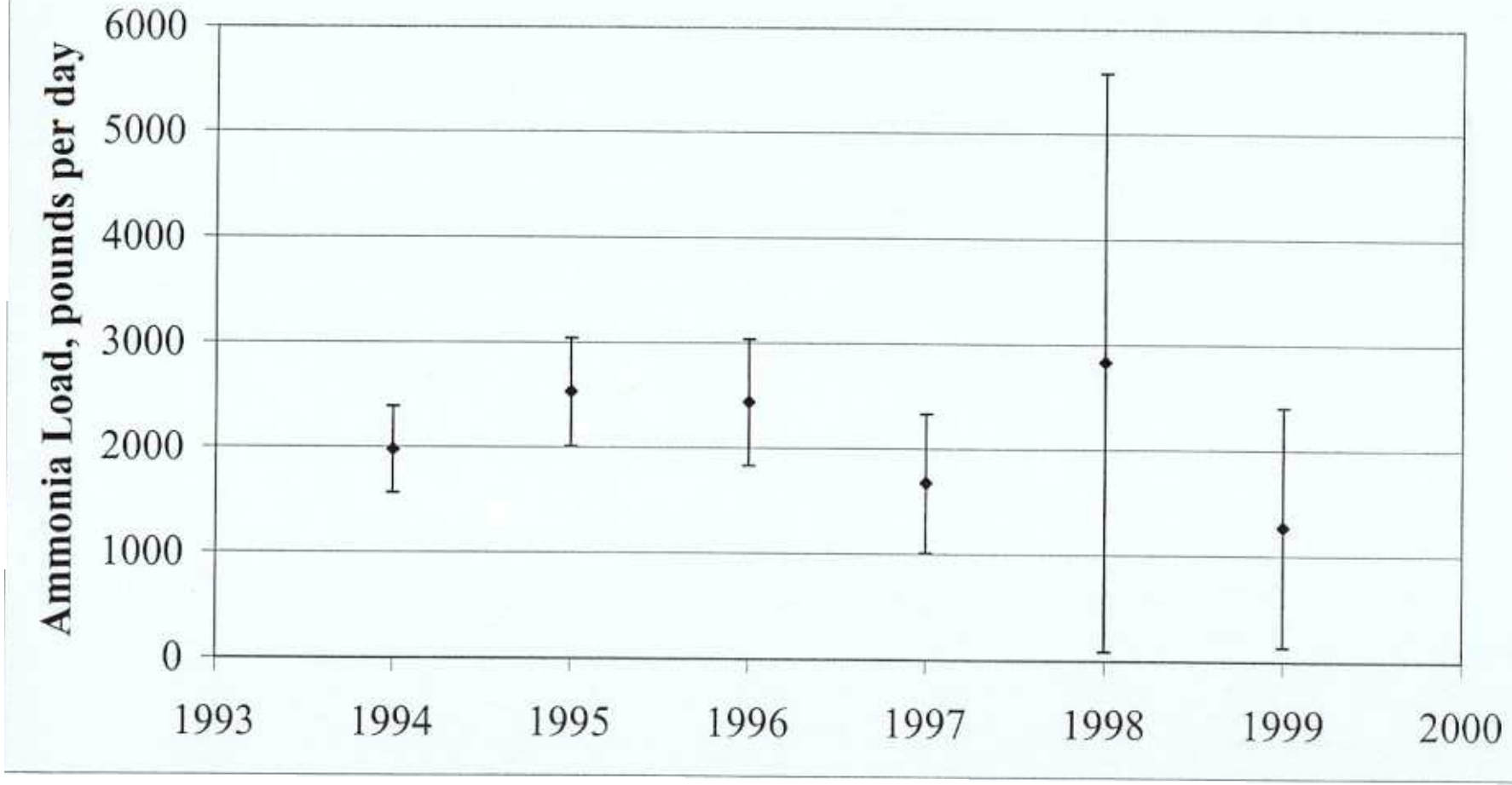


TABLE 1-1

ONONDAGA LAKE ICE COVER

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Winter	Date Ice First Reported	Approximate Days of Ice Cover, North Basin	Approximate Days of Ice Cover, Lakewide *(diary notes >90%)*
87-88	12/31/87	70 days	20 days
88-89	12/14/88	75 days	9 days (4+5)
89-90	12/6/89	90 days	30 days (26 + 4)
90-91	12/27/90	54 days	6 days
91-92	12/19/91	59 days	19 days (14+5)
92-93	12/14/92	76 days	13 days
93-94	12/23/93	78 days	18 days
94-95	12/12/94	53 days	5 days
95-96	12/13/95	32 days	11 days (9+2)
96-97	1/9/97	47 days	19 days
97-98	12/31/97	15 days	0 days
98-99	12/23/98	62 days	12 days (6+6)
99-00	1/17/00	42 days	28 days

TABLE 1-2
ONONDAGA LAKE WATERSHED LAND USE FOR SELECTED TRIBUTARIES

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Tributary	Percent Agricultural	Percent Urban	Percent Forest
Onondaga Creek	4.5	49.2	46.3
Nine Mile Creek	31.8	17.5	50.7
Otisco Lake	42.6	8.0	49.4
Ley Creek	0	70.6	29.4
Harbor Brook	9.7	50.5	39.8

Source: *Sept. 1994. Technical Memorandum on Watershed Modeling prepared by Moffa & Associates for the Onondaga County Draft Municipal Compliance Plan/Draft Environmental Impact Statement.*

TABLE 1-3

PHASED EFFLUENT LIMITS SPECIFIED BY THE ACJ

Onondaga Lake 1999 Annual Report
Onondaga County, New York

PARAMETER	PHASE	EFFLUENT LIMIT (Note seasonal limits for ammonia)	REQUIRED COMPLIANCE DATES	PROJECTED COMPLIANCE DATE
Ammonia Nitrogen	I	8,700 ppd (7/1 – 9/30)	January 1998	MET
		13,100 ppd (10/1 – 6/30)		
	II	2 mg/l (6/1 – 10/31)	May 1, 2004	Will proceed directly to Phase III limits
		4 mg/l (11/1 – 5/31)		
	III	1.2 mg/l (6/1 – 10/31) *	December 1, 2012	May 1, 2004
		2.4 mg/l (11/1 – 5/31) *		
Phosphorus	I	400 ppd	January 1998	MET
	II	0.12 mg/l	April 1, 2006	May 1, 2004
	III	0.02 mg/l *	December 1, 2012	December 1, 2012

ppd = pounds per day

* Final effluent limits for ammonia and phosphorus (effective December 1, 2012) may be modified based on revised TMDL for Onondaga Lake. NYSDEC anticipates promulgating revised TMDLs for Onondaga Lake on or about January 2009, subject to EPA approval as provided pursuant to section 303(d) of the Clean Water Act.

TABLE 1-4

SUMMARY OF PRIORITY WATERBODIES LIST SEGMENTS, ONONDAGA LAKE WATERSHED

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Priority Waterbodies List						
Segment	Size	Class	Affected Use	**Severity**	**Pollutant**	**Source**
Bloody Brook	**0.5 mi**	**B**	**Bathing**	**Precluded**		
Furnace Brook	**1.0 mi**	**B**	**Fish propagation**	Stressed	Silt	**Hydrologic modification**
Geddes Brook	**0.5 mi**	**D**	**Fish propagation**	**Precluded**	**Metals**	**Industrial**
Geddes Brook	**2.5 mi**	**C(T)**	**Fish propagation**	**Threatened**	**Oxygen demand**	**Municipal**
Harbor Brook	1.5 mi	B,D	Fishing	Precluded	**Aesthetic**	**CSO**
Harbor Brook	**1.0 mi**	**C(T)**	**Fish propagation**	**Threatened**	**Silt**	**Construction**
Ley Creek & Tributaries	**3.0 mi**	**B**	**Fishing**	**Precluded**	**Aesthetic**	**CSO**
Nine Mile Creek	**1.0 mi**	**D**	**Fish propagation**	**Precluded**	**Salts**	**Industrial**
Onondaga Creek	**17.0 mi**	**D**	**Bathing**	**Precluded**	**Silt**	**Other (mud boils)**
Onondaga Lake & Outlet	**2944 Acres**	**B**	**Bathing**	**Precluded**	**Pathogens**	**CSO**
Otisco Lake	**400 A**	**AA**	**Bathing**	**Impaired**	**Silt**	**Other**
1998 303 (d) List of Waterbodies Designated as Priority for TMDL						
Segment	**Size**	**Class**	**Affected Use**	**Severity**	**Pollutant**	**Source**
Geddes Brook	0.5 mi	C	Fish Propagation	Precluded	Ammonia	Runoff
Harbor Brook	1.5 mi	B,C	Fish Propagation	Precluded	**Nutrients**	**CSO**
Ley Creek & Tributaries	3.0 mi	B	Fish Propagation	Precluded	**Nutrients**	**CSO**
Nine Mile Creek	1.0	C	Fish Propagation	Precluded	**Nutrients**	**Runoff**
Onondaga Creek	17 mi	B, C(T)	Fish Propagation	Precluded	**Nutrients**	**CSO, agriculture**
Onondaga Lake & Outlet	2944 Acres	B	Bathing	Precluded	**Nutrients**	**CSO, municipal, runoff**
Seneca River	15.6 mi	B	Fish Propagation	Impaired	**Oxygen demand**	**Zebra mussels, stratification**

CHAPTER 2
METHODS

2.1 TRIBUTARY SAMPLING AND FIELD MEASUREMENTS

Tributaries to Onondaga Lake were sampled on 29 occasions between January 5 and December 21, 1999. These 29 events encompassed the routine biweekly program plus several high flow events to ensure that the flow record was adequately sampled. Samples were collected at all stations on these occasions. In addition, three storm events were monitored during 1999. Storm event samples were collected on Onondaga Creek (4 stations), Ley Creek (2 stations), and Harbor Brook (2 stations) over a period of several days for each event. These data are presented and discussed in Chapter 5. Sampling locations, parameters and schedules are detailed in Figure 2-1 and Table 2-1.

In-situ data (pH, dissolved oxygen, temperature, specific conductance, and oxidation-reduction potential) were collected at each location using a Surveyor III or IV manufactured by the Hydrolab Corporation of Austin, Texas. Instrument calibration and post-calibration checks were recorded in a bound calibration log.

Water samples for chemical analysis were collected and analyzed according to EPA Requirements for Water Planning and Management (40 CFR 136, 1991) and EPA 600/4-82-029, 1982 as detailed in the EPA-approved Quality Assurance/Quality Control (QA/QC) plan for this project. Sampling and analysis were also consistent with New York State's Environmental Laboratory Approval Program, through which the County's environmental laboratory is certified (ELAP#10191).

Tributary samples were collected as a composite of multiple samples across the entire cross section of the stream. According to NYSDEC guidance, the composite samples are more representative of the water-suspended sediment ratio of the stream itself (NYSDEC 1997 Program Plan for Rotating Intensive Basin Studies Water Quality Section, April 1997). Since many contaminants of concern are transported with the suspended sediment fraction, the overall loading estimate is considered to be more accurate when based on the composite samples.

Most of the tributary streams in the Onondaga Lake watershed are now sampled using a depth-integrating sampler which is designed to accumulate a water-suspended sediment sample at a velocity comparable to the stream velocity. Depending on the depth and velocity of the stream, a depth integrated sample is collected from a bridge using a sampling crane or by wading the stream with a hand-held sampler. Multiple transects are sampled. There are a few exceptions to this general approach , as summarized in Table 2-2. The East Flume is sampled as the flow goes over a v-notched weir, and the sample bottles are filled directly from the cascade of water through the weir. Ley Creek, which has low water velocity at the Park St. monitoring station, is sampled using a Kemmerer bottle, taking three samples over the cross section of the stream. The bottle samples through the entire depth of the water column. Finally, the County continues to sample the Onondaga Lake outlet using a Wildco beta sampler at 2- and 12-foot depths. This sampling technique is used because of the bidirectional flow regime in the lake outlet.

Prior to implementation of the AMP in August 1998, tributary samples were collected using a single mid-channel dip with a stainless steel bucket (pail sampling method). To evaluate the potential implications of the change in sampling methods, paired samples have been collected on Onondaga Creek at Dorwin Ave. since August 1998 using both the pail and depth integrated techniques. The paired samples have been analyzed for total phosphorus (TP) and total suspended solids (TSS). Results of the paired sampling effort are discussed in Chapter 3.

Daily mean flow values as reported by USGS were coupled with the measured concentration data to estimate load. Storm event data were also included in the 1999 calculation of annual loads. Flow-weighted average concentrations over each 24-hour period of the event were paired with daily average flows and added to the annual data set. Method 2 of the FLUX program is used to calculate loads. The network of flow gauging stations in the Onondaga Lake watershed is partially funded by OCDDS through a cooperative arrangement with USGS. Daily provisional and finalized flow monitoring data are provided by the USGS Water Resources Division office in Ithaca for use in calculating loading rates and mass balances.

2.2 LAKE SAMPLING AND FIELD MEASUREMENTS

Onondaga Lake was sampled every two weeks between March 29 and December 14, 1999 (total 20 events) at the "South Deep" station and four times at the "North Deep" station (Figure 2-1 and Table 2-3). During the fall mixing period of late October 1999, the County field team completed additional sampling events for a limited number of parameters in order to track dissolved oxygen concentrations. Field sampling was conducted on eight dates between October 5 (when cooling and mixing was evident) through October 25th when mixing was complete. Monitoring was intense during the most critical period, with five field days between October 19th and 25th.

Sampling stations were located using GPS navigational equipment, with a differential to increase accuracy and precision. The coordinates are: South Deep 43° 04' 67" N Latitude, 76° 11' 88" W Longitude; North Deep 43° 05' 93" N Latitude, 76° 13' 73" W Longitude.

In-situ data for pH, DO, temperature, specific conductance, and oxidation-reduction potential (Redox) were collected at half-meter intervals throughout the water column using a Hydrolab Surveyor III or IV. Calibration and calibration checks were conducted before and after each sampling event. Other field data collected include Secchi disk transparency and underwater illumination. Light availability data were collected at 20-cm intervals to the secchi disk depth using a Li-Cor photometer.

Samples were collected for laboratory analysis using a submersible pump or a WildCo Beta sampler, depending on the parameter to be analyzed. Pumping lines were purged of previous sample water prior to sample collection. Also, all sample containers were rinsed with sample water prior to being filled. Composite samples, equal sample volumes collected at discrete depths, were mixed in a churn. The depths of composites were determined in the field after the thermal stratification regime was determined using the Hydrolab to measure temperature and other field parameters. For example, epilimnetic composites were typically composed of equal volumes of water sampled at 0, 3, 6, and 9 meters depth. However, during July the epilimnion extended only to 6 m, so the composite sample included water collected at 0, 3 and 6 meters. Typically, the hypolimnetic composite consisted of water collected at 12, 15, and 18-meter depths. All sampling equipment used on Onondaga Lake is dedicated to this purpose only. Field blanks were incorporated into each monitoring event to evaluate the effectiveness of equipment decontamination (rinsing) between sites.

Samples for phytoplankton and zooplankton were collected biweekly from April to September and monthly in October and November at the South Deep site. Three additional samples were taken from the North Deep site (April, June, and September). Phytoplankton and chlorophyll *a* samples were collected using a tygon tube, inner diameter 2 cm, lowered through the epilimnion to the top of the thermocline. When the lake was not stratified, the tube sampler was lowered to a depth of 9 m. In addition to the depth-integrated sample, discrete samples were collected at depths of 1 and 3 m. This sampling program was implemented to enable comparisons between the discrete sampling method, used historically on Onondaga Lake, and the integrated tube method. Results of the paired samples are discussed in Chapter 8. Phytoplankton samples (125 ml) were pre-preserved with acid Lugol solution. Zooplankton samples were collected with an 80-micron mesh net that was 86 cm long and 24 cm in diameter. The net was towed through the oxygenated portion of the water column. Specimens were preserved in 70 percent ethanol. Veligers samples were collected with a 0.5 meter net with 53-micron mesh net through the epilimnion. Samples were preserved with sugar formalin solution.

The 1999 Ambient Monitoring Program incorporates the findings and recommendations detailed in Dr. William Walker's report entitled "A Statistical Framework for the Onondaga Lake Ambient Monitoring Program Phase I" dated January 15, 1999. As part of the report, the AMP designs for total phosphorus, total nitrogen, total kjeldahl nitrogen, ammonia nitrogen, transparency, chlorophyll-a, and fecal coliforms were evaluated for expected precision of yearly and long-term geometric means, power for detecting trends, and adequacy to support lake mass-balance calculations.

Specific recommendations include:

- The sampling frequencies for chlorophyll-a, transparency, and bacteria (fecal coliforms, enterococci) at the Lake South deep station be increased from biweekly to weekly between May and September in provide improved basis for detecting long-term trends in these variables.
- Duplicate chlorophyll-a and bacteria samples to be collected at the Lake South station on a monthly basis between May and September.
- Phytoplankton counts on both epilimnetic and photic zone composites at a biweekly frequency between May and October.

Weekly bacteria and transparency measurements at the near-shore stations in the northern portion of the lake designated as Class B.

2.3 LABORATORY ANALYSIS

Chain-of-custody procedures, equipment description and calibration, reagents and analytical procedures used by the OCDDS Environmental Laboratory are those outlined by the ELAP of the New York State Department of Health and modified for the DEC-approved Quality Assurance Project Plan for this monitoring program. A list of those methods and their precision and accuracy as determined by the ELAP program is presented in Table 2-4.

Effective June 1, 1999, the OCDDS Environmental Laboratory began to measure metals in the water samples using an ICP (Inductively Coupled Plasma) instead of the flame and furnace atomic absorption (AA) method that had been used since the 1970s. The change in analytical technique will result in improved limits of detection for many of the inorganic metals present in the lake and streams.

2.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Some of the QA/QC methods for field and analytical procedures are required as part of the Environmental Laboratory Analytical Protocol (ELAP) certification program. Other methods and criteria are adapted from guidance provided by EPA and NYSDEC for use in their water programs. The EPA's standard criteria for precision, accuracy, representativeness, completeness, and comparability provide a benchmark for the County's program. These standard criteria are discussed in 40 CFR 30.503.

A. **Precision.** The agreement between the concentrations of analytes measured in two individual samples collected from the same depth is considered "field precision". However, this evaluation includes both laboratory and field sources of variability. For routine lake and tributary monitoring, a single lake depth (6 m) and tributary site (East Flume) were sampled in duplicate and the complete set of parameters analyzed. The program goal is for 90% of the field duplicates to have a relative percent difference (RPD) less than 20 percent. However, when concentrations are close to the limit of analytical detection, this goal may not be feasible.

B. **Accuracy.** Accuracy, how close a measured value is to a "true" concentration, was assessed through a blind laboratory audit, discussed in Chapter 3. As an ELAP-certified laboratory, the METRO environmental laboratory participates in regular proficiency audits. Statistical screening of outliers is also conducted to identify suspect data points.

C. **Representativeness.** In order to obtain representative data that reflect the conditions of the lake and tributaries, samples were collected as described in Tables 2-1 and 2-2. Lake samples were collected during the ice-free period from the surface to the bottom. Conditions in the upper waters were analyzed and presented separately from those of the lower waters to describe differences between the epilimnion and hypolimnion during the period of thermal stratification.

The composite tributary sampling methodology is considered by NYSDEC to provide improved estimates of the true water quality in a stream's cross section. Samples of the lake outlet were taken at 2 and 12 feet to accommodate the bidirectional flow and density stratification that occurs in the lake outlet, particularly during low flow.

D. **Comparability.** Documentation of procedures and results of the monitoring program have been maintained by OCDDS since 1968. The data set collected in 1999 is comparable with that of previous years, with some exceptions brought about by the AMP. The sampling station on Onondaga Creek was moved from Spencer St. to Kirkpatrick St. in order to pick up the flow from one additional combined sewer overflow. To examine the impact of the change in methodology for the tributary sampling, paired sampling of the two sample collection methods was conducted. These samples were analyzed for total phosphorus and total suspended solids. Results of the paired analysis are discussed in Chapter 3.

E. **Completeness.** Completeness refers to the number of samples successfully collected, analyzed, and validated as compared to the proposed scope of effort. Data validation is a several-party effort, with data scrutinized first by laboratory personnel for errors in sample coding or transcription, then by OCDDS staff for completeness as compared

to the work plan, and by EcoLogic scientists for limnological reasonableness. As a final check, Dr. William Walker statistically screens data for outliers prior to their inclusion in the long-term database.

F. Field Audit. Audits of the field sampling program on the lake and tributaries were completed in 1999. The NYSDEC Region 7 sampling coordinator worked with the County's field team leaders to provide orientation and training on the depth-integrated composite sampling methodologies for the tributaries.

2.5 CALCULATION OF VOLUME AVERAGES FOR THE EPILIMNION AND HYPOLIMNION

The lake data were reduced into "volume-weighted averages" for the epilimnion, or upper waters (0 to 9 meters) and the hypolimnion, or lower waters (12, 15 and 18 meters). Concentration of analytes measured at each depth are multiplied by a factor that represents the lake volume at that depth; the products are then summed and divided by the sum of factors. Thus, the volume-weighted measurements take into account the differences in concentrations and volume in the different layers of the lake. These volume-weighted results are used to characterize the water quality of the upper and lower layers of Onondaga Lake and track changes over time. Volume averaging factors are summarized in Table 2-5.

TABLE 2-

SAMPLING PROGRAM FOR ONONDAGA LAKE TRIBUTARIES, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Sampling site numbers correspond to the following sites:

1 Nine Mile Creek @ Lakeland (Rt. 48)
2a Harbor Brook @ Hiawatha Blvd.
2b Harbor Brook @ Velasko Rd.
3a Onondaga Creek @ Kirkpatrick St.*
3b Onondaga Creek @ Dorwin Ave.
4 Ley Creek @ Park St.
5 Tributary 5A @ State Fair Blvd.(1)
6 METRO Effluent(2,6)
7 Allied East Flume
8a Onondaga Lake Outlet @ Long Branch Rd.--2 ft.
8b Onondaga Lake Outlet @ Long Branch Rd.--12 ft.

Parameter	Sampling Sites											Frequency(3)
	1	2a	2b	3a	3b	4	5	6	7	8a	8b	
Cd, Cr, Cu, Ni, Pb, Zn, As, Hg, K	X	X	X	X	X	X	X	X	X	X	X	Quarterly
Ca, Na, Mg, Mn, Fe	X	X	X	X	X	X	X	X	X	X	X	Biweekly
CN	X	X	X	X	X	X	X	X	X	X	X	Quarterly
Phenols	X	X	X	X	X	X	X	X	X	X	X	Quarterly
BOD_5, TSS(4), TDS, Cl, SiO_2, SO_4, TP, SRP, NO_3, NO_2, TOC, TOC-F, TIC	X	X	X	X	X	X	X	X	X	X	X	Biweekly
TKN, NH_3-N, Org-N	X	X	X	X	X	X	X	X	X	X	X	Biweekly
ALK-T	X	X	X	X	X	X	X	X	X	X	X	Biweekly
F. Coli, Enterococci	X	X	X	X	X	X	X	X	X	X(5)		Biweekly
Salinity, pH, Temperature, Conductivity, DO Redox Potential (7)	X	X	X	X	X	X	X	X	X	X	X	Biweekly

1) Tributary 5A flow will also be monitored quarterly (during the Extended Tributary sampling events, which includes the quarterly and biweekly parameters).

2) METRO effluent sampled biweekly for all parameters. If any flow is bypassed on sampling date, this water is sampled for the same parameters as the fully treated effluent.

3) A minimum of 5 tributary sampling events will be conducted for predetermined high flow conditions.

4) In addition, samples were collected side-by-side at the Onondaga Creek (Dorwin Ave.) and Nine Mile Creek sampling sites using the depth integrated and grab sample techniques for the parameters TSS and TP.

5) Sample was collected at the surface of the Lake Outlet.

6) Daily METRO data was obtained for BOD, TSS, pH, temperature, TP, and NH3-N.

7) A Hydrolab profile (of insitu parameters) was obtained at the Onondaga Lake outlet at Longbranch

TABLE 2-2

SUMMARY OF TRIBUTARY SAMPLING TECHNIQUES

Onondaga Lake 1999 Annual Report
Onondaga County, New York

TRIBUTARY	TECHNIQUE
Onondaga Creek at Kirkpatrick St.	Depth-integrating sampler, crane from bridge
Onondaga Creek at Dorwin Ave.	Depth-integrating sampler, crane from bridge
Harbor Brook at Velasko Rd.	Depth-integrating sampler, hand-held (wade stream)
Harbor Brook at Hiawatha Blvd.	Kemmerer sample, three points composited
Nine Mile Creek at Rt. 48	Depth-integrating sampler, crane from bridge
Ley Creek at Park St.	Kemmerer sample, three points composited
Tributary 5A	Depth-integrating sampler, hand-held (wade stream)
East Flume	Sample bottles filled from sampling churn with water collected at weir with jar
Onondaga Lake Outlet	Wildco (point) sampler at 2 ft. and 12 ft. depths

TABLE 2-3

SAMPLING SCHEDULE OF PHYSICAL, CHEMICAL, AND BIOLOGICAL PARAMETERS IN ONONDAGA LAKE

Onondaga Lake 1999 Annual Report
Onondaga County, New York

	METERS							
PARAMETER	**0**	**3**	**6**	**9**	**12**	**15**	**18**	**FREQUENCY**
	EPILIMNION[1]				HYPOLIMNION[1]			
Cd, Cr, Cu, Ni, Pb, Se, Zn, As, K	Composite				Composite			Quarterly
Hg		X					X	April, August, October
CN	Composite				Composite			Quarterly
Phenols	Composite				Composite			Quarterly
Ca, Na, Mg, Mn, Fe	Composite				Composite			Biweekly
Cl, SO_4	Composite				Composite			Biweekly
TS, TSS, VSS, TVS, TDS, SiO_2, TOC, TOC-F, TIC	X		X		X		X	Biweekly
BOD_5	X	X	X	X	X	X	X	Biweekly
TP[2], SRP	X	X	X	X	X	X	X	Biweekly
F-TKN, NO_3, NO_2	Composite				Composite			Biweekly
TKN, NH_3-N, Org-N	X	X	X	X	X	X	X	Biweekly
ALK-T	Composite				Composite			Biweekly
Fecal Coliform, Enterococci[8]	X							Biweekly
CHLOR-A[3], PHAEO-A	Composite							Weekly
Sulfide[4]					X	X	X	Biweekly
pH, Temperature, Salinity, Conductivity, Dissolved Oxygen, Oxidation-Reduction Potential	Measured every half-meter from 0- to 18-meter depth							Biweekly
Underwater Illumination profile, Secchi Depth[5]	Recorded at each site							Biweekly
Phytoplankton[3]	X	X						[3]
Dreissenid Veligers	Composite							[7]
Zooplankton[6]	Composite				X			[6]

Table 2.3_99.doc

TABLE 2-3 (continued)

SAMPLING SCHEDULE OF PHYSICAL, CHEMICAL, AND BIOLOGICAL PARAMETERS IN ONONDAGA LAKE (August – December 1999)

Ambient Monitoring Program
Onondaga County, New York

[1] *Please note that "Epilimnion" and "Hypolimnion" composite samples collected during the sampling events are based on the thermocline depth determined through the Hydrolab field profile (Temperature, pH, D.O., Specific Conductivity). Composites were made by mixing equal volumes of samples from each depth.*

[2] *A "Special" TP 500 ml sample was collected during the South Deep biweekly sampling events at 1m depth between (June 1 - September 30).*

[3] *Weekly Phytoplankton and Chlorophyll-a samples were collected as epilimnion and photic zone (2x Secchi depth, but above the thermocline) composites. Duplicate Chlorophyll-a samples were collected monthly at the Lake South Deep station (May – September).*

Frequency of Phytoplankton samples were:
South Deep station: biweekly from April - November and monthly January, February, March, December.
North Deep: quarterly (during the Double lake sampling events).

[4] *Sampling of sulfides only if anoxic conditions were determined through the Hydrolab profile (completed prior to sampling).*

[5] *In addition, biweekly Secchi disk measurements at near shore stations (Figure 2.2) June – September and weekly at the South Deep Station June – September.*

[6] *Zooplankton was collected as a net tow through the epilimnion and as a 12 meter vertical net haul.*
Frequency of Zooplankton sampling was:
South Deep station: biweekly from April - November and monthly January & February (as weather permitted), March, December.
North Deep: quarterly (during the Double lake sampling events).

[7] *Frequency of Veligers samples was:*
South Deep station: biweekly from April - November.
North Deep: quarterly (during the Double lake sampling events).

Duplicate bacteria samples collected on a monthly basis at the Lake South Deep station (May – September)

TABLE 2-4

ANALYTICAL PROCEDURES FOR WATER QUALITY ANALYSES
1999 MONITORING PROGRAM

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Code	Methods *	Limit of Detection (mg/l)	Accuracy (%)	Precision (%)
Bio Oxy Demand 5-day	BOD5	2:(5210)	2.0	100.5	15.0
Carbon. Bio Oxy Demand 5-day	CBOD5	2:(5210 B)	2.0	97	12.0
Total Alk as CaCO3	ALK-T	1:(310.1)	1.0		
Total Organic Carbon	TOC	1:(415.1)	0.1	101.0	5.0
Total Organic Carbon - Filtered	TOC-F	1:(415.1)	0.1		
Total Inorganic Carbon	TIC	OI ANAL 1989	1.0	99.0	5.0
Total Kjeldahl Nitrogen as N	TKN	3:(10-107-06-2-D)	0.1	102.0	4.0
Ammonia Nitrogen as N**	NH3-N	3:(10-107-06-1-A)	0.05	101.0	7.0
Organic Nitrogen as N	ORG-N	3:(10-107-06-2-D)	0.001		
Nitrate as N	NO3	3:(10-107-04-1-B)	0.01	96.0	4.0
Nitrite as N	NO2	3:(10-107-04-1-B)	0.01	100	4.0
Total Phosphorus	TP	3:(10-115-01-1-E)	0.001	101.0	4.0
Soluble Reactive Phosphorus	SRP (OP)	1:(365.2)	0.001	98.0	2.3
Silica	SiO2	1:(370.1)	0.1	100.5	4.8
Sulfates	SO4	1:(375.4)	5.0	103	6.5
Total Sulfides	S=	1:(376.1)	0.2		
Total Solids	TS	1:(160.3)	1.0		
Total Volatile Solids	TVS	1:(160.4)	1.0		
Total Suspended Solids	TSS	1:(160.2)	1.0		
Total Volatile Suspended Solids	VSS	1:(160.4)	1.0		
Total Dissolved Solids	TDS	1:(160.1)	1.0	98.4	2.0
Arsenic (VGA)	As	1:(206.3)	0.002	105.9	6.3
Total Cadmium	Cd	4:(200.7)	0.0015(0.0004)*	101.2	4.8
Total Calcium	Ca	1:(215.1)	2.0	93.1	2.9
Total Chromium	Cr	4:(200.7)	0.002(0.0005)*	95.9	5.9
Chloride	Cl	3:(10-117-07-1-B)	1.0	101.0	3.0
Residual Chlorine	CL2 RES	1:(330.4)	0.1		
Total Copper	Cu	4:(200.7)	0.0015(0.0004)*	100.8	3.2
Chlorinated Cyanide	CN-CL2	3:(10-204-00-1-A)	0.002		
Total Cyanide	CN-T	3:(10-201-00-1-A)	0.002	101.0	6
Total Iron	Fe	4:(200.7)	0.02	105.3	3.8
Total Lead - furnace	Pb - GFA	1:(239.2)	0.002 (0.0005)*	103.6	5.1
Total Magnesium	Mg	1:(242.1)	0.25	97.8	2.9
Total Manganese	Mn	4:(200.7)	0.002	100.7	3.6
Total Mercury (Cold Vapor)	Hg	1:(245.2)	0.0002	99.5	2.9
Selenium (VGA)	Se	2:(3114B)	0.002	103.2	3.1
Total Sodium	Na	1:(273.1)	5.0	98.7	2.2
Total Nickel	Ni	4:(200.7)	0.010(0.002)*	100.6	3.3
Potassium	K	1:(258.1)	0.020	99.1	3.2
Total Silver	Ag	4:(200.7)	0.0015	100.8	4.2
Total Zinc	Zn	4:(200.7)	0.002(0.0005)*	104.5	3.1

TABLE 2-4 (CONTINUED)

Parameter	Code	Methods *	Limit of Detection (mg/l)	Accuracy (%)	Precision (%)
Conductivity	COND	2:(2510B)	-		
Dissolved Oxygen - Field	DO - Field	1:(360.1)	0.1		
Dissolved Oxygen - Lab	DO - Lab	1:(360.1)	-		
Dissolved Oxygen - Winkler	DO - Winkler	1:(360.2)	-		
pH	pH	1:(150.1)	-		
Temperature	TEMP	1:(170.1)	-		
Phenol	PHENOL	3:(10-210-00-1-B)	0.01	99.0	15.0
Phaeophytin *a*	PHEO-A	2:(10200 H.2)	0.0002		
Chlorophyll *a*	CHLOR-A	2:(10200 H.2)	0.0002		
Fecal Coliform	FCOLI-MF	2:(9222 D)	2.0 (cells/100 ml)		

Methods listed are applicable for all matrices of water, wastewater, and surface waters.

* Indicates method has a lower level of detection due to sample concentration

** Changed to 0.05 mg/l on March 19, 1999.

1: Indicates USEPA Methods for Chemical Analysis of Water and Waste 1979

2: Indicates Standard Methods (18th Edition)

3: Indicates Lachat Instruments QuickChem Methods: Approved for use by USEPA - NYSDOH - ELAP

4: Indicates USEPA "Methods for the Determination of Metals in Environmental Samples" Supplement 1, May 1994

TABLE 2-5

VOLUME AVERAGING FACTORS, ONONDAGA LAKE
BATHYMETRIC CALCULATIONS

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Sample Depth	Volume-Averaging Factor
0 m	1.6892
3 m	2.9252
6 m	2.5490
9 m	2.2726
12 m	1.9383
15 m	1.5005
18 m	0.8283

CHAPTER 3

QUALITY ASSURANCE/QUALITY CONTROL

3. OVERVIEW OF TECHNIQUES AND RESULTS

Several techniques were employed during 1999 to assess and document integrity of the sample collection and analysis process. These techniques included field and laboratory audits and collection and analysis of duplicate samples. Lake and tributary samples were routinely analyzed for major cations and anions so that the electrochemical (charge) balance could be calculated. To assess the impact of switching to depth-integrated sampling of tributaries, paired samples were collected on Onondaga Creek Dorwin Ave. and Nine Mile Creek at Lakeland (Rt. 48) using old and new methods.

The 1999 data set was screened prior to its use in calculations or addition to the long-term database. Screening criteria included limnological reasonableness (for example, distribution of chemicals as a function of depth, thermal stratification, and season; charge balance; or the relationship between total and dissolved fractions of a parameter), compliance with analytical protocols (holding time, preservation, calibration check samples). Further, data were screened for outliers from the long-term database. Relative percent difference between field duplicate samples was calculated. Rejected data were removed from the database.

Overall, data quality was very high. The laboratory successfully completed more than 20,000 analyses of water collected from Onondaga Lake, the lake tributaries, and the Seneca River.

A significant data quality issue was related to measurements of trace concentrations of heavy metals, notably copper and zinc. Results of numerous heavy metal analyses were too close to the analytical limit of detection or associated quality control (field blank) samples to distinguish from zero. The limits of detection for associated samples were raised to correspond with concentrations measured in the blanks. Results that are not different from laboratory control samples are considered non-detects. A total of 83 metals samples were flagged as non-detects during the quality control review; 47 of the affected metals results were tributary samples and 36 were lake samples.

For the field duplicates, 91% of the lake samples and 86% of the tributary samples were within 20% relative percent difference (RPD). There was a consistent pattern of increasing RPD with decreasing concentration; variability between duplicates increased as concentrations approached the analytical limit of detection. To assess the effect of sample concentration on relative percent difference between field duplicates the data are also presented in histograms of absolute value of differences between replicate samples. A reasonable control limit for these analyses is plus or minus twice the limit of detection.

Charge balance results indicated that 99% of the tributary samples were within 20% RPD of the summed milliequivalents of anions and cations. The mean RPD for the charge balance on tributary samples was 5.2%, median 4.5%. For lake samples, 100% of the analyses balanced anions and cations within 20%. The mean RPD for lake samples was 5.9%, median 5.5%. River samples were not analyzed for all major anions and cations.

The 1999 field audit indicated that lake samples were collected and handled in accordance with the Field Sampling Plan and Quality Assurance Project Plan. Minor revisions to sample collection techniques were suggested, particularly for the biological samples of phytoplankton and zooplankton.

The 1999 laboratory audit was designed to evaluate the accuracy of the METRO laboratory and other regional laboratories certified in the ELAP program in measuring ammonia, total P and nitrite plus nitrate N in aqueous samples. The range of concentration included in the audit reflects the range of ambient concentrations in Onondaga Lake, the lake tributaries, and the Seneca River. Four commercial laboratories (CES, Upstate Laboratory, Life Sciences Laboratory, and O'Brien & Gere Laboratory) plus the METRO

laboratory were supplied with spiked samples prepared by Environmental Laboratory Services. The audit also included a Matrix Spike/Matrix Spike Duplicate (MS/MSD) analysis using lake water collected from the epilimnion; two of the samples were spiked with the same known amount of TP, ammonia N, and nitrite plus nitrate N.

The results of the laboratory audit are summarized in Table 3-1 and Figures 3-1 and 3-2. With the exception of METRO laboratory results, data are coded to disguise the identity of the participating commercial laboratories. The findings indicate that accuracy tended to improve with increasing concentration of analytes, as reflected by the trend to decreasing coefficient of variation (relative standard deviation) and decreasing bias.

Finally, 1999 field blanks were screened for background contamination levels. Contamination of the field blanks with the heavy metals copper and zinc has been discussed. Analysis of the 1999 data also reveals background concentrations of total P in the range of 0.012 mg/l. The causes of and potential solutions to this contamination of the field blanks is under active investigation.

3.2 TRIBUTARY RESULTS

A. **Compliance with Analytical Protocols**. Samples were collected according to the field sampling plan, and preserved in the field. The field team checked adequacy of preservation with pH indicator strips and immediately placed samples on ice. METRO laboratory consistently met holding times in 1999.

B. **Duplicate analyses.** In 1999, duplicate samples were collected at the East Flume. The majority of duplicate analyses met the data quality objective of 20% relative percent difference (RPD). Summary histograms of distribution of RPD for selected analytical parameters are plotted in Figure 3.3a. The highest RPD between duplicate samples was detected for calcium, iron, manganese, and total Kjeldahl nitrogen. Summary histograms for the absolute value of differences in concentration between selected results are presented in Figure 3-3b.

C. **Sampling methodology comparison**. Paired samples were collected at two sites, Nine Mile Creek at Lakeland and Onondaga Creek at Dorwin Ave, using both depth-integrated and pail sampling methods. Results of the paired sampling effort are displayed in Figure 3-4.

   The methodology was changed from pail sampling to depth-integrated sampling on several tributaries with implementation of the AMP in August 1998. This paired sampling effort has been included in the County's monitoring program to evaluate whether a systematic difference exists between the two sampling methods.

   Results of the paired sampling effort for TSS and TP indicate that there is no consistent difference between the sampling methods. The slopes of the regression lines are close to one. Intercepts on the regression are close to zero, with the exception of TSS measurements on Nine Mile Creek. For this stream, pail sample results tend to be lower by approximately 2.7 mg/l of suspended solids. As discussed at the August 2000 Onondaga Lake Technical Advisory Committee, the analysis indicates that comparable the two sampling techniques result in comparable concentrations of TP and TSS. This change in sampling procedure does not introduce a systematic bias into tributary loading calculations that would indicate a false trend.

D. **Charge Balance.** Charge balance data indicate that data quality for these seven parameters (chloride, calcium, sodium, total alkalinity, sulfate, magnesium, and potassium) is high.

E. **Limnological Reasonableness.** The tributary data set does not have obvious errors or outliers. Ambient concentrations of several heavy metals in the tributaries approach analytical limits of detection routinely achieved by METRO laboratory. As a consequence, results of the quality control samples such as equipment blanks are frequently comparable to measured results in the tributaries. Affected samples are summarized in Table 3-2. Concentrations of copper and zinc were frequently indistinguishable from background concentrations measured in the blanks.

F. **Field Blanks.** Field blanks were collected as part of each tributary sampling event. Laboratory water was processed through the sampling devices (e.g. dunker, churn, pail) as if it was stream water. The sample was submitted to the METRO laboratory for analysis. These results are summarized in Table 3-3. Note that the highest percentage of measurements with concentrations in the field blanks greater than five times the limit of detection was the total phosphorus analyses. Persistent problems with some parameters related to dissolved salts were also noted (refer to TDS, alkalinity, potassium). For several analytes the reported limit of detection as presented in Table 2-4 was not achieved. Actual limits of detection for Ca, Cr, Mg, Ni, and organic N were different than reported (compare the LOD in Table 3-3 with the target LOD in Table 2-4). These differences are attributable to changes in analytical methodology and/or matrix interference in the samples.

G. **Summary of Rejected Tributary Data.** In 1999 only metals results were flagged (reported values changed to non-detects) prior to inclusion in the database or used in calculations and plots.

3.3 LAKE RESULTS

A. **Compliance with Analytical Protocols.** Overall, samples were collected according to the field sampling plan, and preserved adequately in the field. The METRO laboratory consistently met holding times.

B. **Duplicate analyses.** A duplicate sample was consistently collected at the 6-m south deep station. The epilimnetic composite was analyzed as a second field duplicate. Histograms of the distribution of the RPD of each analyte are presented in Figure 3-5 a and b. Note that a significant fraction of the duplicate analyses for iron, lead, manganese, nickel, zinc, filtered TKN, TSS, organic nitrogen, phaeophytin, VSS, TVS and SRP do not meet the data quality objective of RPD within 20%.

C. **Charge Balance**. The charge balance data indicate that data quality for these seven parameters (chloride, calcium, sodium, total alkalinity, sulfate, magnesium, and potassium) is high. 100% of the lake analyses were within 20% RPD in the milliequivalent balance of anions and cations.

D. **Limnological Reasonableness.** Similar to the tributary results, there were metals results in the lake data set that are close to the analytical limit of detection. In several cases, concentrations of heavy metals in the analytical samples were comparable to levels measured in the quality control samples such as the equipment blanks. These results are retained in the data set, but flagged as being non-detects. Affected data points are summarized in Table 3-4.

E. **Field Blanks.** Field blanks were collected as part of each lake sampling event. Laboratory water was processed through the sampling devices (e.g. dunker, churn, or pump) as if it were lake water. The sample was submitted to the METRO laboratory for analysis. These results are summarized in Table 3-5. Note that the total P analyses exhibited the highest percentage of measurements with concentrations in the field blanks greater than five times the limit of detection. The laboratory and field teams are actively investigating the source of the background contamination. Note that the SRP analyses are not subject to the background contamination issue. This observation has focused the investigation on the digestion component of the phosphorus analytical process. Persistent problems with some parameters related to dissolved salts were also noted (refer to TDS, alkalinity, potassium).

For several analytes the reported limit of detection as presented in Table 2-4 was not achieved. Actual limits of detection for Ca, Cr, Mg, Ni, and organic N were different than reported (compare the LOD in Table 3-5 with the target LOD in Table 2-4). These differences are attributable to changes in analytical methodology and/or matrix interference in the samples.

F. **Summary of Rejected Lake Data.** With the exception of the metals results all lake data were acceptable.

3.4 SENECA RIVER RESULTS

A. **Compliance with Analytical Protocols.** The Seneca River samples were collected and analyzed in accordance with the Field Sampling Plan and Quality Assurance Project Plan. Bottle types, preservatives, and holding times were in compliance with analytical protocols.

B. **Field Duplicates.** Duplicate samples were collected at Buoy 316 and analyzed for the entire suite of laboratory parameters. Relative percent difference between the field duplicates was generally less than 20% with exceptions as noted in Table 3-6.

C. **Charge Balance.** The Seneca River samples were not analyzed for the seven major cations and anions. No charge balance calculations were performed.

D. **Limnological Reasonableness.** No flags were noted in the 1999 data set.

E. **Summary of Rejected Data.** All Seneca River data were acceptable.

3.5 RECOMMENDATIONS

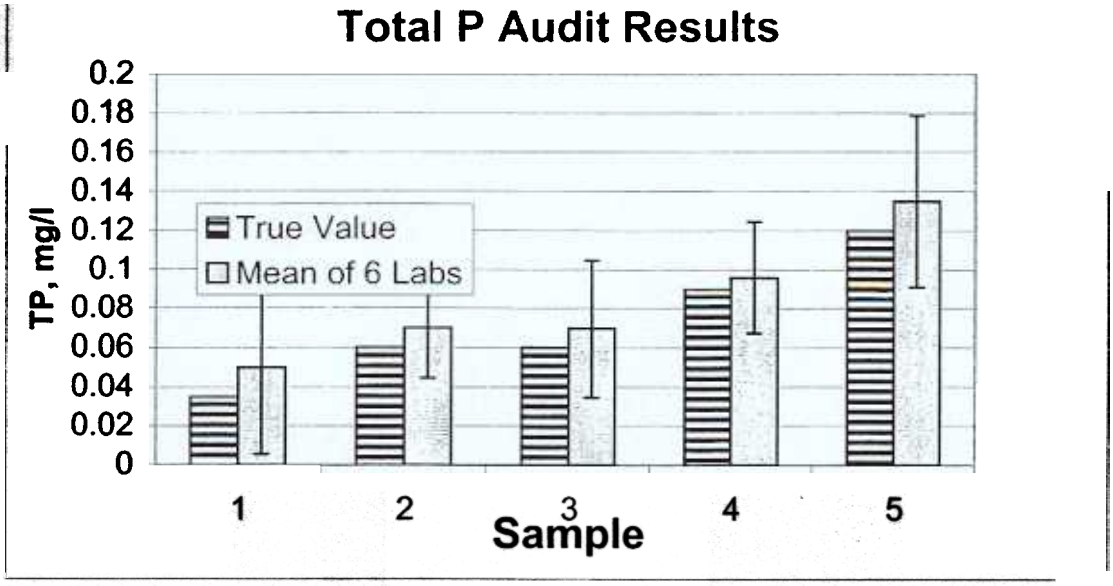
(1) The laboratory data management system reports the analytical results with a variable number of significant digits. Station codes are not consistently applied, which makes sorting and appending data to the historical database difficult. For example, special samples such as the paired analyses for TP in pail and depth-composited samples are not consistently referenced. This inconsistency in reporting should be corrected.

(2) The laboratory and field sampling crews should investigate the potential sources of contamination in the metals analyses. The entire sampling and analytical process should be examined, including preparation of field blanks, concentrations of metals in the nitric acid preservative, and background concentrations in laboratory water. As of the date of this report, water samples are poured into pre-cleaned disposable containers for metals analysis. This modification may reduce the background concentrations in blanks.

(3) Consider reporting only concentration, not annual load, of metals with a significant percentage of the observations flagged with respect to limit of detection or contamination of the associated field blanks.

(4) Locations of the tributary duplicate sample should be rotated.

(5) Based on the data set from August 1998 – December 1999 the flow-weighted composite sampling devices provide comparable results for TP and TSS analyses. The pail sampling should be discontinued in favor of the flow-weighted composite sampling. There will be no systematic bias introduced into the tributary results.



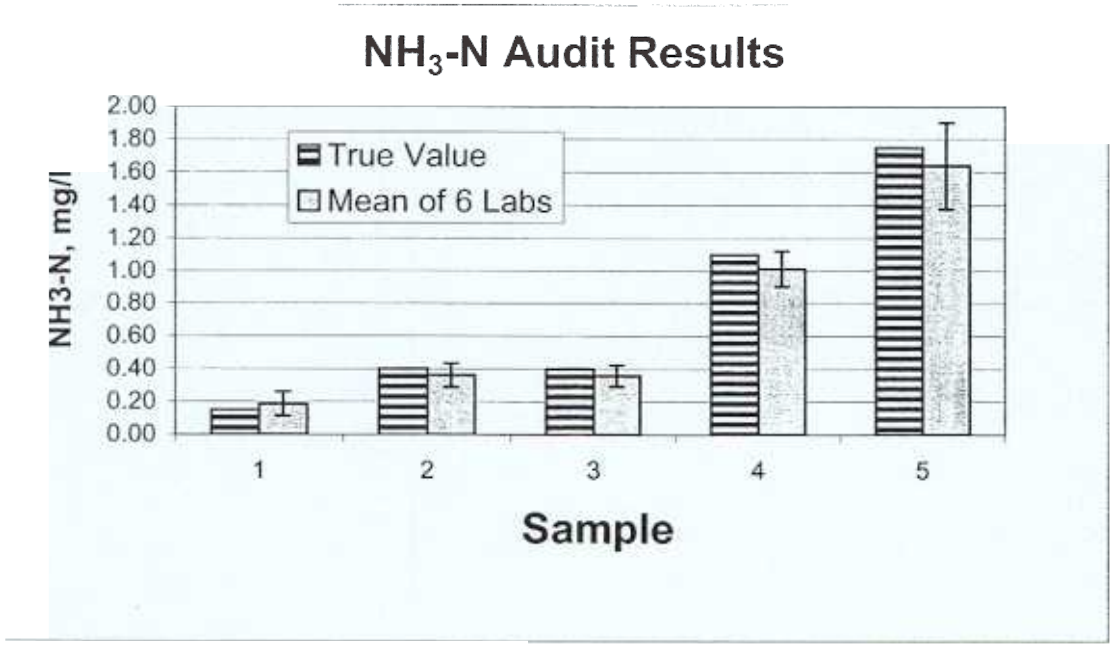
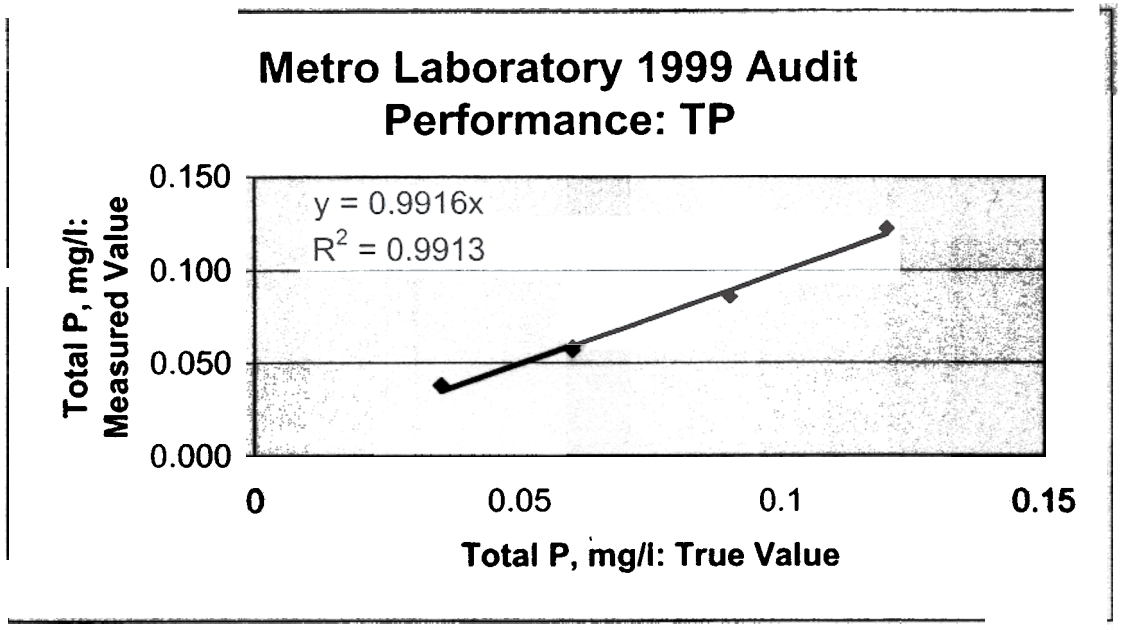


FIGURE 3-1. Results of Laboratory Audit and Round-Robin, December 1998. Error bars depict one standard deviation. Participating laboratories include: Metro, ELS, C&S, OB&G, Upstate and Life Sciences Lab.



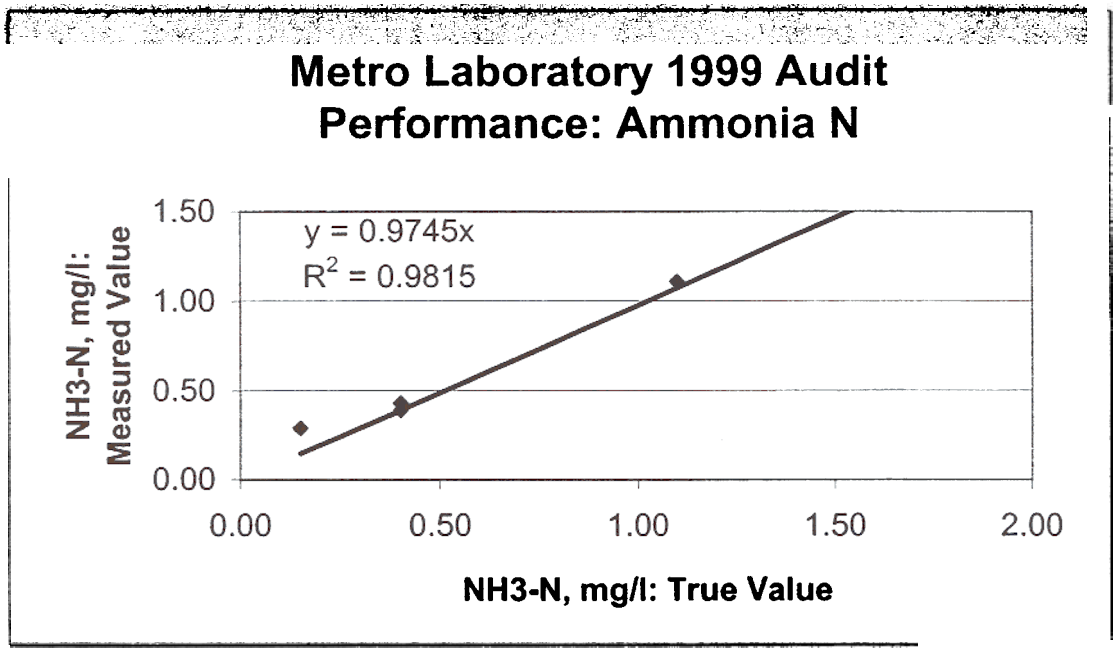


Figure 3-2. 1999 Laboratory results, Onondaga County Department of Drainage and Sanitation, Environmental Laboratory at Metro.

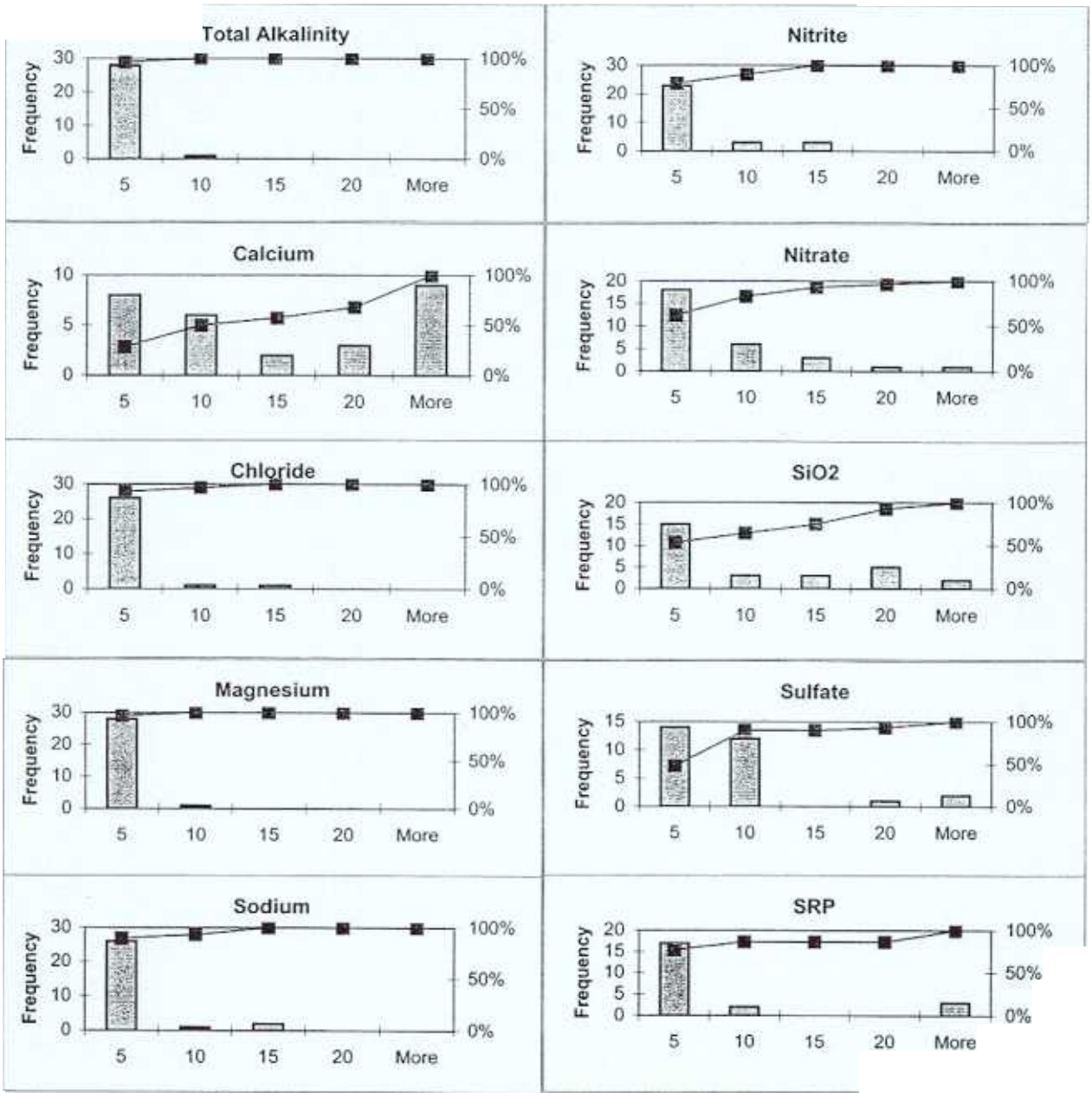


Figure 3-3a. Results of field Duplicates, Tributary Samples. 1999.

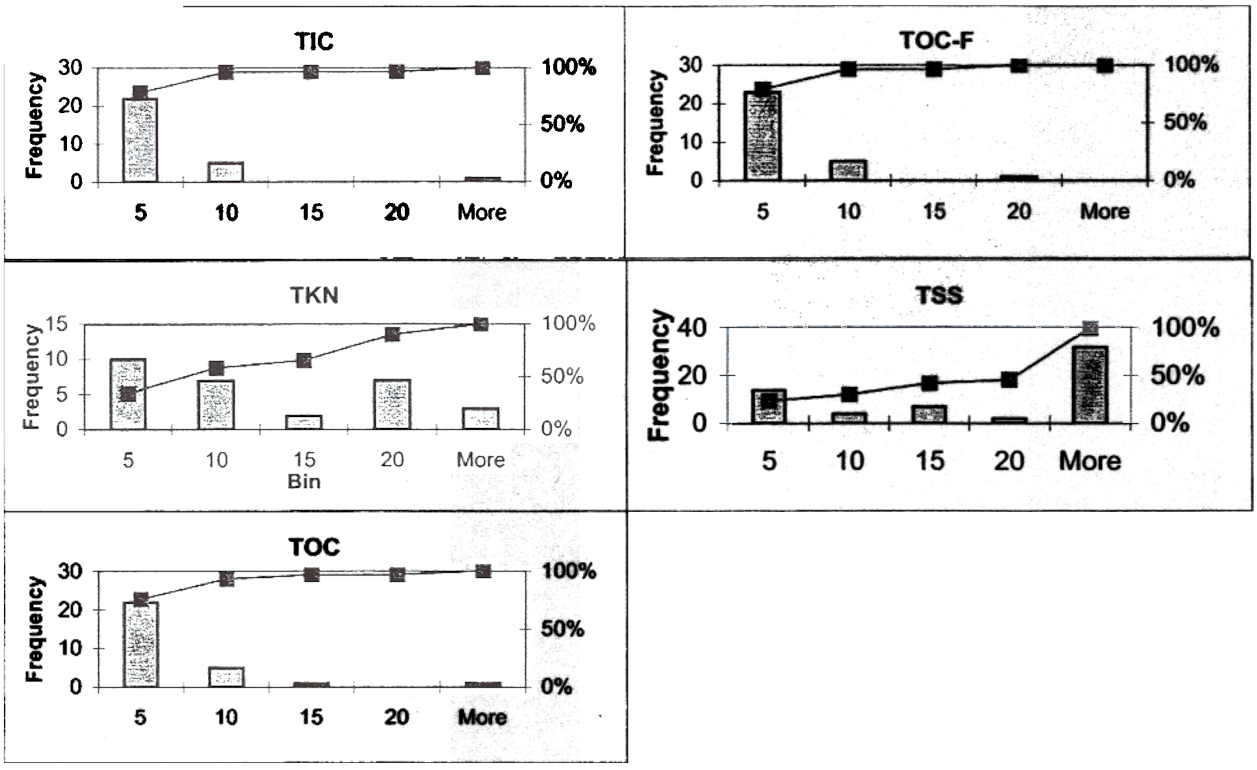


Figure 3-3a (continued). Results of field Duplicates, Tributary Samples. 1999.

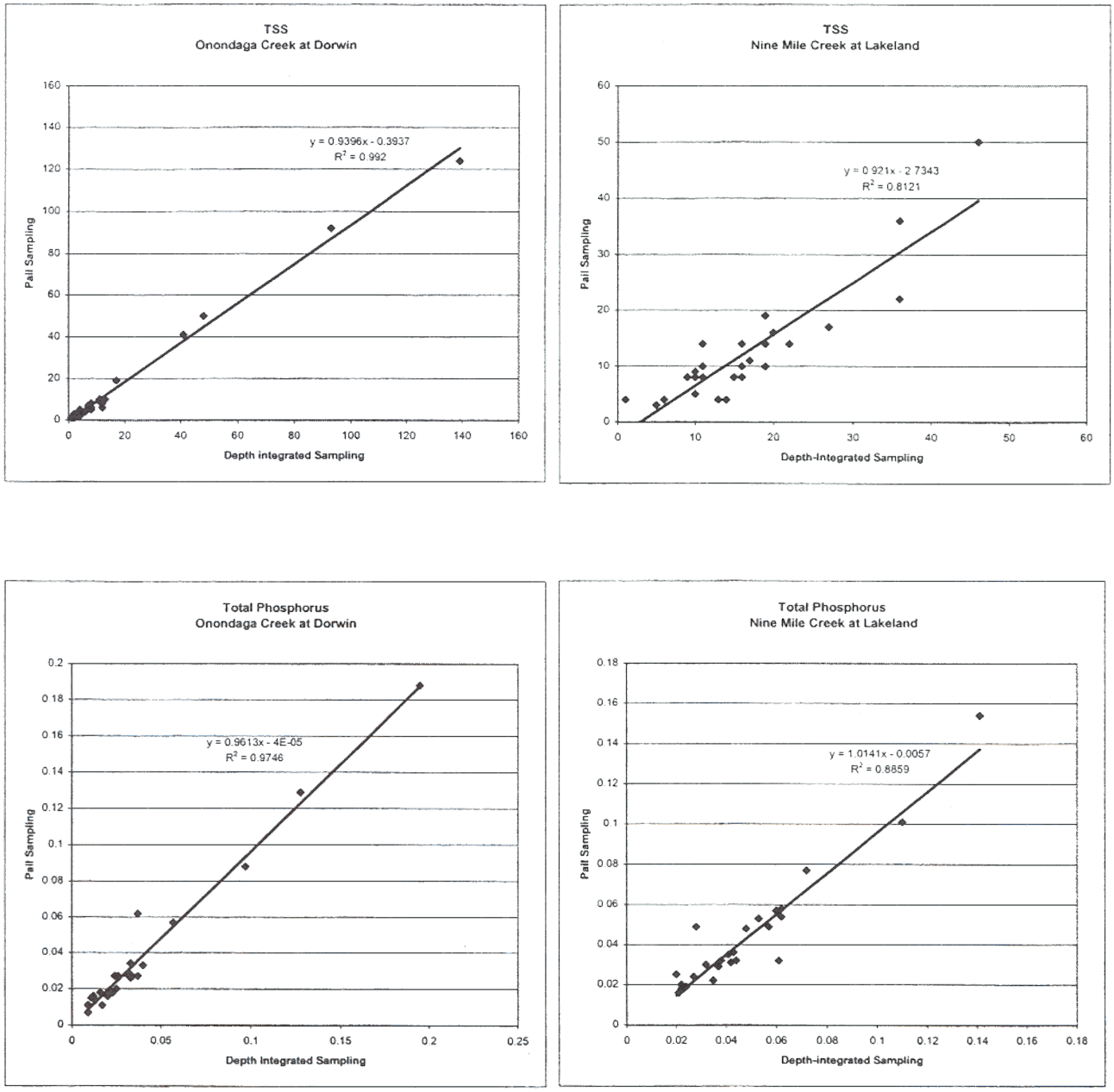


Figure 3-4. Comparisons of depth-integrated sampling methods with pail sampling methods for Total Phosphorus and Total Suspended Solids.

Onondaga Creek at Dorwin Ave. and Nine Mile Creek at Lakeland

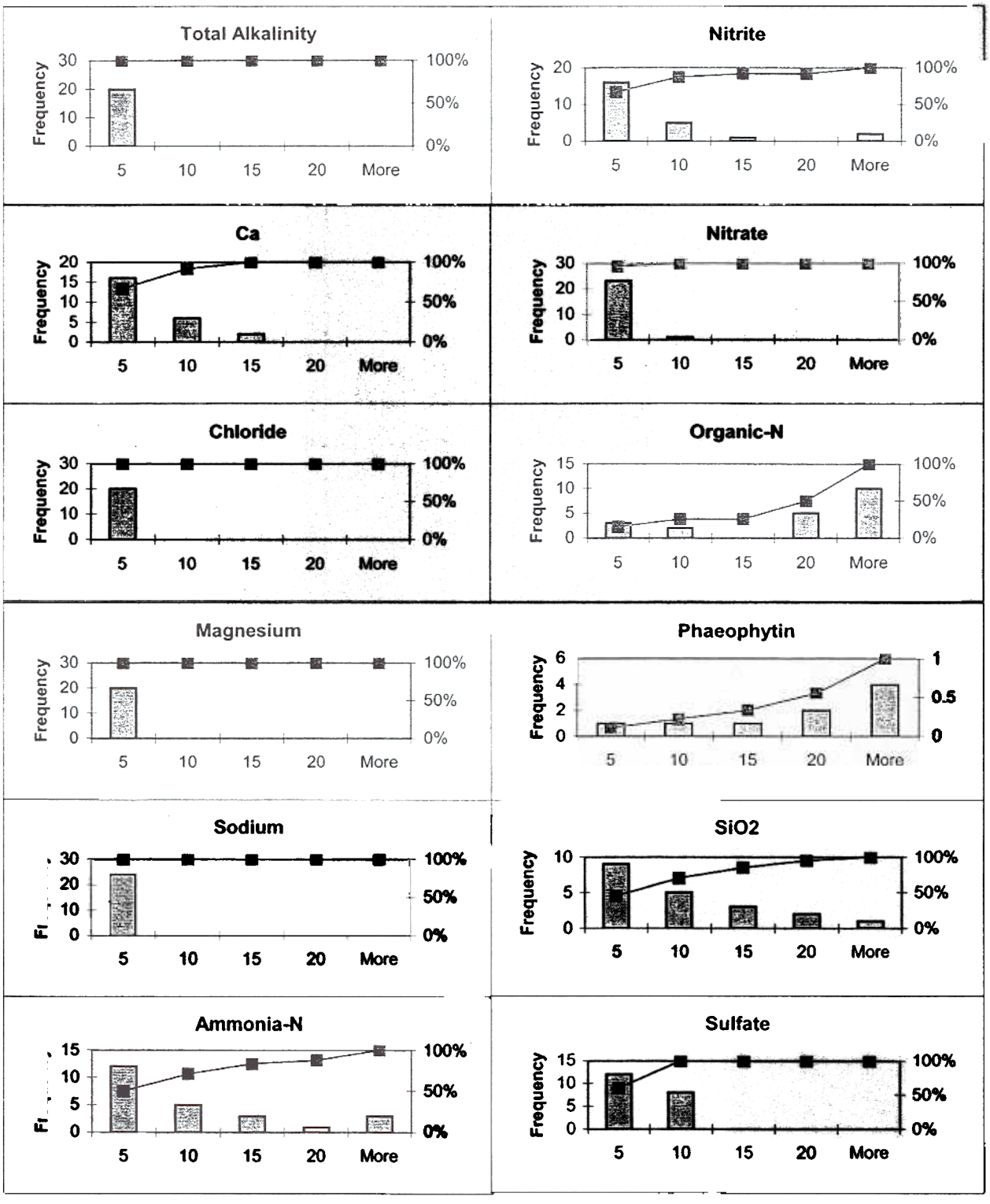


Figure 3-5a. Results of Field Duplicates, Lake Samples. 1999.

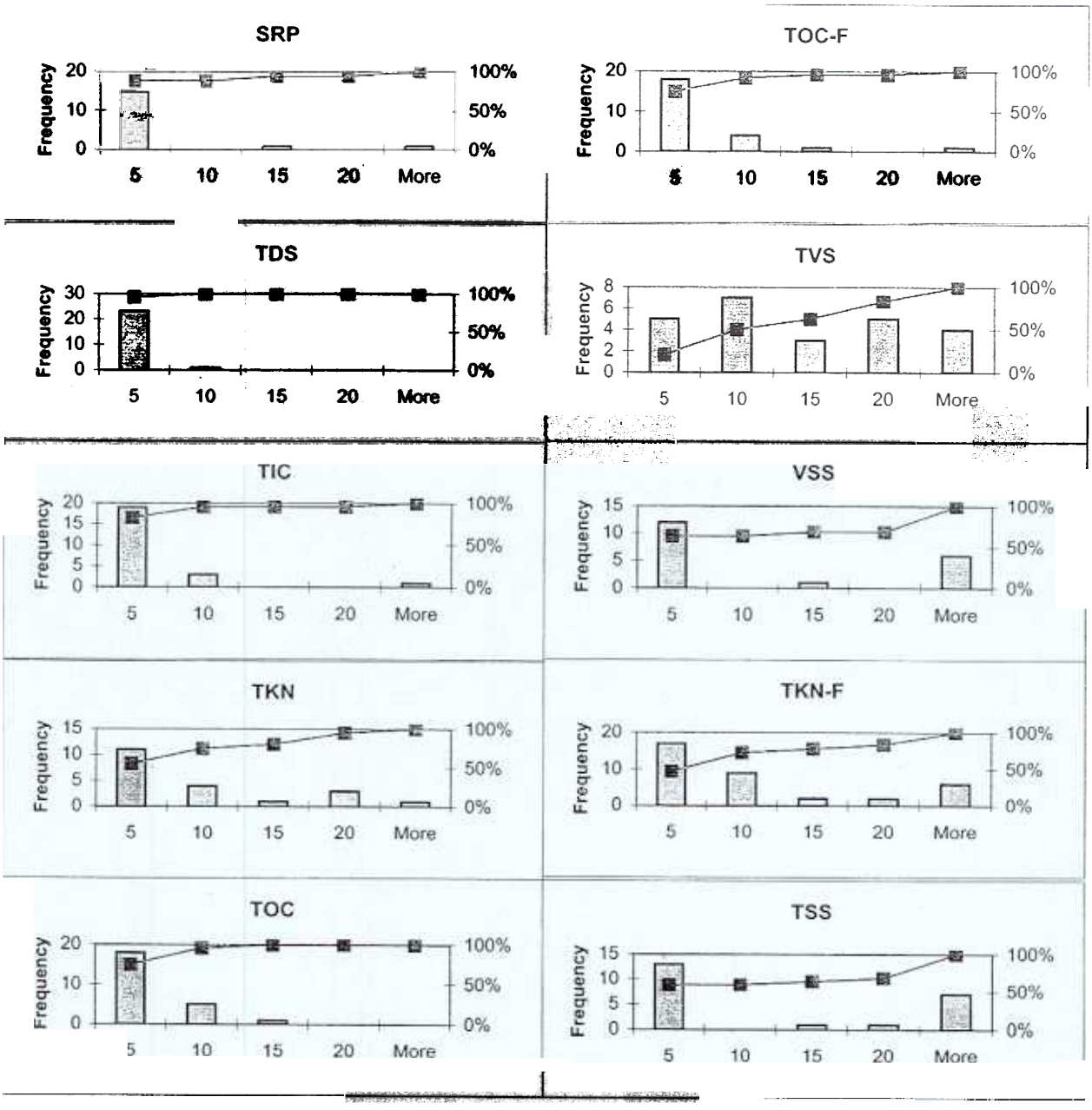


Figure 3-5a (continued). Results of Field Duplicates, Lake Samples. 1999.

Table 3-1
RESULTS OF LABORATORY AUDIT
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Total P	True Value	Metro	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Relative Std Dev	Relative Error (Percent Bias)
AU-1	0.035	0.038	0.038	0.031	0.14	0.025	0.0281	88.8	62.8
AU-2	0.060	0.059	0.064	0.056	0.12	0.07	0.051	36.2	24.4
AU-3	0.060	0.057	0.062	0.057	0.14	0.06	0.0425	50.3	29.3
AU-4	0.090	0.086	0.092	0.08	0.15	0.1	0.0676	29.9	20.1
AU-5	0.120	0.122	0.13	0.114	0.22	0.13	0.0935	32.5	21.5

Ammonia N	True Value	Metro	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Relative Std Dev	Relative Error (Percent Bias)
AU-1	0.150	0.29	0.13	0.200	0.1	0.25	0.149	39.4	40.1
AU-2	0.400	0.43	0.38	0.420	0.3	0.25	0.392	19.8	13.7
AU-3	0.400	0.39	0.39	0.430	0.31	0.25	0.38	18.4	12.9
AU-4	1.100	1.11	1.1	0.960	0.84	1.1	0.969	10.7	8.2
AU-5	1.750	1.66	1.8	1.510	1.4	1.4	2.07	16.0	13.3

Nitrite plus Nitrate N	True Value	Metro	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Relative Std Dev	Relative Error (Percent Bias)
AU-1	0.200	0.34	0.16	0.210	0.2	0.18	0.2	29.7	17.5
AU-2	0.400	0.69	0.33	0.430	0.39	0.34	0.3	34.6	23.3
AU-3	0.400	0.67	0.33	0.430	0.39	0.34	0.5	28.7	22.5
AU-4	1.200	1.93	1	1.240	1.2	0.97	1.3	27.3	18.1
AU-5	2.200	3.38	1.9	2.140	2.2	1.6	2.2	27.1	16.2

MS/MSD Results

spike 0.15 TP		Lake	MS	MSD	Percent Recovery (1)	Percent Recovery (2)	RPD
	Metro	0.056	0.217	0.233	107.3	118	7.1
	Lab 1	0.055	0.21	0.21	103.3	103.3	0.0
	Lab 2	0.056	0.202	0.201	97.3	96.7	0.5
	Lab 3	0.09	0.28	0.28	126.7	126.7	0.0
	Lab 4						
	Lab 5	0.0539	0.181	0.18	84.7	84.1	0.6
	Mean	0.062			103.9	105.7	1.6
	St Dev	0.016			15.3	16.9	3.1

spike 0.5 NH3-N		Lake	MS	MSD	Percent Recovery (1)	Percent Recovery (2)	RPD
	Metro	1.24	1.73	1.77	98	106	2.3
	Lab 1	1.3	1.8	1.8	100	100	0.0
	Lab 2	1.12	1.93	1.88	162	152	2.6
	Lab 3	0.86	1.2	1.2	68	68	0.0
	Lab 4	1.9					
	Lab 5	1.03	2.11	2.06	216	206	2.4
	Mean	1.24			128.8	126.4	1.5
	St Dev	0.358			59.5	53.7	1.3

spike 1.5 NO3+NO2		Lake	MS	MSD	Percent Recovery (1)	Percent Recovery (2)	RPD
	Metro	1.12	3.37	3.32	150	146.7	1.5
	Lab 1	1	2.3	2.3	86.7	86.7	0.0
	Lab 2	1.28	2.73	2.67	96.7	92.7	2.2
	Lab 3	1.2	2.7	2.6	100	93.3	3.8
	Lab 4	1.9					
	Lab 5	1.43	2.74	2.8	87.3	91.3	2.2
	Mean	1.32			104.1	102.1	1.9
	St Dev	0.318			26.3	25.0	1.4

TABLE 3-2

TRIBUTARY SAMPLES AFFECTED BY REVISED TRIBUTARY DETECTION LIMITS. REPORTED RESULTS SHOULD BE REPLACED WITH A DESIGNATION OF "NON-DETECT"

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Date	Analyte	Sample
3/30/99	Cd	Lake Outlet 2 and 12
		Ley Cr
	Cr	Lake Outlet 12
	Zn	Onondaga Cr @ Kirk
		Nine Mile
		Lake Outlet 12
		Harbor Br
		Onondaga Cr @ Dorwin
		Trib 5a
6/22/99	Cr	Onondaga Cr @ Kirk
		Allied E Flume
		Nine Mile
		Onondaga Cr @ Dorwin
		Harbor @ Velasko
	Cu	ALL SAMPLES
	Zn	Onondaga Cr @ Dorwin
		Lake Outlet 2 and 12
		Nine Mile
		Trib 5a
		Onondaga Cr @ Kirk
9/14 and 9/19, 1999	Cu	Lake outlet 2 and 12
	Zn	Lake outlet 2 and 12
11/9/99	Cu	Lake outlet 2 and 12
	Zn	ALL SAMPLES

TABLE 3-3
Summary of Field Blank Analyses
1999 Onondaga Lake Tributary Samples

Parameter	LOD	N	Blank Concentrations		Number of Measurements		Percent of Measurements	
			Mean	Median	> 2x LOD	>5x LOD	> 2x LOD	>5x LOD
T-ALK	1	48	2	2	13	1	27	2
As	0.002	8	<0.002	<0.002	0	0	0	0
BOD	2	58	<2	<2	0	0	0	0
Ca	10	58	11	10	4	0	7	0
Cd	0.0004	8	0.00058	0.0004	2	0	25	0
Chloride	1	58	<1.0	<1.0	0	0	0	0
Cyanide	0.002	7	<0.0020	<0.0020	0	0	0	0
Cr	0.005	8	0.0005	0.0005	0	0	0	0
Cu	0.0004	8	0.0026	0.0015	7	2	88	25
Fe	0.02	58	0.03	0.04	6	0	10	0
K	0.02	8	0.13	0.12	8	4	100	50
Mercury	0.0002	7	<0.0002	<0.0002	0	0	0	0
Mg	0.25	58	<0.25	<0.25	0	0	0	0
Mn	0.002	58	0.004	0.002	26	1	45	2
Na	5	58	<5	<5	0	0	0	0
NH3	0.05	58	0.07	0.05	5	0	9	0
Ni	0.025	8	0.0280	0.0250	0	0	0	0
Nitrite	0.01	58	<0.01	<0.01	0	0	0	0
Nitrate	0.01	58	<0.01	<0.01	0	0	0	0
Organic N	0.1	58	0.14	0.1	6	2	10	3
Lead	0.0005	58	0.0012	0.0010	4	1	7	2
Phenol	0.01	5	0.021	0.018	2	0	40	0
SiO2	0.1	58	0.15	0.10	5	2	9	3
SO4	5	58	<5	<5	0	0	0	0
SRP	0.001	38	0.0012	0.0010	0	0	0	0
TDS	1	58	10	7	38	35	66	60
TIC	1	56	<1	<1	0	0	0	0
TKN	0.1	58	0.17	0.12	13	2	22	3
TOC	1	58	<1	<1	0	0	0	0
TOC-F	1	58	<1	<1	0	0	0	0
TP	0.001	87	0.011	0.011	82	74	94	85
TSS	1	87	1.1	1.0	1	1	1	1
Zn	0.002	8	0.011	0.008	8	2	100	25

TABLE 3-4

LAKE SAMPLES AFFECTED BY REVISED LAKE DETECTION LIMITS. REPORTED RESULTS SHOULD BE REPLACED WITH A DESIGNATION OF "NON-DETECT"

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Date	Analyte	Sample ID
11/30/99	Cr	Lake epi north
		Lake epi north dup
4/6/99	Cu	Epi south
		Epi south dup
		Lake epi north
		Lake epi north dup
		Lake hypo north
7/13/99		Epi south
		Epi south dup
		Lake hypo south
		Lake epi north
		Lake epi north dup
		Lake hypo north
11/30/99		Epi south
		Lake hypo south
		Lake epi north
		Lake epi north dup
		Lake hypo north
4/6/99	Zn	Epi south
		Epi south dup
		Lake hypo south
		Lake epi north
		Lake epi north dup
		Lake hypo south
6/29/99		Epi south
		Epi south dup
		Lake hypo south
9/21/99		Epi south
		Epi south dup
		Hypo south
		Lake epi north
		Lake epi north dup
		Lake hypo north
11/30/99		Epi south
		Epi south dup
		Lake epi north

TABLE 3-5
Summary of Field Blank Analyses
1999 Onondaga Lake Samples

Parameter	LOD	N	Blank Concentrations		Number of Measurements		Percent of Measurements	
			Mean	Median	> 2x LOD	>5x LOD	> 2x LOD	>5x LOD
Ag	0.0004	5	<0.0004	<0.0004	0	0	0	0
T-ALK	1	21	3	2	19	2	90	10
As	0.002	5	<0.002	<0.002	0	0	0	0
BOD	2	20	<2	<2	0	0	0	0
Ca	10	20	10.4	10	1	0	5	0
Cd	0.0004	5	<0.0004	<0.0004	0	0	0	0
Chloride	1	21	1.1	1	1	0	5	0
Cyanide	0.002	4	<0.002	<0.002	0	0	0	0
Cr	0.005	5	<0.005	<0.005	0	0	0	0
Cu	0.0004	5	0.002	0.0016	3	3	60	60
Fe	0.02	20	0.047	0.03	4	2	20	10
K	0.02	5	0.236	0.2	5	5	100	100
Mg	0.25	20	<0.25	<0.25	0	0	0	0
Mn	0.002	20	0.0026	0.002	3	0	15	0
Na	5	20	5.2	5	0	0	0	0
NH3	0.05	21	0.069	0.05	3	0	14	0
Ni	0.025	5	<0.025	<0.025	0	0	0	0
Nitrite	0.01	21	<0.010	<0.010	0	0	0	0
Nitrate	0.01	21	0.011	0.01	1	0	5	0
Organic N	0.1	20	0.1445	0.1	5	0	25	0
Lead	0.0005	5	0.0008	0.0006	1	0	20	0
Phenol	0.01	5	<0.01	<0.01	0	0	0	0
Se	0.002	5	<0.002	<0.002	0	0	0	0
SiO2	0.1	20	0.403	0.1	4	3	20	15
SO4	5	20	<5	<5	0	0	0	0
SRP	0.001	22	0.0017	0.001	5	1	23	5
TDS	1	21	7.3	2	7	6	33	29
TIC	1	19	<1	<1	0	0	0	0
TKN	0.1	21	0.19	0.16	8	0	38	0
TKN-F	0.1	20	0.17	0.14	8	0	40	0
TOC	1	20	<1	<1	0	0	0	0
TOC-F	1	21	<1	<1	0	0	0	0
TP	0.001	22	0.012	0.012	20	18	91	82
TS	1	20	11.2	4	19	9	95	45
TSS	1	20	<1	<1	0	0	0	0
TVS	1	20	4.7	2	7	5	35	25
VSS	1	20	<1	<1	0	0	0	0
Zn	0.002	5	0.0099	0.0099	4	2	80	40

Table 3-5 lake blanks.xls

TABLE 3-6

Summary of Field Duplicate Results
Seneca River Monitoring
July, August, Sept. 1999

Parameter with RPD Over Criteria*	Number >20% RPD / Number of observations	Average RPD of observations > 20%	Ratio of average concentration of all 1999 samples to limit of detection (LOD) of the analytical method
Chlorophyll *a* (tube composite)	3/3	40%	11 (concentration 2.2 µg/l; LOD 0.2 µg/l)
Ammonia (surface and bottom)	4/6	70%	4.6 (concentration 0.23 mg/l, LOD 0.05 mg/l)
Phaeophytin (tube composite)	2/3	46%	12.8 (concentration 2.55 µg/l; LOD 0.2 µg/l)
SRP (surface and bottom)	1/6	34%	40 (concentration 0.041 mg/l; LOD 0.001mg/l)
TSS (surface and bottom)	2/6	47%	4 (concentration 4 mg/l; LOD 1 mg/l)

* Parameters with RPD <20% are not listed.

CHAPTER 4

TRIBUTARY RESULTS

4.1 HYDROLOGY

1999 was a dry year. Only 30.88 inches of precipitation were measured at Syracuse's Hancock Airport, well below the long-term annual average of 38.93 inches. The fall of 1998 was dry, and the 1999 calendar year began with a precipitation deficit of approximately five inches. Precipitation was slightly above normal in the winter of 1999 but was very low from April through the end of the year (Figure 4-1). The proportional contribution of the tributaries and METRO to the lake's hydrologic budget calculated in 1999 reflects the dry conditions (Figures 4-2 and 4-3).

Based on measured inflows from tributaries and METRO and the lake volume, Onondaga Lake's water was replaced approximately 2.3 times in 1999, below the 1971 – 1999 average of 3.7 flushes per year. As discussed in Chapter 1, the flushing rate calculation assumes that the lake is completely mixed and does not consider thermal stratification. Hypolimnetic water is actually retained in the lake longer than epilimnetic water. Flushing rate and annual precipitation are closely related, as most water inflow originates as precipitation within the watershed. The discharge of treated wastewater from METRO, which contributes a significant fraction of the water flow to the lake, is relatively constant from year to year.

The 1999 hydrographs reported by USGS for the four largest natural tributaries (Onondaga Creek, Nine Mile Creek, Ley Creek, and Harbor Brook) reflect these precipitation statistics. With the exception of a few isolated high flow events, streamflow was below long-term average values. Low flows persisted through the end of the year (Figure 4-4).

Tributary sampling dates are depicted on Figure 4-4. The biweekly monitoring program adequately sampled the flow regime during 1999 (Figure 4-5). Three storms were sampled in 1999 in addition to the routine monitoring program (which is designed to capture at least five high flow events).

During 1999, the METRO plant provided advanced secondary treatment and phosphorus removal to 21.94 billion gallons, discharged through outfall 001. An additional 612 million gallons was discharged through outfall 002 following primary treatment and chlorination. Flows through outfall 002 occurred on 32 days in 1999 (Figure 4-6).

4.2 CONSTITUENT LOADS AND CONCENTRATIONS

External loads of chemicals, solids, and microorganisms to Onondaga Lake were calculated using a customized version of the software program FLUX (AUTOFLUX) developed by Dr. William Walker Jr. Method 2 of FLUX was used to calculate the flow-weighted average concentrations and the annual loads, and to estimate the standard error and coefficient of variation associated with the loading estimates. This method evaluates the relationships between flow and concentration of constituents in each tributary, stratifies data into different flow regimes, and uses the relationship between flow and concentration to project the concentration of constituents over the unsampled period of the hydrologic record. For this reason, it is important that the monitoring program include representative low, moderate, and high flows. For some water quality parameters concentration increases with flow and capturing high flow events in the annual monitoring program is a critical factor in improving the accuracy of annual load calculations.

The annual external load of materials to Onondaga Lake is summarized in Table 4-1. Loads estimated from the 1999 monitoring program are compared to the average load over the previous ten years (1989 – 1998). In general, loads of all constituents were low in 1999 reflecting the combination of the dry year and improved wastewater treatment at METRO. Loads of ammonia and Kjeldahl nitrogen were reduced by approximately 48% from the long-term average and the loading of nitrate increased by 19%. Nitrite N load decreased by approximately 25%. This shift in nitrogen species is a result of the nitrification of the METRO effluent (biological oxidation of ammonia to nitrate in the treatment process) that was evident from June through mid-December. Reduction in the external loading of organic carbon components

(measured as biochemical oxygen demand and total organic carbon) was significantly reduced in 1999 in response to improved treatment at METRO. The external load of SRP decreased in 1999 as well.

The average concentrations (both flow-weighted and arithmetic averages) of constituents in the lake's tributaries, METRO effluent, and the lake outlet are summarized in Tables 4-2 and 4-3. Note that average concentrations are calculated using the laboratory limit of detection when observations are below that limit. The frequency of observations below the analytical limit of detection is summarized in Table 4-4.

The standard error of the estimated mean presented in Table 4-3 is an indicator of the variability in concentrations of the constituents measured in each tributary. This result reflects natural variability, parameters such as fecal coliform bacteria and suspended solids are present in the streams in higher concentrations following storm events. Analytical variability is another factor; constituents typically present at concentrations close to the analytical limit of detection such as zinc and nitrite-N are measured with less accuracy.

Review of Tables 4-2 and 4-3 indicates the following:

1. Comparison of METRO treated effluent (which receives advanced secondary treatment) and METRO bypass flows (which receive primary treatment and chlorination) illustrates the removal efficiency of the facility's biological treatment plus chemical phosphorus removal. Note the lower concentrations of total suspended solids, BOD, TOC, TP, and SRP in the fully-treated effluent compared with the bypassed flows. Constituents present in particulate form, such as the metals Cr, Cu, Fe, Pb, Mg, and Zn, are also significantly higher in the bypassed flow. The fecal coliform data indicate that chlorination of the bypassed flows was not always sufficient to kill indicator organisms (and presumably pathogens).

2. Note the high concentration of chloride in Onondaga Creek in 1999. Until recently, it was unusual for the average chloride concentration in this tributary to exceed that of Nine Mile Creek, which has residual Solvay waste material (enriched in calcium and chloride) deposits in the lower reaches of the watershed. The two streams have different ionic profiles; Nine Mile Creek is a calcium chloride dominated system, and Onondaga Creek is a sodium chloride dominated system (Table 4-5). The baseflow chloride concentration in Onondaga Creek was higher than in Nine Mile Creek in 1999, as evident from the different relative magnitude of flow-weighted vs. arithmetic average concentrations (discussed below). In a dry year such as 1999 elevated chloride present in baseflow are less diluted by precipitation and surface runoff. Aquifer depressurizing wells in the Tully Valley (Onondaga Creek headwaters) may be contributing to the elevated chloride concentrations as well. The concentration of chloride measured at the Kirkpatrick St. sampling site was consistently higher than the concentration measured at Spencer St. Field reconnaissance has confirmed the gradual increase in chloride concentration in this stream reach which appears to result from upwelling saline groundwater.

3. The largest differences between flow-weighted and arithmetic means is exhibited for parameters with a strong relationship between discharge and concentration. Note, for example, that the 1999 flow-weighted average chloride concentration in Nine Mile Creek was 490 mg/l, while the conventional average was 684 mg/l. For Onondaga Creek, the 1999 chloride relationship was 528 mg/l flow-weighted average and 977 mg/l arithmetic average concentration. The relationship between chloride concentration and stream flow of Onondaga Creek and Nine Mile Creek is plotted in Figure 4-7.

The 1999 loading estimates for each tributary are presented in Table 4-6. Standard errors of the loading estimates (as calculated by AUTOFLUX) are included. METRO effluent loads are calculated using the more extensive database of measurements required by the facility's SPDES permit.

Average concentrations and loads of the major ions and nutrients are plotted in Figures 4-8 and 4-9. Percentage contribution of each tributary to the total 1999 external load to Onondaga Lake is summarized in Table 4-7. Review of these figures and tables indicates the following results:

Nine Mile Creek, with 31 % of the flow, contributed 44.7 % of the calcium to the lake. Chloride load to the lake from this stream was proportional to its flow (31%).

2 Flow through the largest tributary, Onondaga Creek, represented 37.8 % of the hydrologic inflow to the lake. This stream continued to be the largest source of suspended solids to the lake, with 55 % of the annual load.

The METRO effluent (fully treated plus bypass) dominated the external loading of constituents found in wastewater including organic carbon, nitrogen, phosphorus, and fecal coliform bacteria. Most notable is nitrogen; METRO effluent (fully treated plus bypass) represented 83 % of TKN and 90 % of ammonia N loading in 1999. Phosphorus loading from METRO was estimated at 55 % of the total external load in 1999.

4.3 METALS LOADING CALCULATIONS

Load estimates for the tributaries and METRO are calculated using near-continuous measurements of flow coupled with occasional measurements of concentration. Tributary samples are grab samples while most samples of METRO effluent are 24-hour composites. Each load estimate is presented with its standard error indicating the magnitude of uncertainty associated with projecting concentration over the unsampled portion of the annual record. Standard error is reduced if the number of samples is large or if concentrations tend to be highly consistent. For example, the standard error of the estimated phosphorus load from METRO, with daily measurements of concentration, is 1.7%, the standard error of the Nine Mile Creek estimate, with biweekly measurements supplemented with high flow events, is 21.3%.

Load calculations for parameters present in streams at concentrations close to the analytical limit of detection have two additional sources of uncertainty. First, analytical precision and accuracy are reduced as concentrations approach the analytical limits of detection. Reported load estimates thus have an additional uncertainty that may not be adequately reflected in the calculated standard error. Second, when substances are present in trace concentrations it can be difficult to differentiate ambient concentrations from contamination of sampling equipment or bottles, atmospheric deposition in the field or laboratory, or impurities in laboratory reagents.

Concentration and loading estimates for certain metals are subject to these uncertainties. Based on an evaluation of historical data collected throughout the United States, limit of detection and contamination problems limit the quality of reported data for the metals cadmium, copper, lead, nickel, silver, zinc, and mercury (Windom et al. 1991). Analytical methods for monitoring metals in water and wastewater have been developed and published by EPA, but these methods are inadequate for determining ambient concentrations of some metals in some surface waters (EPA Office of Water, October 1993).

To help overcome this limitation, EPA and USGS have developed protocols for clean sampling and analytical techniques. Accurate and precise measurement of low ambient concentrations requires actions in several interrelated areas (EPA, Office of Water, October 1993):

- Use of clean techniques during collecting, handling, storing, preparing, and analyzing samples to avoid contamination
- Use of analytical methods with sufficiently low limits of detection
- Avoiding interference in the quantification (instrument analysis) step
- Use of blanks to assess contamination
- Use of matrix spikes (sample spikes) and certified reference materials to assess interference and contamination
- Use of replicates to assess precision
- Use of certified standards

EPA recognizes the importance of documenting those measures taken to ensure that ambient metals data are precise and accurate. By documenting data quality, data users are better able to interpret the findings and assess whether there are any limitations to data usability. Onondaga County's field and laboratory teams have incorporated several EPA recommendations into their sample collection and analysis program. Equipment blanks are run for each lake and tributary sampling event to assess background contamination during sample collection and handling. Replicate analyses are performed. The laboratory uses certified reference materials and standards in accordance with state ELAP requirements. The METRO laboratory continues to work towards achieving lower analytical limits of detection.

However, metals results are frequently at or below the analytical limit of detection currently achieved by the METRO laboratory (recall discussion in Chapter 3). Copper and zinc results are most affected. Estimating annual load for these constituents is problematic when the analytical results are consistently close to or less than the limit of detection. The "true" ambient concentration is between zero and the limit of detection. Historically, the annual monitoring program has calculated and reported loads using the limit of detection in the calculations. This assumption produced estimated loads that are consistently biased high.

The cold vapor atomic absorption method routinely used by the METRO lab can measure ambient mercury to 0.2 µg/l (200 ng/l). Using Method 1631 (cold vapor atomic spectroscopy) outside specialty laboratories can achieve a limit of detection of approximately 0.1 ng/l. When results of these low-level analyses are compared with historical data, it is clear that annual external loads of mercury calculated using the analytical limit of detection (0.2 µg/l) have been significantly biased high. Ambient concentrations are orders of magnitude less than 0.2 µg/l when measured using the low detection level method. Annual loads of mercury reported in previous annual reports should therefore be disregarded. Beginning with the1998 report, annual loads of mercury are not reported.

4.4 SEASONAL PATTERNS OF FLOW AND CONCENTRATION

Seasonal patterns of streamflow and concentrations of selected constituents (ions, nutrients, and suspended solids) are depicted for the major tributaries and METRO effluent in Figures 4-10 through 4-15. In general, dissolved salts demonstrate a strong inverse relationship between stream flow and concentration in the natural tributaries. Higher stream flows in spring dilute the dissolved salts. During low flow periods, the concentrations increase. Peaks in bacteria, solids, and TP are associated with the higher flow conditions. METRO performance is generally independent of flow.

Results of the 1999 water quality monitoring of the lake outlet are plotted in Figure 4-16. Flow through the lake outlet is not gauged. The flow regime is bi-directional; at times, water from the Seneca River flows into the lake. The specific conductance of the Seneca River water is lower than Onondaga Lake water. The plot of specific conductance indicates that a weak chemical stratification existed in the lake outlet on some sampling dates. On these dates, higher salinity lake water was flowing out of the lake, while lower salinity river water was flowing in.

4.5 COMPLIANCE WITH NEW YORK STATE AMBIENT WATER QUALITY STANDARDS

The monitored segments of the Onondaga Lake tributaries are classified C (suitable for fish propagation and secondary water contact recreation). Compliance with the ambient water quality standards is summarized in Table 4-8. Overall, the lake tributaries are in compliance with the following exceptions:

1. The East Flume occasionally violated ambient water quality standards for pH, DO, iron, copper, and cyanide, and regularly violated standards for ammonia and nitrite N.

2. None of the natural tributaries was consistently in compliance with the iron standard.

Compliance of METRO with its SPDES permit limits is summarized in Table 4-9

4.6 TRIBUTARY TREND ANALYSIS

The seasonal Kendall test (Hirsch and Slack 1984) forms the basis of the trend analysis software developed by Dr. William W. Walker to analyze trends in the Onondaga Lake tributary database. The trend analysis is performed on subsets of tributary concentration data. Table 4-10 summarizes results of a ten-year trend analysis of the Onondaga Lake tributary monitoring sites, from 1990 through 1999. Additional discussion of the trends in tributary concentration and loading is included in Chapter 12 of this report. Tributary trend analysis examines changes in both concentrations and annual loads. Adjustments are made for flow, so that patterns such as wet years early in the record and dry years late in the record will not introduce a spurious result.

4.7 EFFLUENT TOXICITY TESTING

Acute effluent toxicity testing is a requirement of the SPDES permit for the METRO facility. Whole effluent toxicity testing was performed twice in 1999 (January and April). Both tests were performed with two organisms to indicate toxicity of the fully-treated plant effluent. The biological organisms were the freshwater invertebrate cladoceran (*Ceriodaphnia dubia)* and the vertebrate fathead minnow (*Pimephales promelas*). AquaTOX Research, Inc. of Syracuse completed the tests in accordance with guidelines published by NYSDEC in the New York State Manual of Toxicity Testing of Industrial and Municipal Effluents.

The effluent toxicity test exposes test organisms to replicate serial dilutions of a 24 hour composite sample of treated tertiary effluent from METRO (both A and B sides of the effluent stream are included in the composite sample). Serial dilutions of treated effluent are made using Onondaga Lake water. Five dilutions of METRO effluent are tested (0%, 6.25%, 12.5%, 25%, 50% and 100% effluent) at four replicates per treatment. The 0% effluent serves as the control. A static renewal design is used; each sample is replaced all at once with a new sample after 24 hours. Mortality of the test organisms is observed after 24 and 48 hours. The 48-hour LC_{50} (percent of effluent that is toxic to 50% of the test organisms after 48 hours) is reported.

For this system, the critical dilution is 50%, which represents a 1:1 dilution between wastewater effluent and the receiving water. This value is based on the relative flow of the METRO discharge compared with the total flow of the Lake's natural tributaries during low flow conditions. In order to pass the effluent toxicity test, there can be no evidence of toxicity in the test organisms relative to the controls at the critical dilution of 50% effluent.

Certain water quality parameters of the effluent and the dilution water (lake epilimnetic water) are measured at the beginning and end of the toxicity testing to identify factors which may be causing or contributing to any observed mortality of the test organisms. Toxicity testing is conducted at a constant water temperature of 25 °C. Ammonia and pH are measured and unionized ammonia is calculated. Other water quality parameters measured include dissolved oxygen, conductivity, alkalinity, hardness, and total residual chlorine.

Results of the 1999 toxicity testing are summarized in Table 4-11. For all tests, the 48-hour LC_{50} was greater than 100% of effluent. There was no evidence of mortality relative to the controls at the critical effluent dilution of 50%. Survival of both test organisms after 48 hours in 100% effluent was not different than survival after 48 hours in 0% effluent (Onondaga Lake water).

The total ammonia concentration in METRO effluent in April was approximately 14 mg/l. During the January toxicity tests, total ammonia in METRO effluent was 4.5 mg/l. Other water quality parameters were relatively consistent between the two sampling dates.

4.8 REFERENCES

EPA Office of Water, October 1993. Policy and Technical Guidance on interpretation and implementation of aquatic metals criteria.

Hirsch, R.M. and J. R. Slack, 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research, 20(6): 727-735.

Windom, H. L. J. T. Byrd, R.G. Smith Jr. and F. Huan, 1997. Inadequacy of NASQAN data for assessing metals trends in the Nation's Rivers. Env. Sci. Technol. 25:1137-1142.

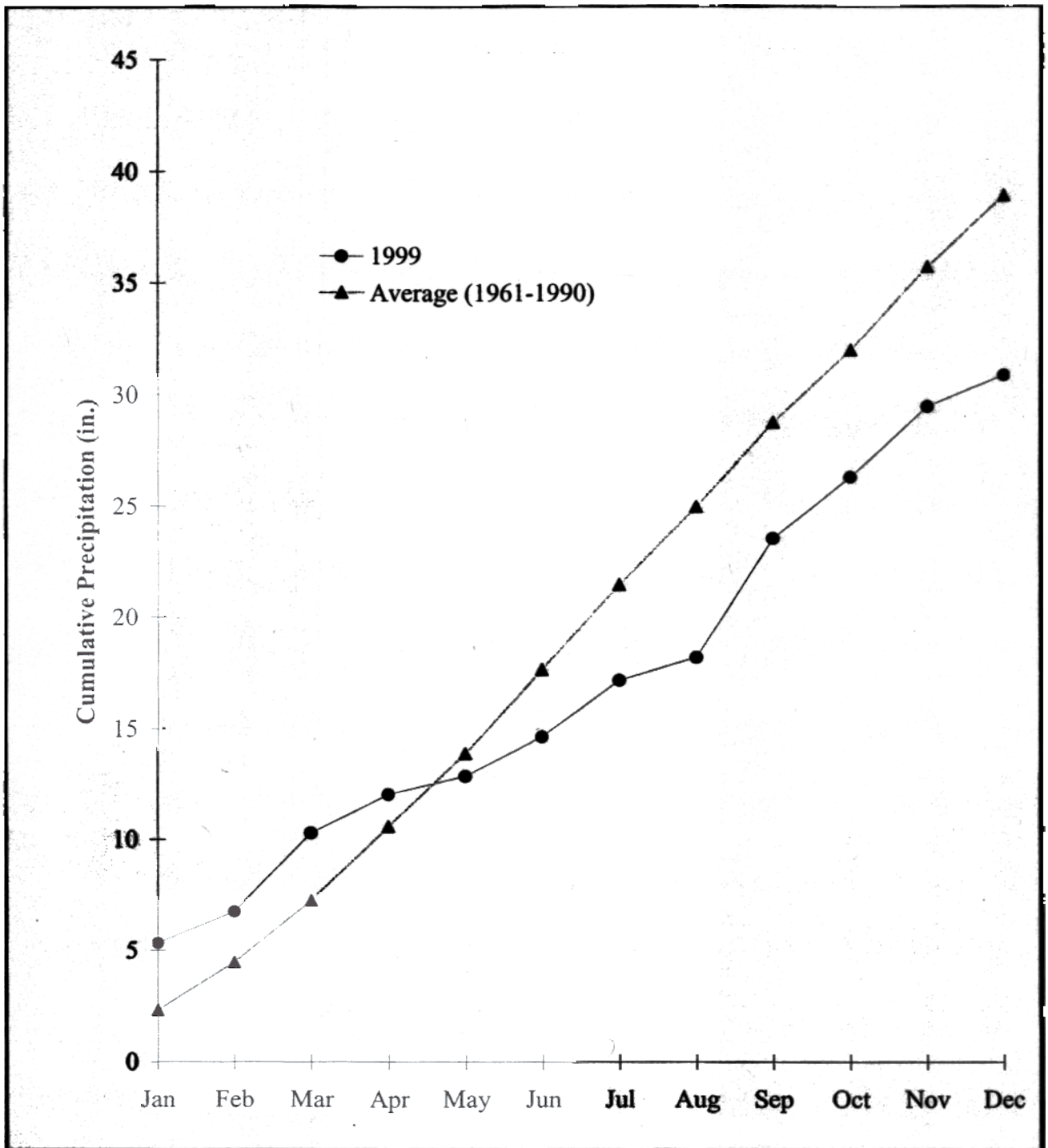
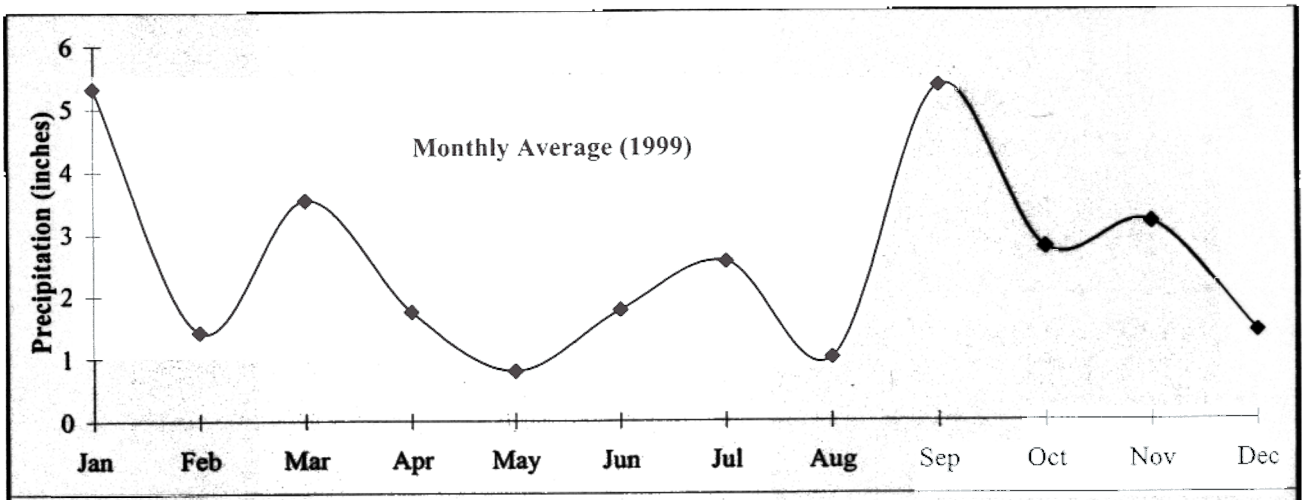
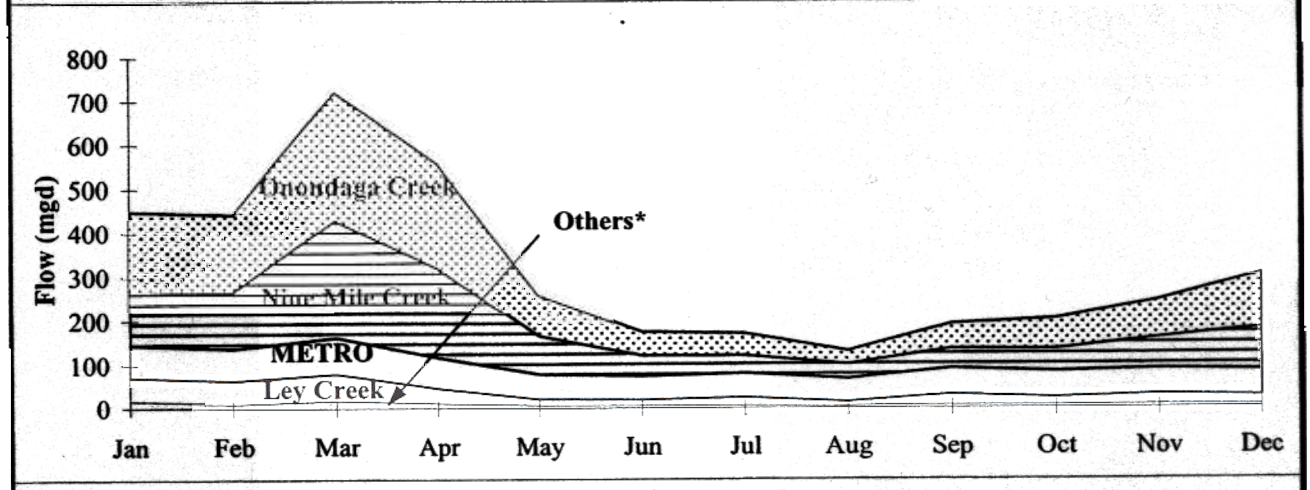
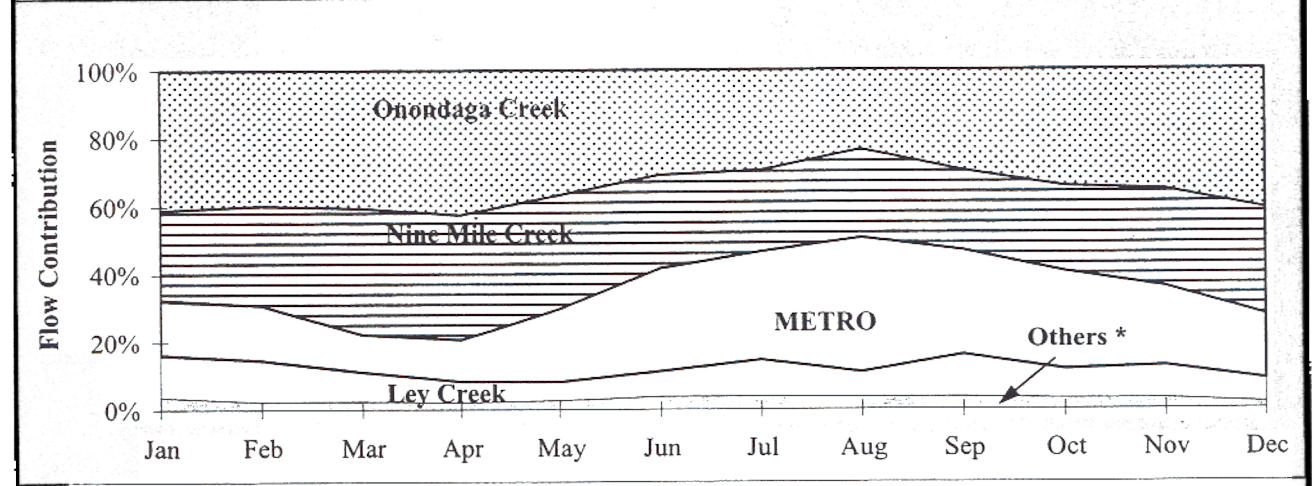


FIGURE 4-1 **CUMULATIVE PRECIPITATION IN 1999 COMPARED WITH THE HISTORICAL AVERAGE, SYRACUSE, NY**







*Others include Harbor Brook, East Flume and Tributary 5A. East Flume data were collected by Onondaga County and Honeywell.'METRO flow includes fully treated effluent (advanced secondary treatment) and by-pass (primary treatment plus chlorination)

FIGURE 4-2 **SEASONAL CHANGES IN PRECIPITATION AND TRIBUTARY INFLOWS TO ONONDAGA LAKE, 1999**

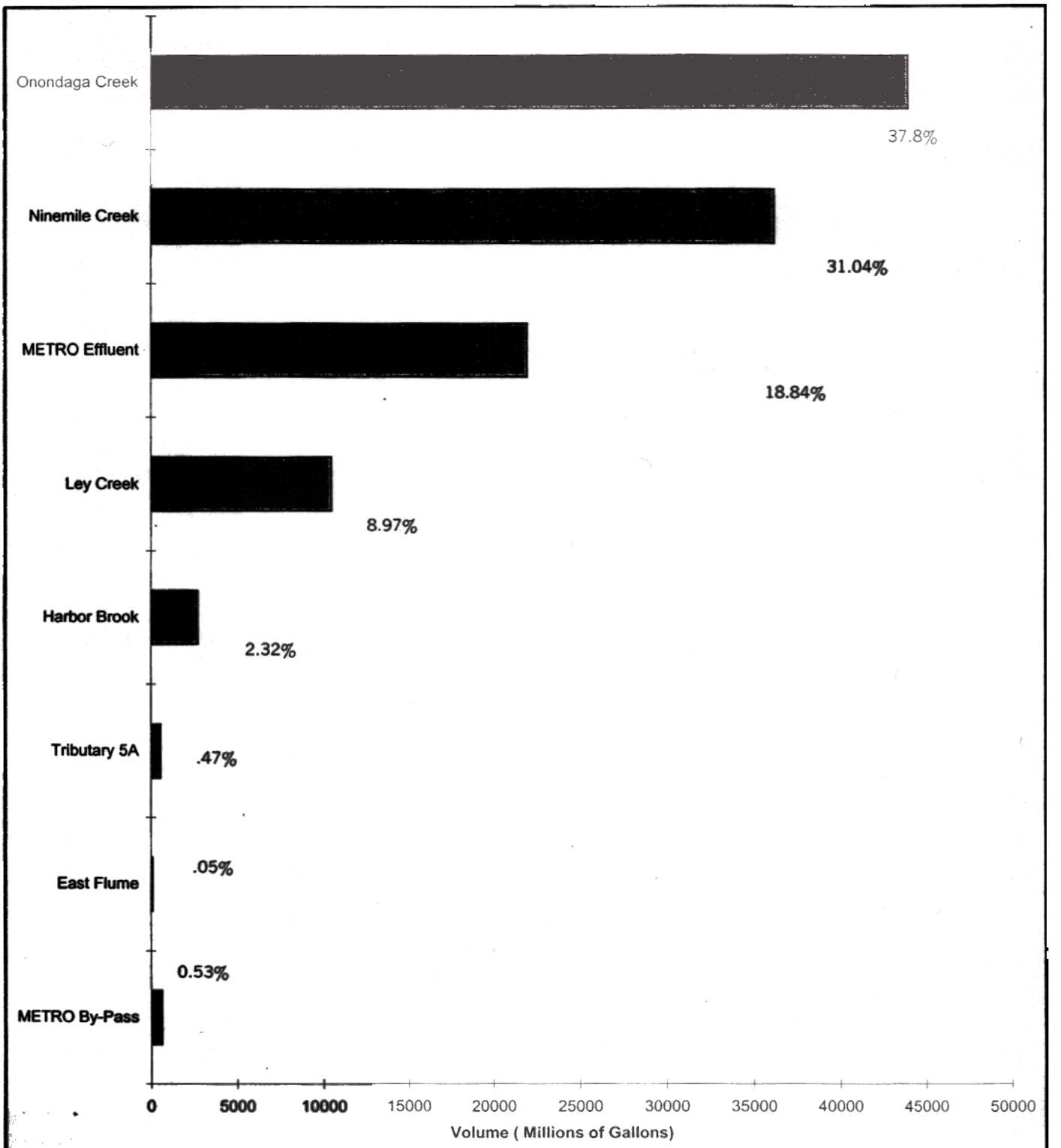


FIGURE 4-3 HYDROLOGIC CONTRIBUTIONS OF TRIBUTARIES TO ONONDAGA LAKE, 1999

3-%FLOWS_99.xls/plot

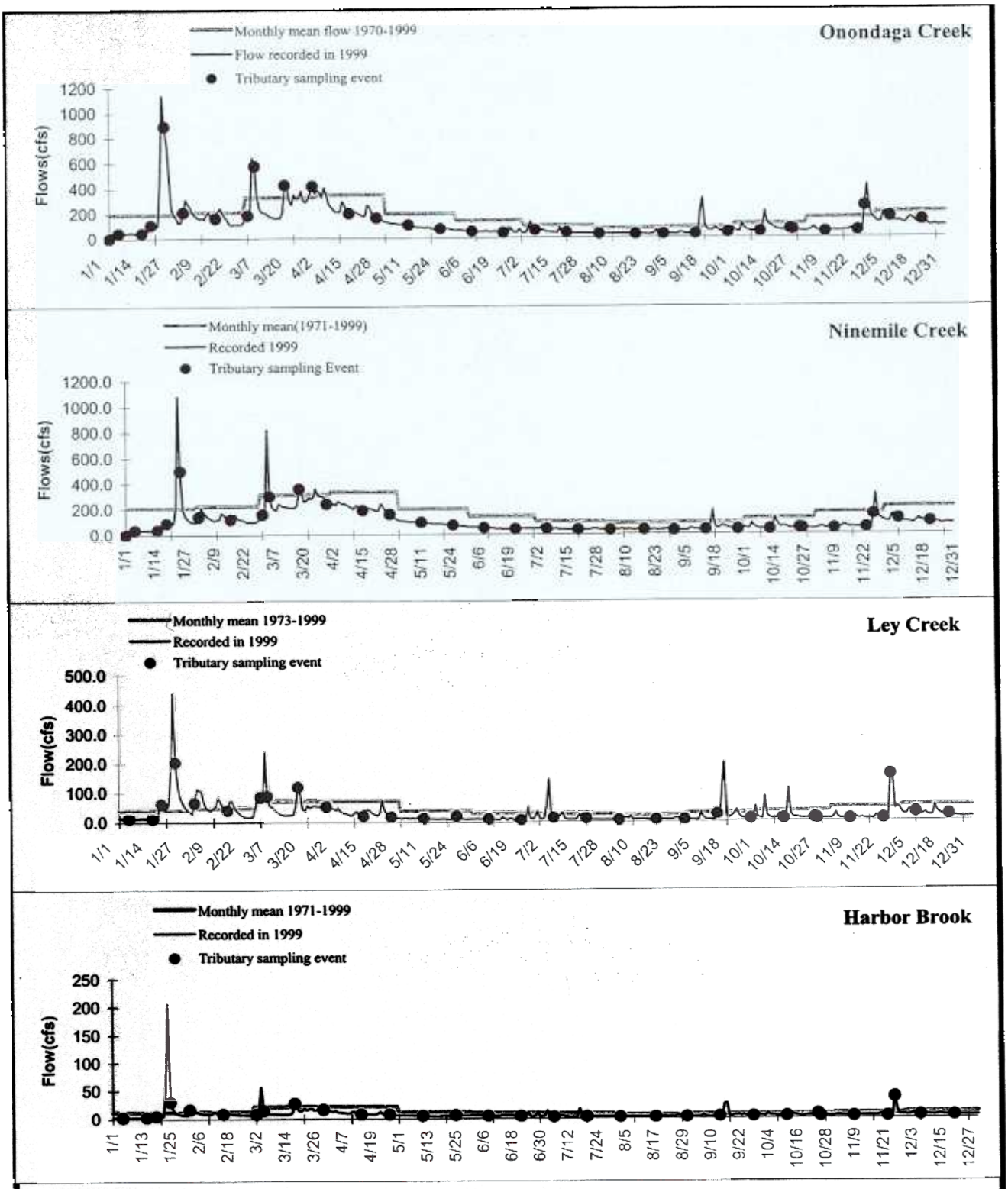
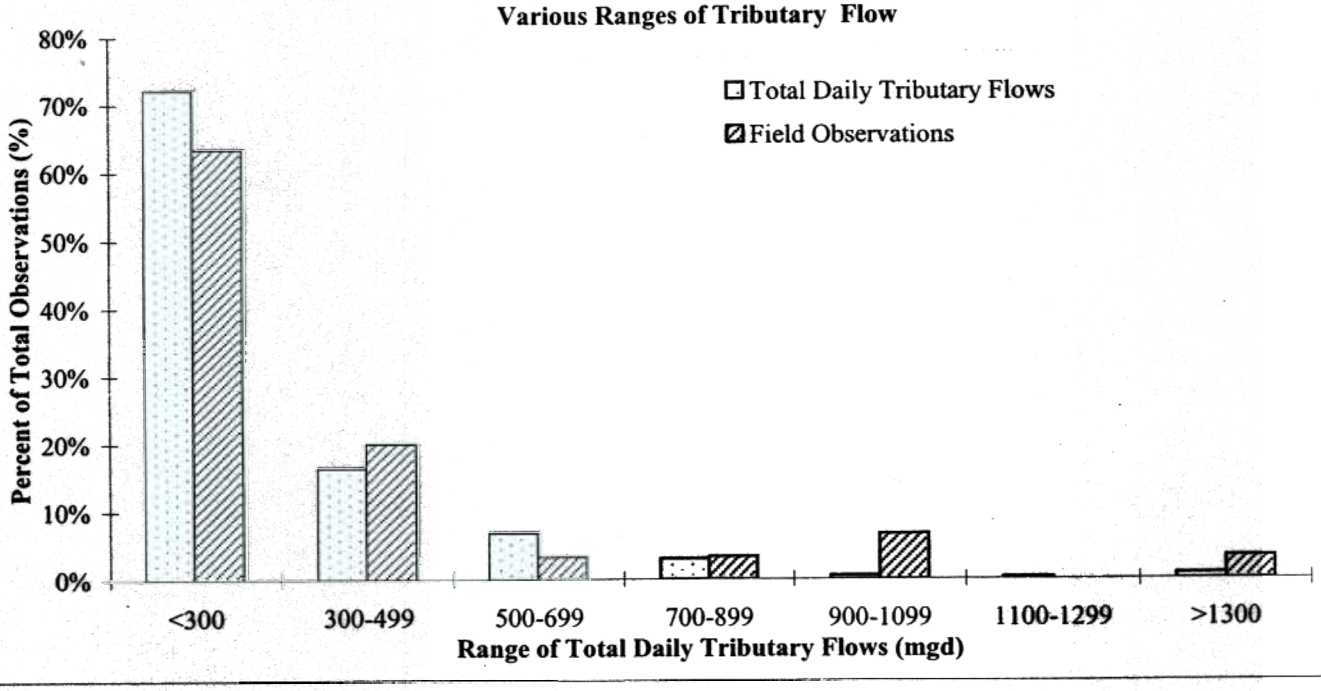
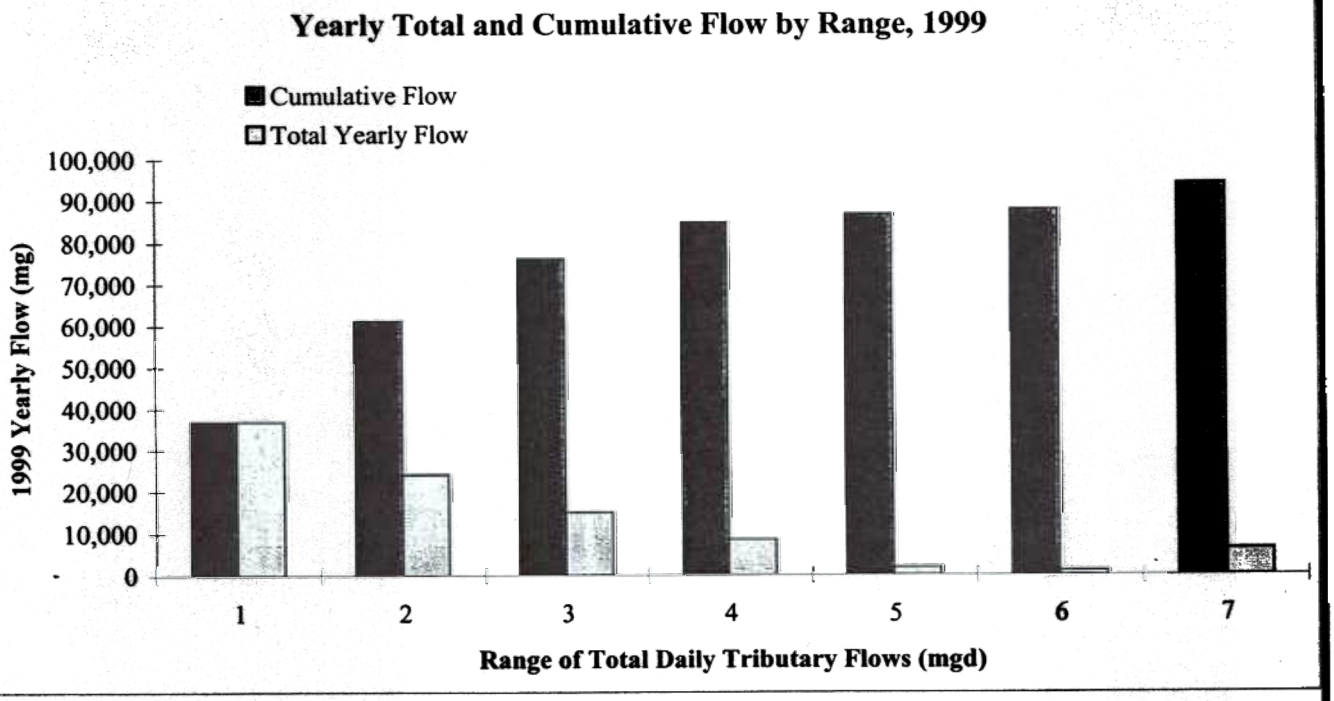


FIGURE 4-4 OBSERVED TRIBUTARY FLOWS IN 1999 COMPARED WITH THE LONG-TERM AVERAGE FLOW RECORD





Note:
The maximum total flow recorded on any day in 1999 was 2870 million gallons (recorded January 24, 1999).
Total flow includes flows recorded at the downstream sites on Harbor Brook, Onondaga Creek, Ley Creek, Nimemile Creek, and monthly averages from available data for Tributary 5A, and East Flume.

FIGURE 4-5 EFFECTIVENESS OF BIWEEKLY MONITORING IN REPRESENTING RANGE OF TRIBUTARY FLOW CONDITIONS

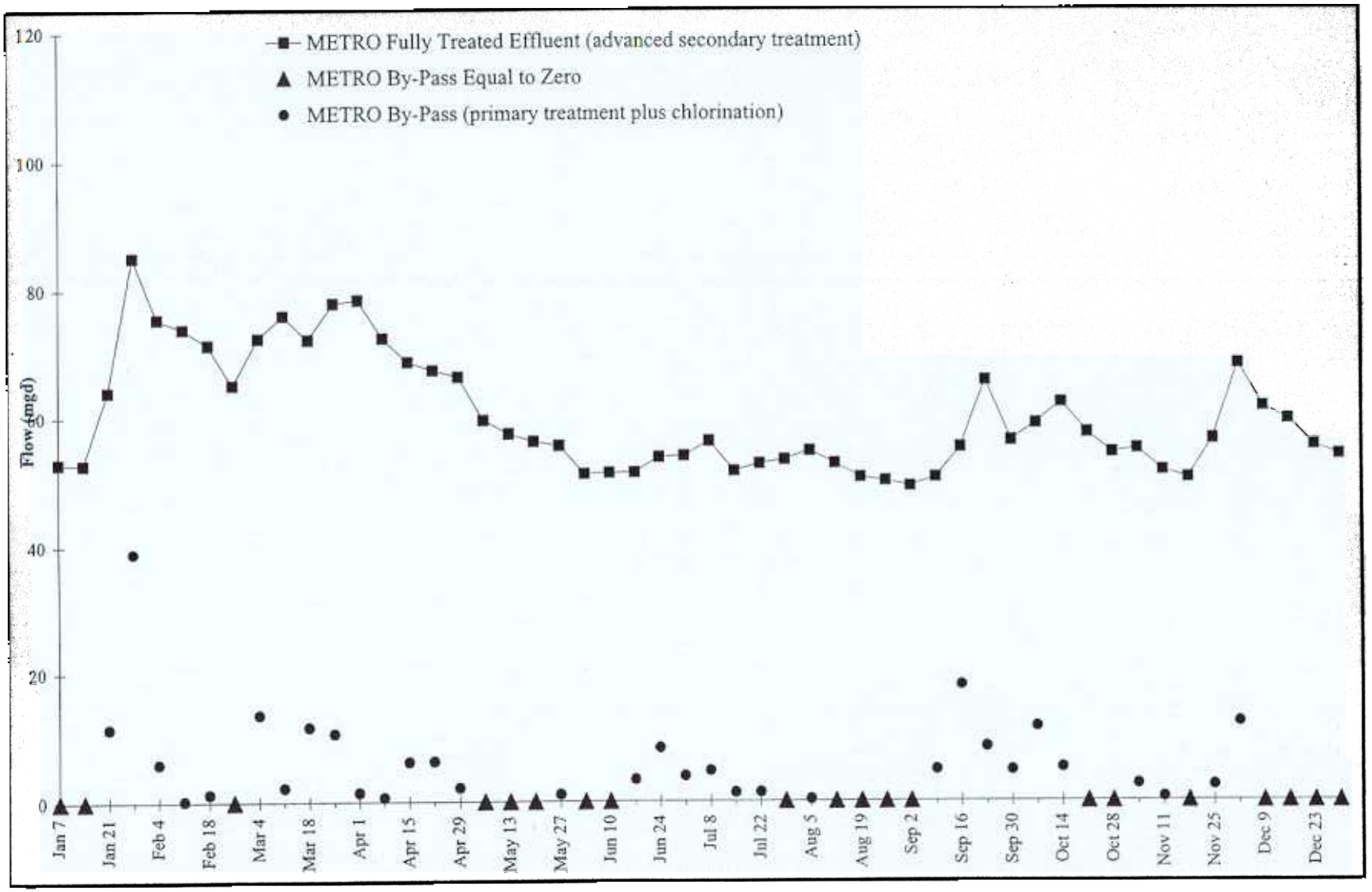
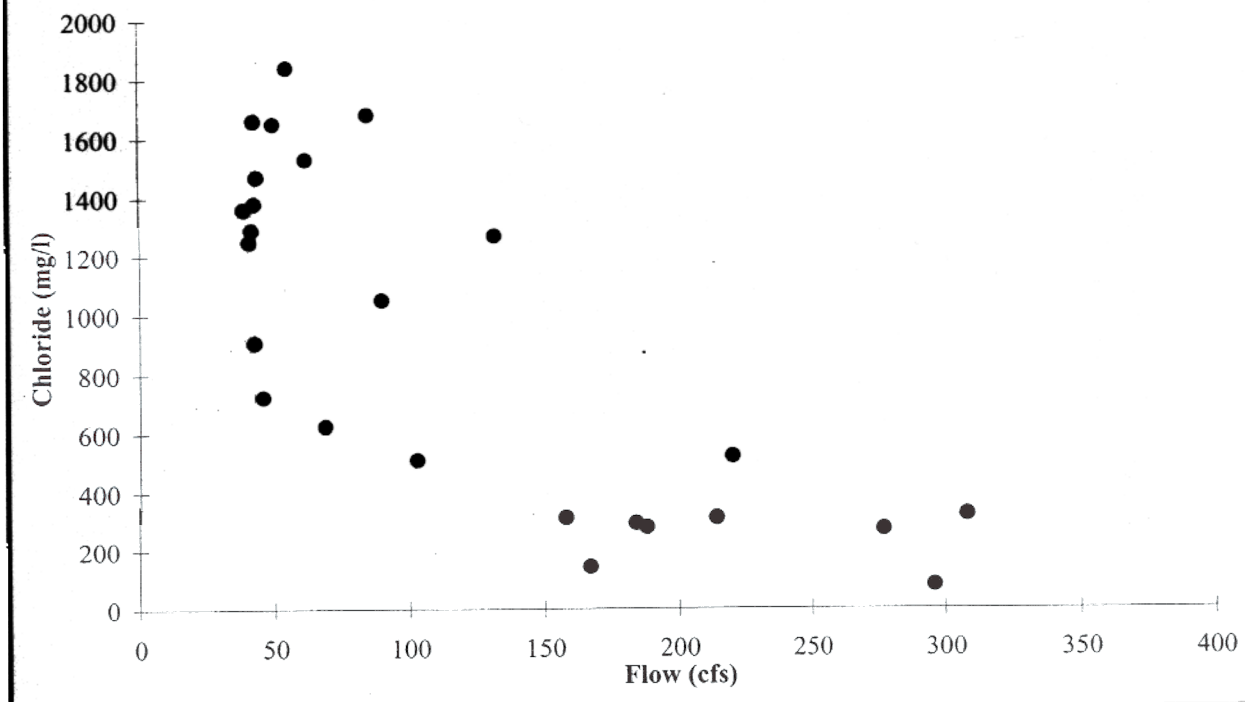


FIGURE 4-6 **WEEKLY-AVERAGED OUTFLOW FROM METRO, 1999**

MET-FLO_99.xls/plot99



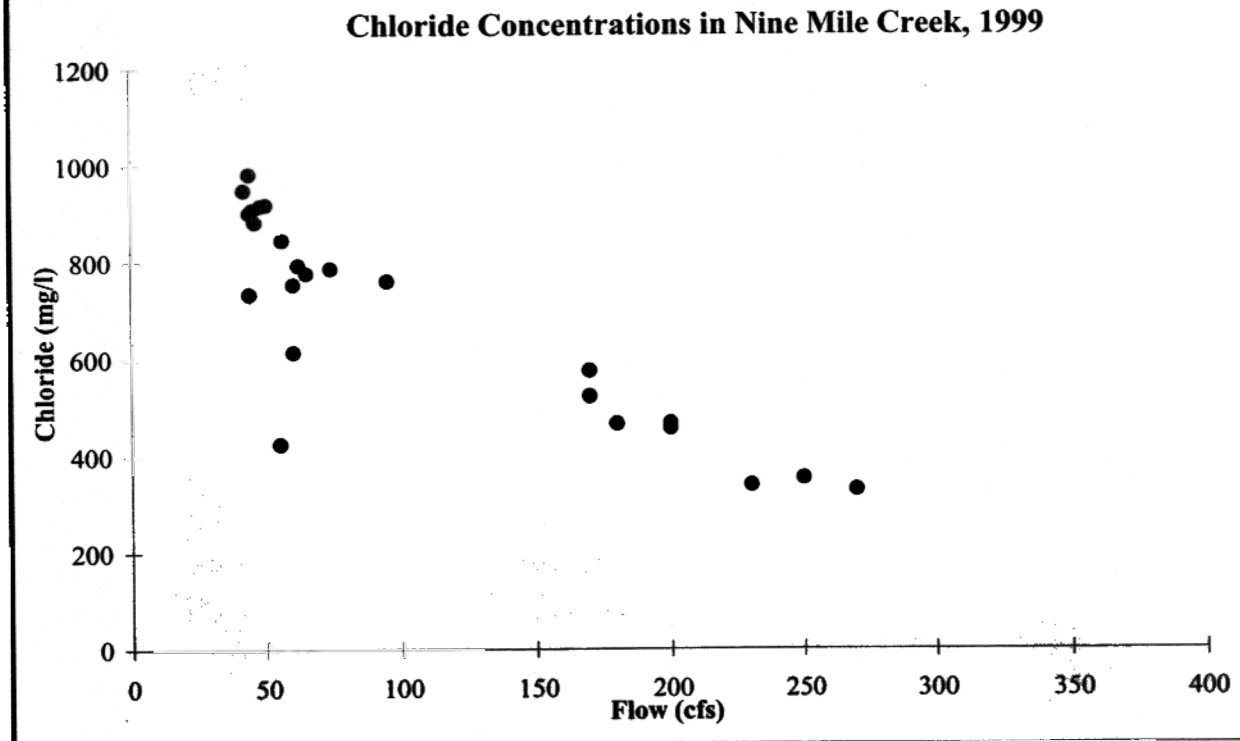
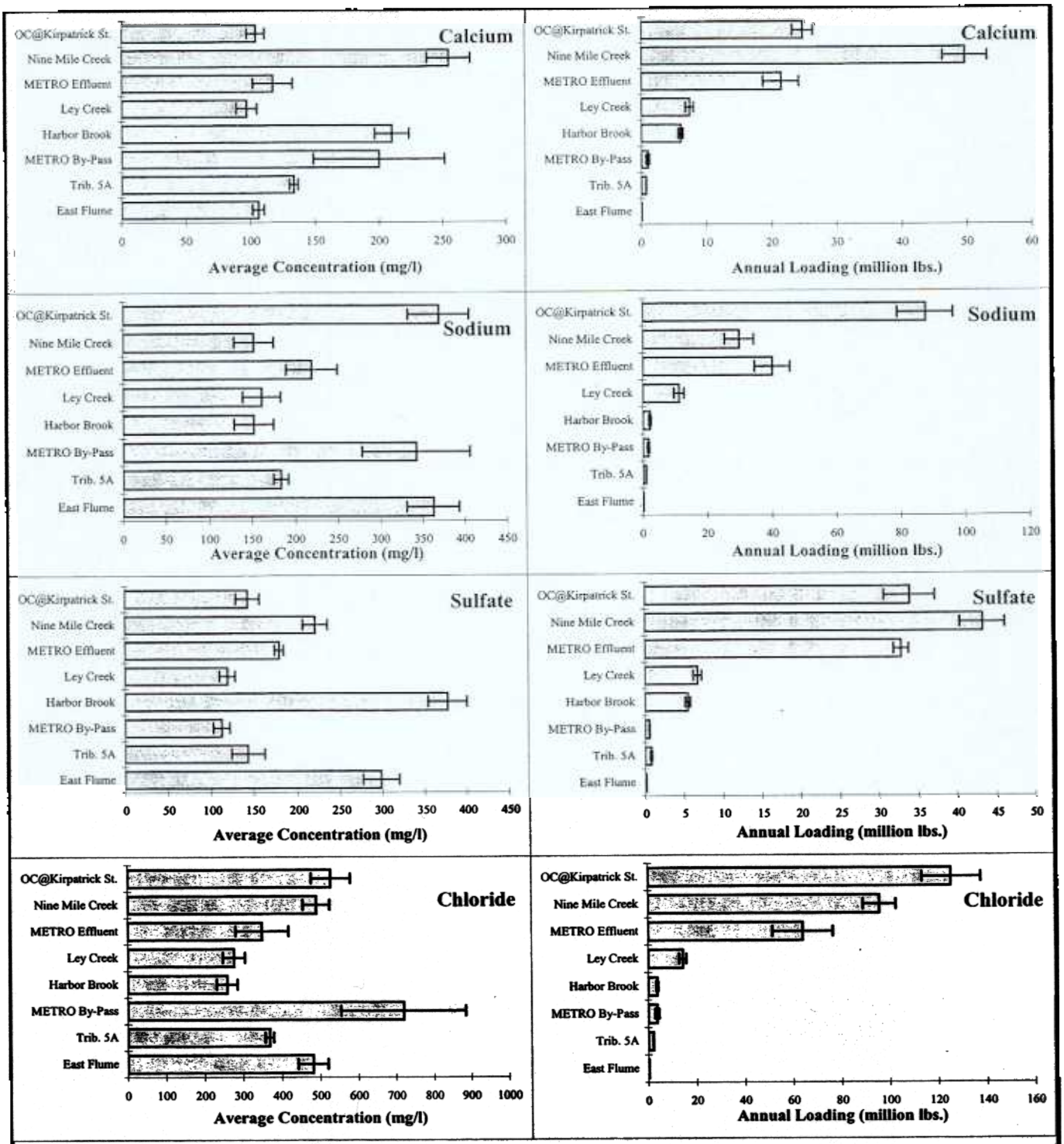
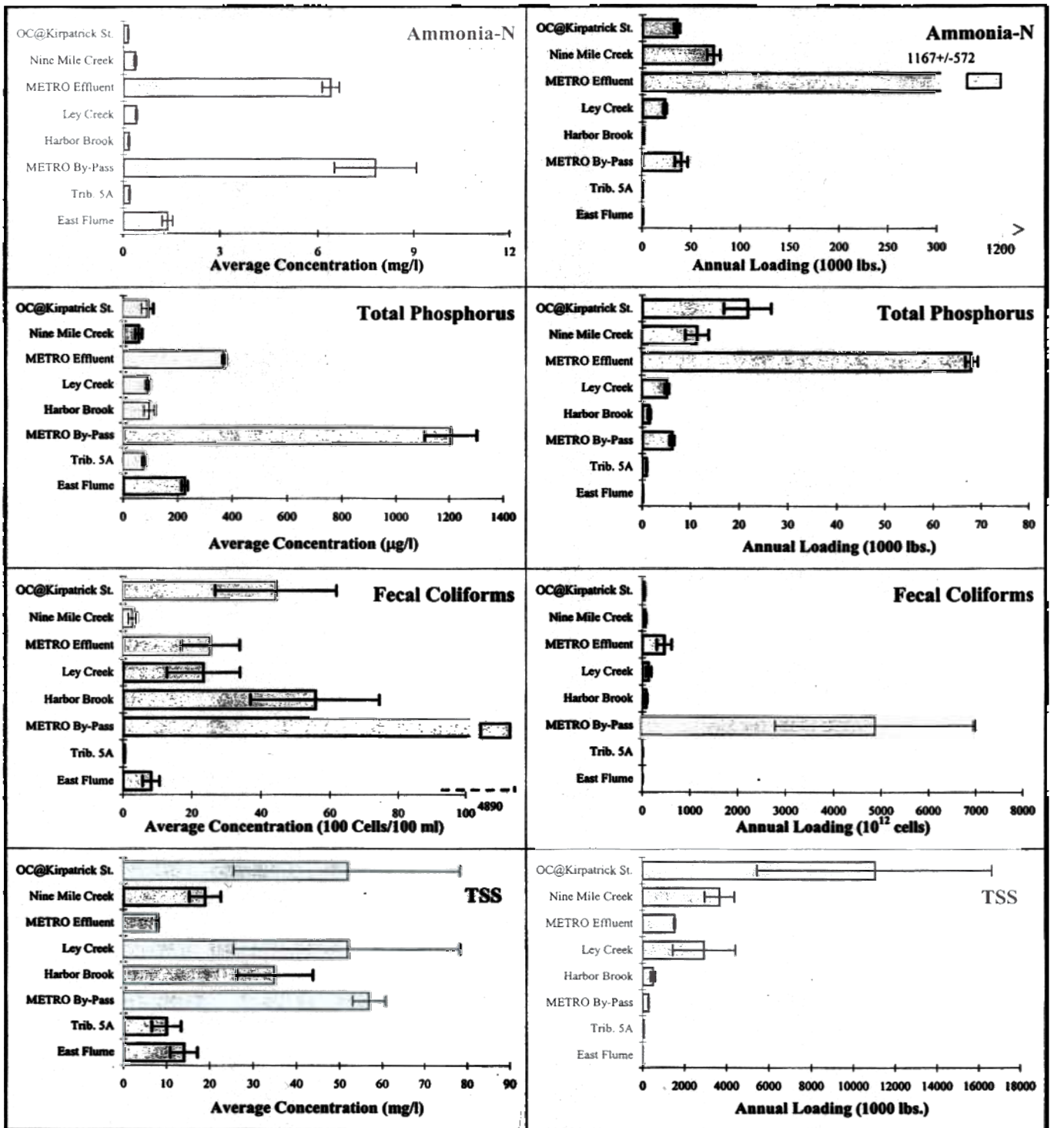


FIGURE 4-7 INVERSE RELATIONSHIP BETWEEN FLOW AND CHLORIDE CONCENTRATIONS IN ONONDAGA AND NINEMILE CREEKS, 1999



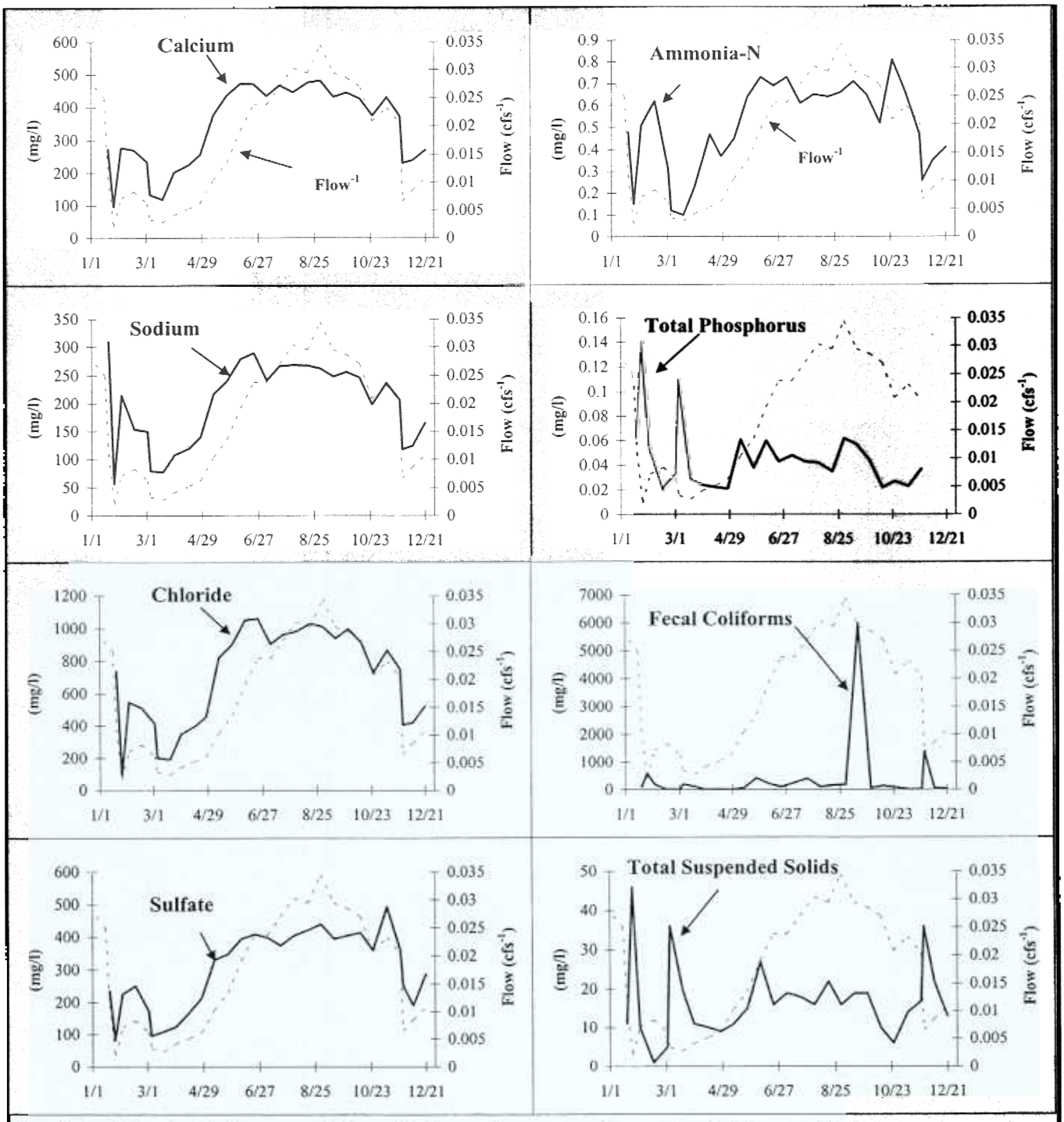
Error calculated by AUTOFLUX

FIGURE 4-8 FLOW-WEIGHTED AVERAGE CONCENTRATIONS AND ANNUAL LOADS OF MAJOR IONS IN ONONDAGA LAKE TRIBUTARIES, 1999



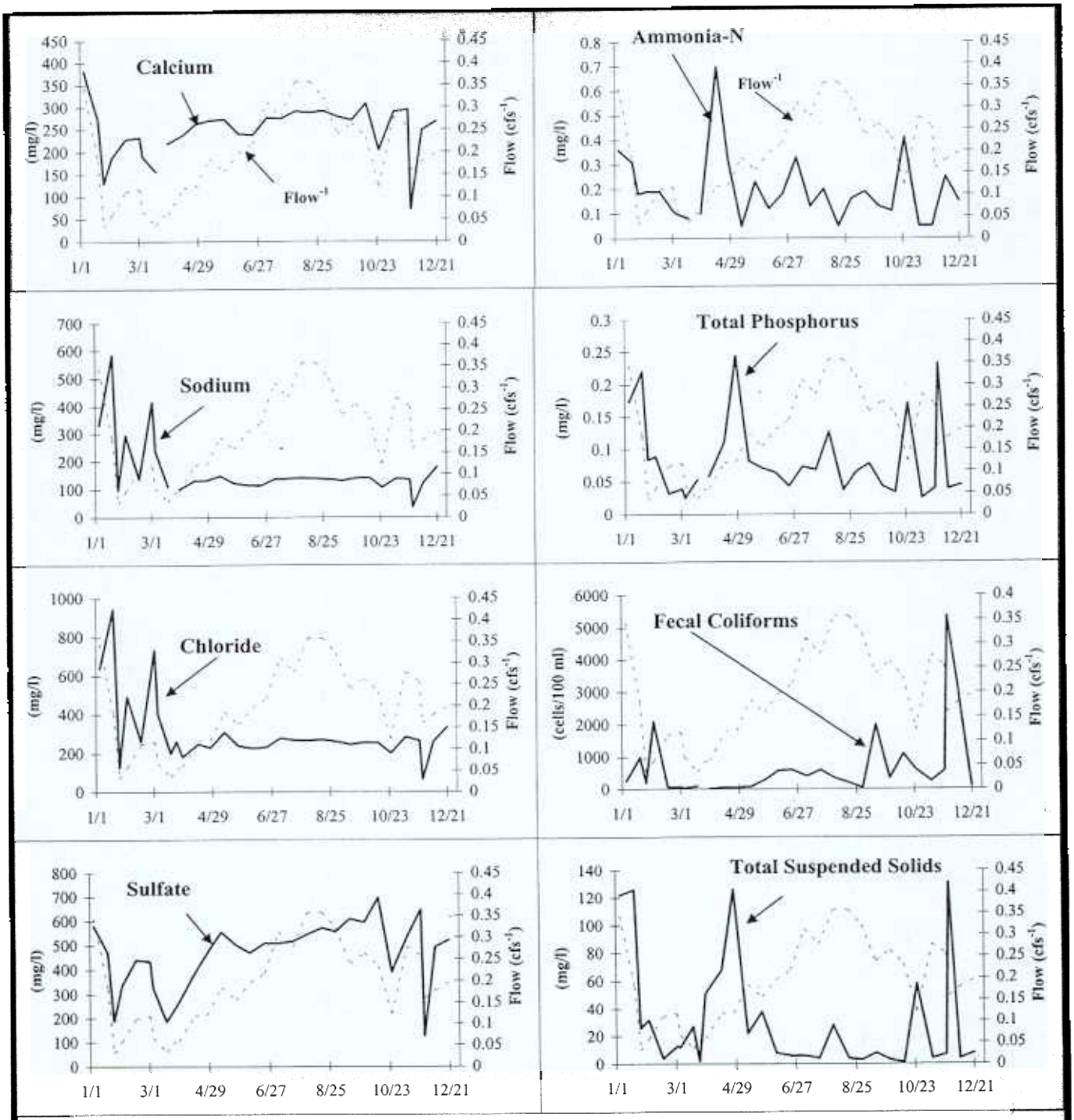
Error calculated by AUTOFLUX

FIGURE 4-9 FLOW-WEIGHTED AVERAGE CONCENTRATIONS AND ANNUAL LOADS OF NUTRIENTS IN ONONDAGA LAKE TRIBUTARIES, 1999



The dotted line is the inverse of flow (higher values mean less water in the creek).

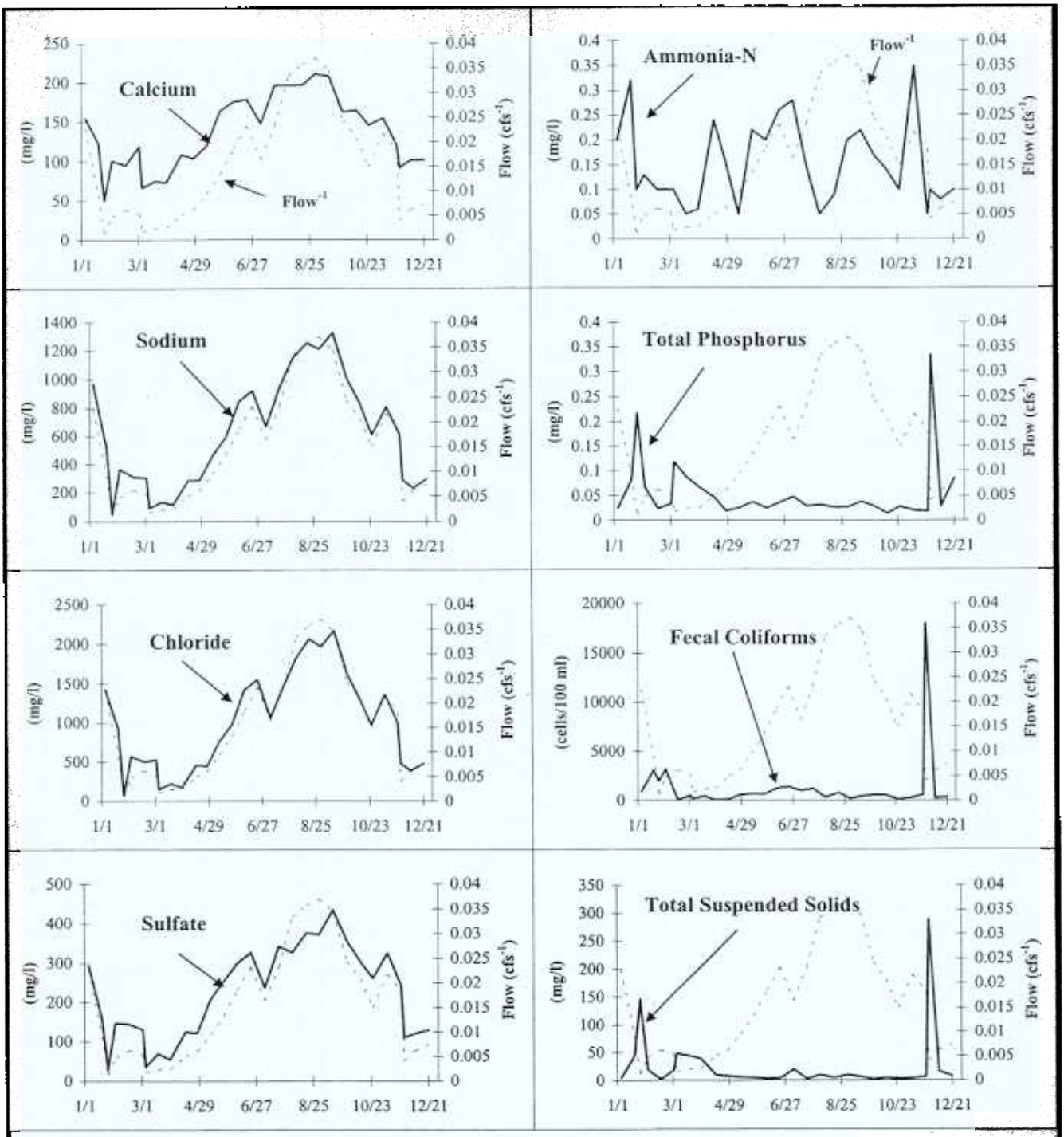
FIGURE 4-10 **SEASONAL CHANGES IN IONS, NUTRIENTS, FECAL COLIFORMS AND TSS IN NINE MILE CREEK, 1999**



The dotted line is the inverse of flow (higher values mean less water in the creek). 10,000 cells/100 ml is the maximum number of fecal coliform cells that the laboratory can detect.

FIGURE 4-11 **SEASONAL CHANGES IN IONS, NUTRIENTS, FECAL COLIFORMS, TSS IN HARBOR BROOK, 1999**

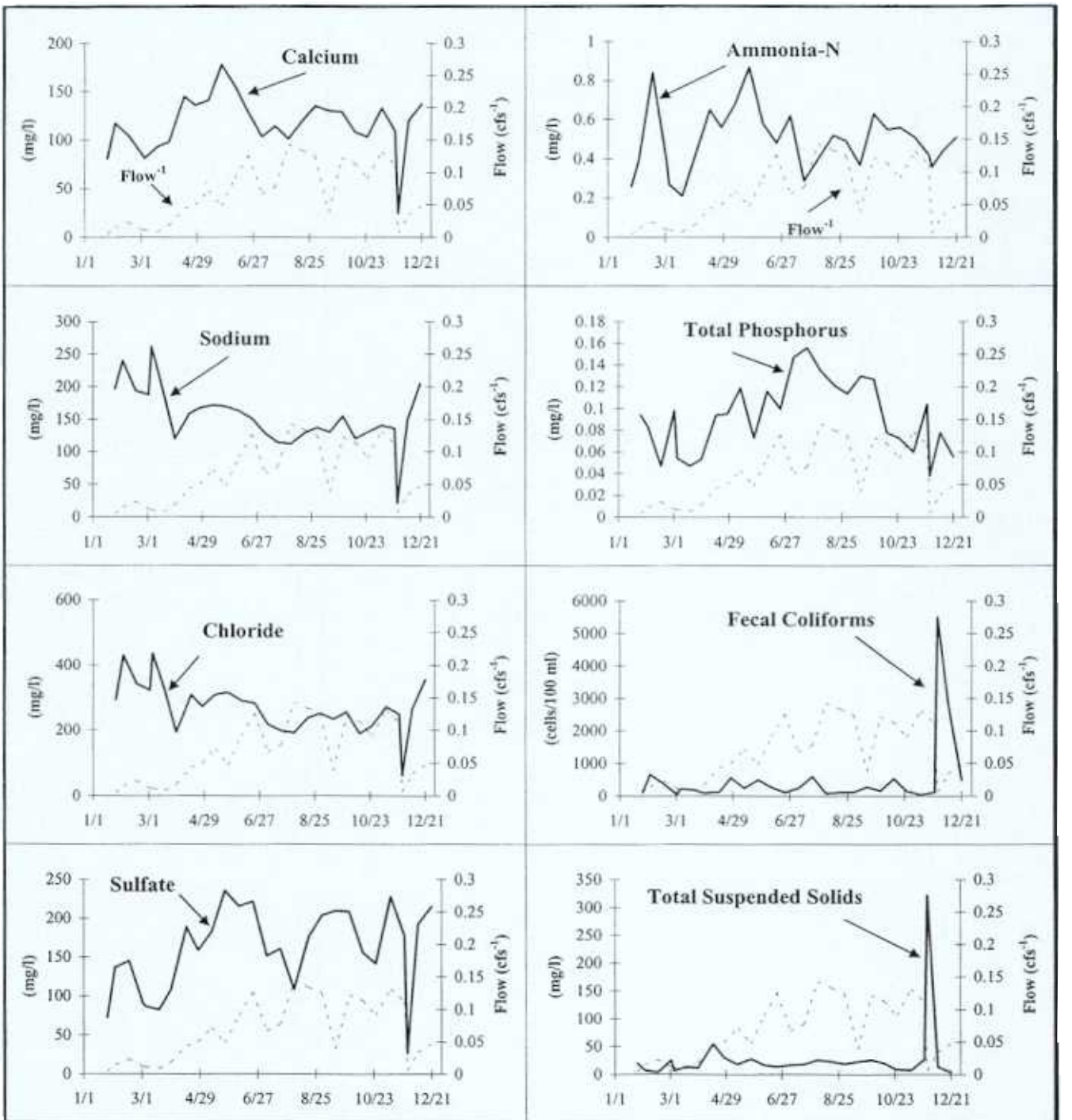
11HARBOR_99.xls/plot



The dotted line is the inverse of flow (higher values mean less water in the creek).

FIGURE 4-12 SEASONAL CHANGES IN IONS, NUTRIENTS, FECAL COLIFORMS AND TSS IN ONONDAGA CREEK, 1999

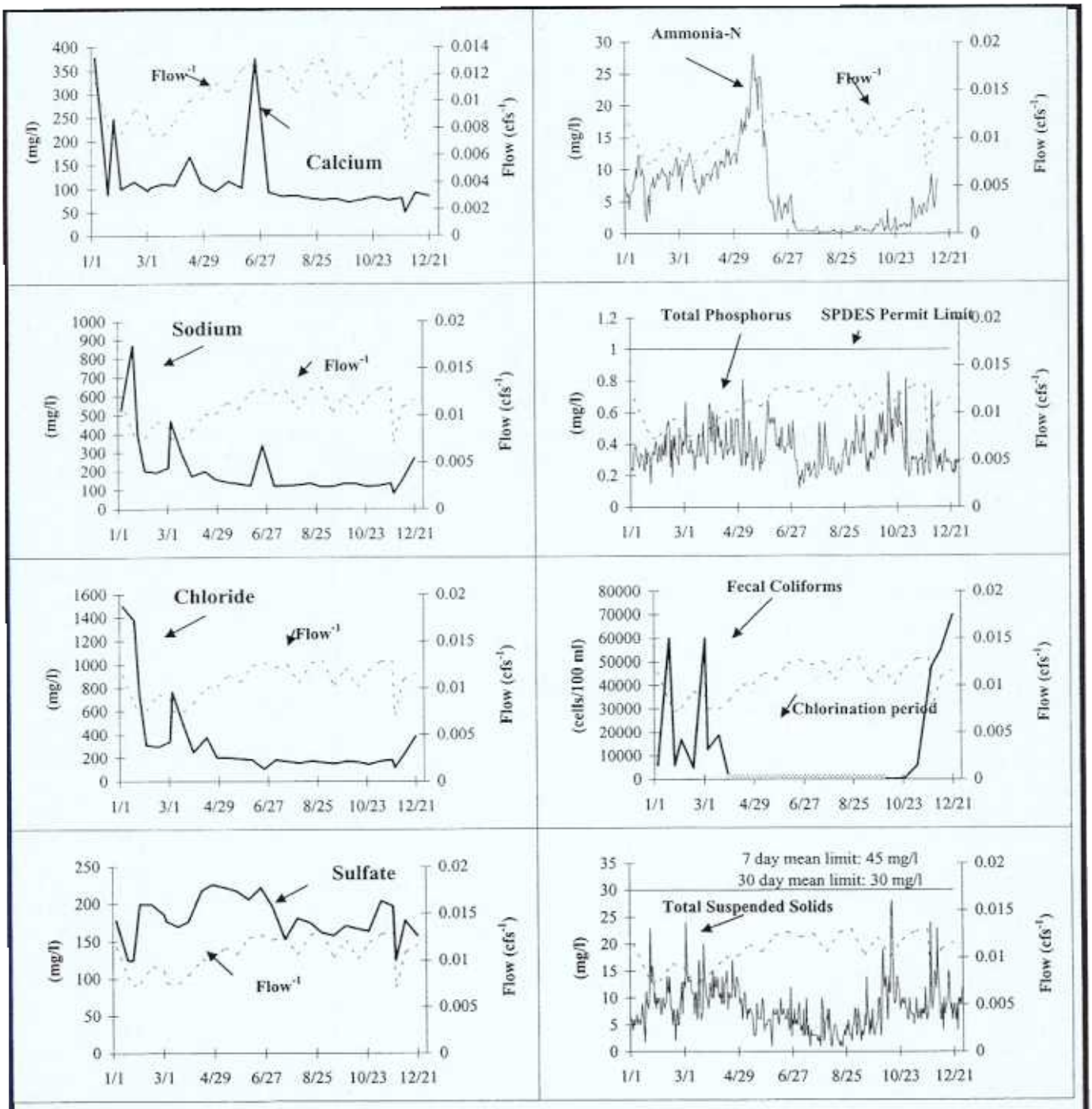
12-ONONrev_99.xls



The dotted line is the inverse of flow (higher values mean less water in the creek).

FIGURE 4-13 SEASONAL CHANGES IN IONS, NUTRIENTS, FECAL COLIFORM, AND TSS IN LEY CREEK, 1999.

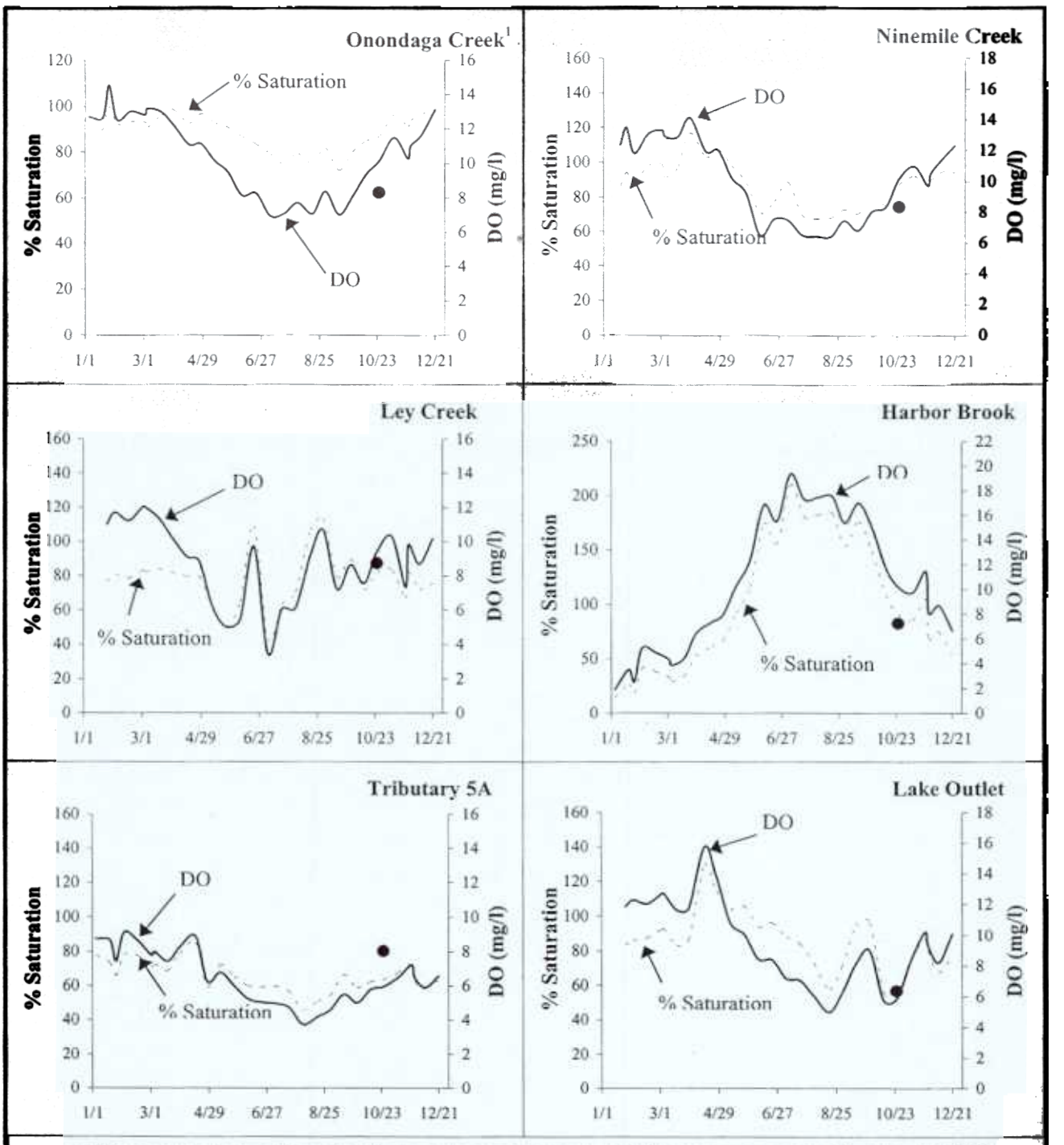
13-LEY_99.xls/plot



The dotted line is the inverse of flow (higher values mean less water in the plant outfall). Ammonia, total phosphorus, total suspended solids data are daily data collected by METRO; other parameters, including flow, are bi-weekly data collected in the annual monitoring program.

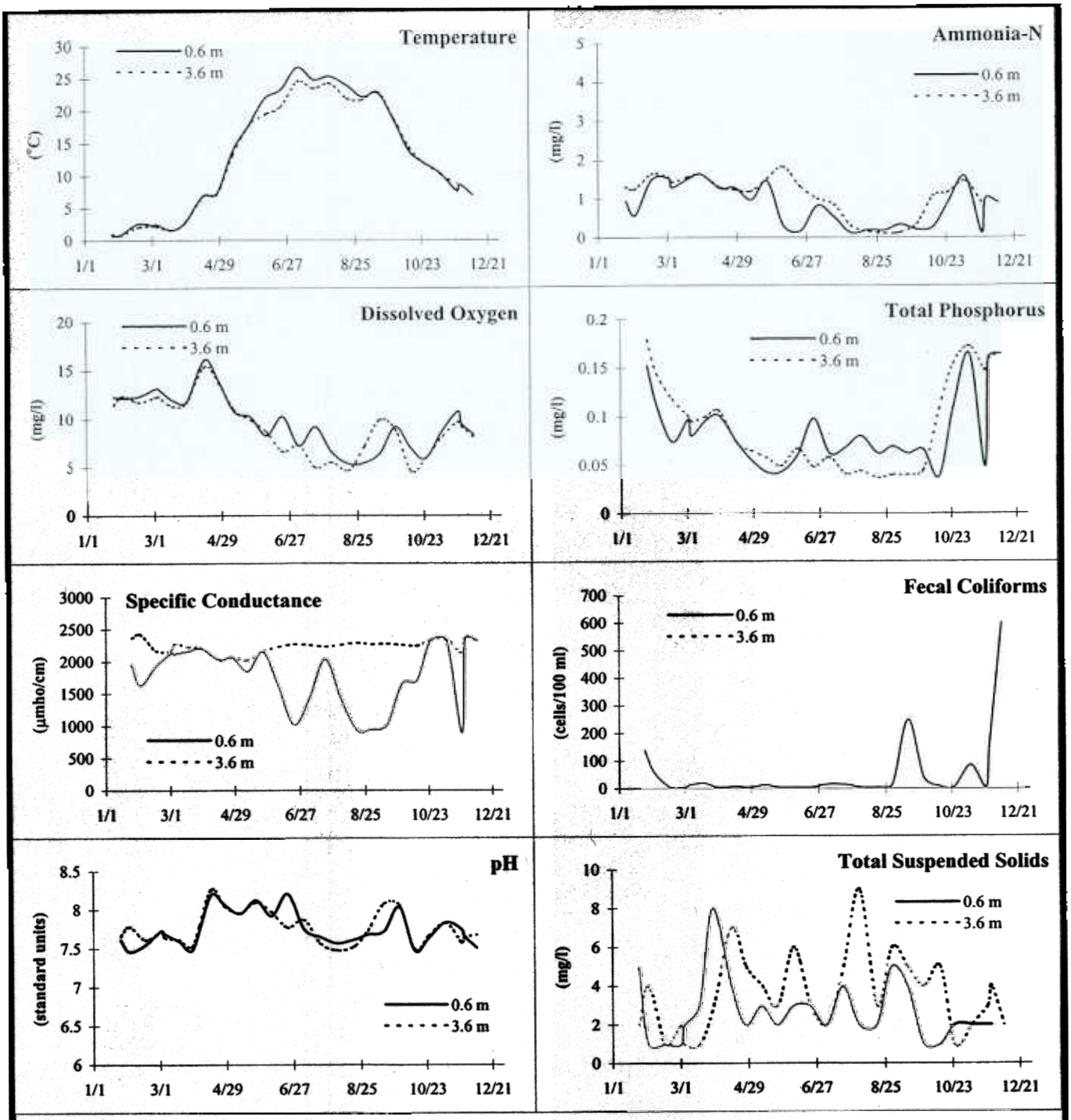
FIGURE 4-14 SEASONAL CHANGES IN IONS, NUTRIENTS, FECAL COLIFORMS, TSS IN METRO EFFLUENT, 1999

14-METRO_99.xls/plot



• DO concentrations in Onondaga Lake at the confluence of the tributary, measured on October 28, 1999. Lake Outlet data shown is the average of observations at 0.6 meters (2 ft.) and 3.6 meters (12 ft.).

FIGURE 4-15 **SEASONAL CHANGES IN DO AND DO (%SAT.) IN 5 TRIBUTARIES AND THE LAKE OUTLET, 1999**



Upper waters are sampled at 0.6 meters (2 ft.) depth; lower waters are sampled at 3.6 meters (12 ft.) depth.

FIGURE 4-16 SEASONAL CHANGES IN UPPER AND LOWER WATERS OF THE ONONDAGA LAKE OUTLET, 1999

TABLE 4-1

999 ANNUAL TRIBUTARY LOADINGS TO ONONDAGA LAKE COMPARED
WITH LOADINGS DURING PREVIOUS TEN YEARS
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Units	Annual Load 1988	Annual Load 1989	Annual Load 1990	Annual Load 1991	Annual Load 1992	Annual Load 1993	Annual Load 1994	Annual Load 1995	Annual Load 1996	Annual Load 1997	Annual Load 1998	Annual Load 1999	Average Load 1988-1998	% Change 1999 from Average
5-day BOD	10^6 lbs.	6.0	6.6	5.5	4.5	5.4	5.0	5.7	5.0	7.9	4.7	4.1	3.9	5.5	-30.1%
Total Alkalinity	10^6 lbs.	147	191	274	167	210	208	182	138	205	171	183	125	188.8	-34.0%
Total Organic Carbon	10^6 lbs.	6.2	7.5	8.8	10.2	6.9	6.0	5.5	4.6	8.9	5.1	4.7	3.8	6.8	-43.9%
TOC-filtered	10^6 lbs.	5.6	7.0	8.0	7.9	5.9	5.2	5.0	4.2	7.6	4.7	4.3	3.1	6.0	-48.7%
Total Inorganic Carbon	10^6 lbs.	35.9	48.8	70.5	42.1	52.7	51.8	46.5	35.3	52.2	42.3	47.3	31.8	47.8	-33.5%
Total Kjeldahl Nitrogen-N	10^6 lbs.	4.2	3.7	4.2	3.6	4.2	3.3	4.1	4.0	4.8	3.4	2.3	2.0	3.8	-47.5%
Ammonia-N	10^6 lbs.	3.4	2.4	3.1	2.7	3.1	2.4	3.0	3.3	3.4	2.5	1.4	1.3	2.8	-51.9%
Nitrate-N	10^6 lbs.	1.11	1.51	1.56	0.98	0.89	0.96	1.03	0.65	1.16	1.05	2.18	1.4	1.2	18.7%
Nitrite-N	10^6 lbs.	0.19	0.13	0.13	0.18	0.13	0.11	0.12	0.09	0.10	0.14	0.12	0.1	0.1	-24.7%
Total Phosphorus	10^6 lbs.	-	-	0.28	0.19	0.16	0.19	0.19	0.13	0.23	0.11	0.16	0.12	0.18	-36.6%
Soluble Reactive P	10^6 lbs.	0.144	0.111	0.068	0.051	0.040	0.039	0.067	0.034	0.054	0.029	0.027	0.022	0.060	-63.6%
Silica	10^6 lbs.	4.0	5.5	7.2	6.0	5.8	5.2	4.9	3.5	5.1	2.4	4.6	4.6	4.9	-7.0%
Calcium	10^6 lbs.	144	151	215	145	162	158	136	107	163	134	132	111	150	-25.7%
Sodium	10^6 lbs.	149	150	200	146	161	176	154	126	182	150	162	174	160	8.9%
Chloride	10^6 lbs.	353	348	512	298	362	405	318	257	335	322	335	309	350	-11.6%
Total Suspended Solids	10^6 lbs.	16.3	48.6	38.4	29.0	25.3	17.4	40.8	14.3	38.7	11.8	35.0	20.1	28.7	-29.9%
Fecal Coliforms	10^9 cells	12.4	12.7	4.7	6.3	9.5	18.9	10.6	8.7	31.4	16.1	12.1	30.3	13.0	132.8%

All loads were calculated using AUTOFLUX. Calculations use the laboratory limit of detection when observations are below that limit. Tributaries included in analysis include Nine Mile Creek, Harbor Brook, Onondaga Creek, Ley Creek, and METRO fully treated.

-: no data available.

TABLE 4-2

AVERAGE CONCENTRATION OF CONSTITUENTS, ONONDAGA LAKE TRIBUTARIES, 1999

Onondaga Lake 1999 Annual Report

Onondaga County, New York

Parameter	Units	Nine Mile Creek	Harbor Brook	Onondaga Creek	Ley Creek	Trib. 5A
pH	std units	7.74	7.69	7.69	7.50	7.85
Temperature	° C	10.22	10.12	9.26	11.44	16.99
Specific Conductance	µmho/cm	2913	2208	3699	1576	1763
Dissolved Oxygen (Field)	mg/l	10.15	9.35	10.50	8.83	6.53
5-day BOD	mg/l	2.04	2.93	2.45	2.48	2.41
Total Alkalinity	mg/l	193	240	214	203	138
Total Organic Carbon	mg/l	2.6	2.5	2.5	5.9	3.8
TOC-filtered	mg/l	2.4	2.3	2.3	5.5	3.6
Total Inorganic Carbon	mg/l	48.0	62.8	54.6	52.5	33.9
Total Kjeldahl Nitrogen as N	mg/l	0.77	0.61	0.48	0.98	0.60
Organic Nitrogen as N	mg/l	0.28	0.42	0.33	0.49	0.40
Ammonia as N	mg/l	0.50	0.19	0.15	0.49	0.20
Nitrate as N	mg/l	0.77	1.26	0.74	0.35	1.6
Nitrite as N	mg/l	0.04	0.02	0.020	0.03	0.04
Arsenic	µg/l	<2	2	2	2	2
Cyanide	µg/l	<2	2	<2	8.5	<2
Total Phosphorus	µg/l	47	85	58	92	163
Soluble Reactive Phosphorus	µg/l	3	18	7	14	81
Silica	mg/l	4.5	5.4	5.2	6.1	7.1
Calcium	mg/l	335	247	135	115	134
Sodium	mg/l	198	169	603	155	185
Sulfate	mg/l	299	463	219	159	147
Chloride	mg/l	684	308	977	271	372
Total Dissolved Solids	mg/l	2072	1440	2150	897	1096
Total Suspended Solids	mg/l	17.0	31.7	27.2	30.0	9.1
Cadmium	µg/l	0.4	0.4	0.4	0.6	0.9
Chromium	µg/l	0.8	1.4	1.1	2.9	24.1
Copper	µg/l	6.9	6.9	6.7	5.5	12.3
Iron	mg/l	0.79	0.81	1.13	1.3	0.78
Lead	µg/l	7.8	7.2	6.0	6.9	4.2
Magnesium	mg/l	39.0	42.4	28.8	23.7	15.5
Manganese	µg/l	70.1	28.5	39.8	133.6	65.7
Nickel	µg/l	5.3	6.4	3.3	2.8	111.0
Potassium	mg/l	8.5	2.8	3.9	3.6	4.6
Zinc	µg/l	6.6	17.9	8.7	20.1	20.5
Phenol	µg/l	22.3	16.5	16.5	13.5	17.8
Fecal Coliforms	cells/100ml	390	705	1412	551	43
Flow - Daily Record Mean	cfs	99	7	120	29	ND
Flow - Sample Date Mean	cfs	111	9	154	39	3

1) METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values are based on data collected biweekly from January 5 to December 21.

2) Flows for Trib. 5A and East Flume are estimated from available data.

NA = not monitored or analyzed in 1999. ND= no data. METRO flow was by-passed on 68 days during 1999.

Calculations use the laboratory limit of detection when observations were below that limit.

TABLE 4-2 (continued)

AVERAGE CONCENTRATION OF CONSTITUENTS, ONONDAGA LAKE TRIBUTARIES, 1999

Onondaga Lake 1999 Annual Report

Onondaga County, New York

Parameter	Units	METRO Effluent [1]	METRO By-Pass	East Flume	Lake Outlet-2ft	Lake Outlet-12ft
pH	std units	NA	NA	8.4	7.7	7.8
Temperature	° C	NA	NA	12.8	12.3	11.8
Specific Conductance	µmho/cm	1655	1744	2331	1780	2246
Dissolved Oxygen (Field)	mg/l	NA	NA	7.2	9.9	9.3
5-day BOD	mg/l	13.1	62	4.0	2.7	2.8
Total Alkalinity	mg/l	165	185	164	144	151
Total Organic Carbon	mg/l	10.9	19.0	6.2	4.5	4.4
TOC-filtered	mg/l	9.3	14.9	5.7	4.1	4.1
Total Inorganic Carbon	mg/l	43	49	39	36	37
Total Kjeldahl Nitrogen as N	mg/l	8.4	17.4	2.2	1.3	1.7
Organic Nitrogen as N	mg/l	2.2	4.5	0.92	0.51	0.60
Ammonia as N	mg/l	6.2	11.8	1.3	0.8	1.1
Nitrate as N	mg/l	5.1	1.01	3.0	1.0	1.3
Nitrite as N	mg/l	0.4	0.14	1.3	0.1	0.13
Arsenic	µg/l	<2	NA	6.8	2.0	<2
Cyanide	µg/l	5.0	NA	5.3	<2	<2
Total Phosphorus	µg/l	369	1,522	219	87	95
Soluble Reactive Phosphorus	µg/l	104	54	101	40	45
Silica	mg/l	5.0	6.1	13.1	2.4	2.2
Calcium	mg/l	118	83	113	111	140
Sodium	mg/l	219	311	331	180	250
Sulfate	mg/l	181	132	344	144	180
Chloride	mg/l	342	481	431	346	498
Total Dissolved Solids	mg/l	1094	1181	1402	931	1296
Total Suspended Solids	mg/l	8.1	58.3	12.3	2.9	3.5
Cadmium	µg/l	0.3	NA	0.4	0.6	0.5
Chromium	µg/l	1.2	NA	1.6	0.7	0.5
Copper	µg/l	7.2	NA	4.2	2.7	2.4
Iron	mg/l	0.79	4.63	0.47	0.14	0.10
Lead	µg/l	2.9	NA	4.3	3.7	3.3
Magnesium	mg/l	17.6	15.6	24.0	20.4	23.7
Manganese	µg/l	49.0	62.4	15.6	22.5	25.1
Nickel	µg/l	12.8	NA	6.4	5.8	6.1
Potassium	mg/l	11.8	NA	14.6	4.1	5.4
Zinc	µg/l	25.5	NA	19.5	12.2	8.4
Phenol	µg/l	17.3	NA	17.8	13.8	11.0
Fecal Coliforms	cells/100ml	14,028	170,000	647	76	NA
Flow - Daily Record Mean	cfs	85	9	ND	ND	ND
Flow - Sample Date Mean	cfs	99	11	0.22	ND	ND

1) METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values are based on data collected biweekly from January 5 to December 21.

2) Flows for Trib. 5A and East Flume are estimated from available data.

NA = not monitored or analyzed in 1999. ND= no data. METRO flow was by-passed on 68 days during 1999.

Calculations use the laboratory limit of detection when observations were below that limit.

TABLE 4-3

FLOW-WEIGHTED AVERAGE LIMNOLOGICAL PARAMETERS IN ONONDAGA LAKE TRIBUTARIES AND STANDARD ERROR OF ESTIMATE, USING AUTOFLUX

Onondaga Lake 1999 Annual Report

Onondaga County, New York

Parameter	Units	Nine Mile Creek		Harbor Brook		Onondaga Creek @ Kirpatrick Street		Ley Creek	
		Concentration	+/- error	Concentration	+/- error	Concentration	+/- error	Concentration	+/- error
5-day BOD		2.0	6.7%	3.0	13.4%	2.4	12.8%	3.0	
Total Alkalinity		182	3.9%	217	6.5%	187	6.5%	175	
Total Organic Carbon		3.1	8.4%	2.8	5.8%	3.0	7.5%	6.3	
TOC-filtered		2.9	7.8%	2.5	6.1%	2.8	8.4%	5.9	
Total Inorganic Carbon		45.8	4.1%	56.7	6.6%	47.6	6.3%	44.8	
Total Kjeldahl Nitrogen as N		0.70	9.2%	0.64	8.3%	0.60	11.0%	0.93	
Organic Nitrogen as N		0.32	21.7%	0.50	12.5%	0.51	13.8%	0.55	
Ammonia as N		0.37	9.2%	0.17	13.5%	0.15	15.5%	0.41	
Nitrate as N		0.97	12.0%	1.32	11.3%	0.90	10.4%	0.44	
Nitrite as N		0.03	11.3%	0.02	9.2%	0.04	29.8%	0.03	
Arsenic		2	0.0%	2	0.0%	2	0.0%	2	
Total Cyanide		2	0.0%	2	0.0%	2	0.0%	8.6	
Total Phosphorus		58.2	21.3%	99.2	15.5%	91.7	20.5%	93.2	
Soluble Reactive Phosphorus		9.7	45.7%	19.2	14.6%	10.7	21.3%	19.1	
Silica		4.5	6.9%	5.0	5.6%	5.5	8.8%	5.5	
Calcium		255	6.8%	210	6.4%	104	6.5%	97	
Sodium		152	15.0%	152	15.0%	369	9.9%	161	
Sulfate		221	6.6%	377	6.2%	143	9.6%	119	
Chloride		490	7.2%	258	10.7%	528	9.7%	253	
Total Suspended Solids		19	19.2%	35	25.0%	47	30.9%	52	
Total Dissolved Solids		1514	6.9%	1252	7.6%	1393	8.4%	829	
Zinc		5.4	18.2%	22.7	20.6%	8.6	16.9%	19.8	
Copper		8.3	14.7%	11.1	36.4%	5.9	9.2%	6.3	
Chromium		0.9	9.1%	0.2	37.2%	0.6	12.2%	3.8	
Cadmium		0.5	6.3%	0.5	7.1%	0.4	0.0%	0.7	
Lead		6.2	17.6%	7.9	9.1%	7.0	12.5%	6.1	
Iron		0.9	14.4%	1.2	33.7%	2.4	35.0%	2.1	
Magnesium		31.6	5.1%	36.5	5.8%	22.8	5.3%	19.4	
Manganese		60.9	6.9%	30.9	15.9%	74.8	26.7%	141.6	
Nickel		9.9	33.0%	11.5	44.0%	2.5	0.0%	3.1	
Phenol		27.8	19.2%	15.5	20.4%	14.9	37.3%	13.8	
Fecal Coliforms		303	37.0%	5,569	47.3%	4,436	39.5%	2,338	

CV = standard error of the concentration estimate. ** METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values are based on data collected bi-weekly from January 5 to December 21.

NA = not monitored or analyzed in 1999.

* = were not evaluated using FLUX since most observations were below the limit of detection.

Calculations use the laboratory limit of detection when observations were below that limit. See Table 4-4.

TABLE 4-3 (CONTINUED)

FLOW-WEIGHTED AVERAGE LIMNOLOGICAL PARAMETERS IN ONONDAGA LAKE TRIBUTARIES AND STANDARD ERROR OF ESTIMATE, USING AUTOFLUX

Onondaga Lake 1999 Annual Report

Onondaga County, New York

Parameter	Units	Trib. 5A		METRO Effluent **		METRO By-Pass		East Flume	
		Concentration	+/- error	Concentration	+/- error	Concentration	+/- error	Concentration	+/- error
5-day BOD	mg/l	2.4	8.2%	13.1	2.2%	49.6	7.3%	4.6	9.2%
Total Alkalinity	mg/l	138	2.0%	163	4.8%	189	11.1%	162	4.2%
Total Organic Carbon	mg/l	3.9	2.5%	10.9	3.3%	14.1	12.9%	6.0	4.5%
TOC-filtered	mg/l	3.6	2.8%	9.3	4.9%	11.6	10.1%	5.4	3.8%
Total Inorganic Carbon	mg/l	33.9	2.4%	41.9	5.2%	52.5	12.2%	36.9	5.8%
Total Kjeldahl Nitrogen as N	mg/l	0.59	14.2%	8.60	3.3%	12.86	10.8%	2.27	8.2%
Organic Nitrogen as N	mg/l	0.40	21.8%	2.17	7.6%	3.73	21.9%	0.91	10.1%
Ammonia as N	mg/l	0.20	9.9%	6.37	4.2%	7.77	16.5%	1.37	11.5%
Nitrate as N	mg/l	1.63	11.3%	5.14	13.8%	2.13	25.4%	3.06	8.1%
Nitrite as N	mg/l	0.04	10.4%	0.44	12.0%	0.11	16.8%	1.40	8.1%
Arsenic	ug/l	2	0.0%	2	0.0%	2.5	20.2%	6.2	14.3%
Total Cyanide	ug/l	2	0.0%	5.5	48.0%	10.4	47.7%	7.3	34.2%
Total Phosphorus	ug/l	79.2	9.3%	371.6	1.7%	1204.9	8.0%	225.5	5.1%
Soluble Reactive Phosphorus	ug/l	73.4	6.8%	84.8	16.8%	28.1	61.4%	111.5	9.9%
Silica	mg/l	7.2	4.4%	5.0	3.3%	6.0	4.3%	12.1	5.4%
Calcium	mg/l	133	2.5%	117	12.9%	200	25.8%	106	4.2%
Sodium	mg/l	183	4.6%	219	13.7%	342	18.8%	362	8.6%
Sulfate	mg/l	143	13.4%	179	2.9%	112	8.5%	298	7.2%
Chloride	mg/l	368	2.9%	349	19.6%	720	23.0%	481	8.2%
Total Suspended Solids	mg/l	10	33.7%	8	2.3%	57	6.6%	14	22.5%
Total Dissolved Solids	mg/l	1087	2.9%	1088	10.3%	1640	20.0%	1415	5.8%
Zinc	ug/l	21.5	41.3%	25.5	24.1%	61.6	16.9%	18.4	17.3%
Copper	ug/l	12.6	30.0%	7.8	35.1%	44.7	21.1%	6.2	38.7%
Chromium	ug/l	25.6	44.1%	1.2	16.9%	26.9	48.0%	2.0	34.5%
Cadmium	ug/l	0.9	37.3%	0.4	6.5%	2.0	0.0%	0.5	7.4%
Lead	ug/l	4.4	39.4%	3.0	21.3%	20.0	0.0%	3.6	25.5%
Iron	mg/l	0.8	15.8%	0.8	7.2%	4.5	21.5%	0.5	35.5%
Magnesium	mg/l	15.4	2.8%	17.5	2.9%	19.5	16.2%	21.7	5.8%
Manganese	ug/l	69.9	12.1%	48.9	6.9%	75.3	6.4%	17.6	15.6%
Nickel	ug/l	112.5	20.6%	12.9	16.0%	25.3	9.8%	10.3	47.5%
Phenol	ug/l	18.4	33.2%	17.7	24.7%	10.0	0.0%	20.0	20.2%
Fecal Coliforms	cells/100ml	45	31.8%	2,536	33.7%	***	43%	825	29.6%

CV = standard error of the concentration estimate. ** METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values are based on data collected bi-weekly from January 5 to December 21.

NA = not monitored or analyzed in 1999.

* = were not evaluated using FLUX since most observations were below the limit of detection.

Calculations use the laboratory limit of detection when observations were below that limit. See Table 4-4.

TABLE 4-4

FREQUENCY OF TOTAL TRIBUTARY OBSERVATIONS BELOW THE LABORATORY LIMIT OF DETECTION, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

	Ninemile Creek at Rt. 48 <LOD : Total#	Harbor Brook at Hiawatha <LOD : Total#	Onondaga Creek at Kirpatrick <LOD : Total#	Ley Creek at Park Street <LOD : Total#	Trib. 5A at Crucible <LOD : Total#	East Flume at Allied <LOD : Total#
5-day BOD	25 : 28	21 : 29	26 : 29	19 : 27	22 : 29	7 : 29
Total Kjeldahl N	0 : 28	1 : 29	0 : 29	0 : 27	0 : 29	0 : 29
Organic Nitrogen-N	4 : 28	26 : 29	2 : 29	0 : 27	4 : 29	1 : 29
Ammonia-N	0 : 28	5 : 29	8 : 29	0 : 27	3 : 29	0 : 29
Nitrate-N	0 : 28	0 : 29	8 : 29	0 : 27	0 : 29	0 : 29
Nitrite-N	0 : 28	2 : 29	9 : 29	0 : 27	1 : 29	0 : 29
Arsenic	4 : 4	3 : 4	3 : 4	3 : 4	2 : 4	0 : 4
Total Cyanide	4 : 4	3 : 4	4 : 4	0 : 4	4 : 4	0 : 4
Soluble Reactive Phosphorus	5 : 22	1 : 22	1 : 22	0 : 22	0 : 22	0 : 22
Total Dissolved Solids	0 : 28	0 : 30	0 : 29	0 : 27	0 : 29	0 : 29
Total Suspended Solids	0 : 28	1 : 30	1 : 29	0 : 27	1 : 29	1 : 29
Copper	0 : 4	0 : 4	0 : 4	0 : 4	0 : 4	0 : 4
Chloride	0 : 28	0 : 30	0 : 29	0 : 27	0 : 29	0 : 29
Chromium	0 : 4	1 : 4	2 : 4	0 : 4	0 : 4	2 : 4
Cadmium	0 : 4	4 : 4	4 : 4	3 : 4	2 : 4	3 : 4
Calcium	0 : 28	0 : 29	0 : 29	0 : 27	0 : 29	0 : 29
Manganese	0 : 28	4 : 29	4 : 29	0 : 27	0 : 29	14 : 29
Mercury	3 : 4	4 : 5	3 : 4	3 : 4	3 : 4	3 : 4
Lead	0 : 4	0 : 4	0 : 4	0 : 4	0 : 4	0 : 4
Nickel	1 : 4	3 : 4	3 : 4	1 : 4	0 : 4	2 : 4
Phenol	2 : 4	1 : 4	2 : 4	2 : 4	2 : 4	2 : 4
Fecal Coliform	2 : 28	4 : 24	3 : 28	1 : 27	8 : 29	1 : 29

TABLE 4-5

CONCENTRATIONS OF MAJOR IONS IN NINE MILE CREEK AND ONONDAGA CREEK WATERS

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Ions	Onondaga Creek		Nine Mile Creek	
	Concentration (meq/l)	Percent Contribution	Concentration (meq/l)	Percent Contribution
Cations				
Ca^{2+}	6.1	19.8	14.7	57.2
Na^{+}	2.3	7.5	3	11.7
Mg^{2+}	22.3	72.4	7.8	30.4
K^{+}	0.1	0.3	0.2	0.8
Anions				
Cl^{-}	4.1	12.9	5.5	20.5
HCO_3^{-}	23.3	73.3	17.4	64.9
SO_4^{2-}	4.4	13.8	3.9	14.6

TABLE 4-6

TOTAL ANNUAL TRIBUTARY LOADINGS TO ONONDAGA LAKE, 1999,
AND STANDARD ERROR OF ESTIMATE, USING AUTOFLUX

Onondaga Lake 1999 Annual Report
Onondaga County, New York

		Nine Mile Creek		Harbor Brook		Onondaga Creek @Kirkpatrick Street		Ley Creek	
Parameter	**Units**	Load	*+/- error*	Load	*+/- error*	Load	*+/- error*	Load	*+/- error*
5-day BOD	lbs.	392,860	*0.7%*	43,070	*13.4%*	570,125	*12.8%*	166,583	*19.3%*
Total Alkalinity	lbs.	35,450,344	*3.9%*	3,158,960	*6.5%*	44,361,825	*6.5%*	9,875,839	*7.4%*
Total Organic Carbon	lbs.	602,548	*8.4%*	40,214	*6.6%*	712,619	*7.5%*	356,393	*4.3%*
TOC-filtered	lbs.	567,986	*7.8%*	36,851	*6.1%*	667,650	*8.4%*	334,626	*4.3%*
Total Inorganic Carbon	lbs.	8,928,962	*4.1%*	826,101	*6.6%*	11,311,880	*6.3%*	2,527,645	*7.7%*
Total Kjeldahl N	lbs.	135,660	*9.2%*	9,345	*8.3%*	142,550	*11.0%*	52,382	*5.9%*
Organic Nitrogen-N	lbs.	62,936	*21.7%*	7,238	*12.5%*	120,561	*13.8%*	31,189	*10.0%*
Ammonia-N	lbs.	72,724	*9.2%*	2,508	*13.5%*	35,391	*15.5%*	23,127	*7.5%*
Nitrate-N	lbs.	189,220	*12.0%*	19,300	*11.3%*	214,555	*10.7%*	24,791	*12.0%*
Nitrite-N	lbs.	6,534	*11.3%*	283	*9.2%*	9,218	*29.8%*	1,874	*9.7%*
Arsenic	lbs.	390	*0.0%*	29	*6.5%*	475	*0.0%*	113	*0.0%*
Total Cyanide	lbs.	390	*0.0%*	29	*0.0%*	475	*0.0%*	483	*17.2%*
Total Phosphorus-P	lbs.	11,358	*21.3%*	1,445	*15.5%*	21,758	*20.5%*	5,254	*12.4%*
Soluble Reactive P	lbs.	1,894	*45.7%*	279	*14.6%*	2,545	*21.3%*	1,074	*10.5%*
Silica	lbs.	874,723	*6.9%*	727,423	*5.6%*	1,294,336	*8.8%*	308,349	*8.1%*
Calcium	lbs.	49,658,395	*6.8%*	6,059,087	*6.5%*	24,772,634	*6.5%*	5,460,858	*5.1%*
Sodium	lbs.	29,868,625	*15.0%*	2,222,262	*6.4%*	87,554,336	*9.9%*	9,087,094	*10.9%*
Sulfate	lbs.	43,209,750	*6.6%*	5,493,515	*6.2%*	33,921,981	*9.6%*	6,715,724	*7.9%*
Chloride	lbs.	95,598,079	*7.2%*	3,762,041	*10.7%*	125,287,832	*9.7%*	14,297,950	*10.7%*
Total Dissolved Solids	lbs.	295,284,820	*6.9%*	18,254,043	*7.6%*	330,727,864	*8.4%*	46,724,775	*8.5%*
Total Suspended Solids	lbs.	3,691,351	*19.2%*	505,220	*25.0%*	11,076,662	*30.9%*	2,943,564	*50.6%*
Cadmium	lbs.	90.9	*6.3%*	6	*7.1%*	95	*0.0%*	42	*27.8%*
Chromium	lbs.	177.9	*9.1%*	31	*37.2%*	136	*12.2%*	216	*19.3%*
Copper	lbs.	1,618.5	*14.7%*	162	*36.4%*	1,398	*9.2%*	354	*11.8%*
Iron	lbs.	174,258	*14.4%*	17,660	*33.7%*	560,585	*5.3%*	116,721	*53.5%*
Lead	lbs.	1,219	*17.6%*	116	*9.1%*	1,651	*12.5%*	346	*31.2%*
Magnesium	lbs.	6,161,225	*5.1%*	531,465	*5.8%*	5,416,322	*5.3%*	1,093,657	*7.5%*
Manganese	lbs.	11,872	*6.9%*	450	*15.9%*	17,769	*26.7%*	7,984	*17.7%*
Nickel	lbs.	1,923	*33.0%*	167	*44.0%*	593	*0.0%*	176	*19.3%*
Potassium	lbs.	1,180,805	*31.1%*	38,824	*4.4%*	1,026,106	*12.3%*	179,313	*15.7%*
Zinc	lbs.	1,060	*18.2%*	331	*20.6%*	2,043	*16.9%*	1,118	*8.4%*
Phenol	lbs.	5,431	*19.2%*	225	*20.4%*	3,541	*37.3%*	3,541	*37.3%*
Fecal Coliforms	10^9 cells	268,499	*37.0%*	368,115	*47.3%*	4,776,237	*39.5%*	597,977	*45.3%*

error = standard error of the loading estimate. ** METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values based on data collected bi-weekly from January 5 to December 21. NA = not monitored or analyzed in 1999.

TABLE 4-6 (continued)

TOTAL ANNUAL TRIBUTARY LOADINGS TO ONONDAGA LAKE, 1999,
AND STANDARD ERROR OF ESTIMATE, USING AUTOFLUX

Onondaga Lake 1999 Annual Report
Onondaga County, New York

		Trib. 5A		METRO Effluent **		METRO By-Pass		East Flume	
Parameter	Units	Load	+/- error	Load	+/- error	Load	+/- error	Load	+/- error
5-day BOD	lbs.	13,758	8.2%	2,404,688	2.2%	253,253	7.3%	2,159	9.2%
Total Alkalinity	lbs.	780,258	2.0%	29,896,118	4.8%	963,913	11.1%	76,382	4.2%
Total Organic Carbon	lbs.	21,788	2.5%	1,991,978	3.3%	72,244	12.9%	2,835	4.5%
TOC-filtered	lbs.	20,447	2.8%	1,704,408	4.9%	59,191	10.1%	2,571	3.8%
Total Inorganic Carbon	lbs.	191,498	2.4%	7,685,931	5.2%	268,250	12.2%	17,440	5.8%
Total Kjeldahl N	lbs.	3,357	14.2%	1,576,358	3.3%	65,707	10.8%	1,074	8.2%
Organic Nitrogen-N	lbs.	2,235	21.8%	396,963	7.6%	19,349	27.6%	429	10.1%
Ammonia-N	lbs.	1,121.9	9.9%	1,166,543	4.2%	39,693	16.5%	645	11.5%
Nitrate-N	lbs.	9,174	12.0%	941,441	13.8%	9,038	42.0%	1,446	8.1%
Nitrite-N	lbs.	238.2	10.4%	81,045	12.0%	582	24.4%	664	8.1%
Arsenic	lbs.	11.27	0.0%	366	0.0%	12.9	20.2%	3.22	14.3%
Total Cyanide	lbs.	11.27	0.0%	1,011	48.0%	53	47.7%	3.22	34.2%
Total Phosphorus-P	lbs.	910.3	6.0%	68,095	1.7%	6,158	8.0%	106	5.1%
Soluble Reactive P	lbs.	414.48	6.8%	15,544	16.8%	143	61.4%	52.3	9.9%
Silica	lbs.	407,615	4.4%	924,925	3.3%	30,892	4.3%	5,707	5.4%
Calcium	lbs.	750,303	2.5%	21,409,882	12.9%	1,022,434	25.8%	50,013	4.2%
Sodium	lbs.	1,034,401	4.6%	40,052,881	13.7%	1,749,723	18.8%	17,115	8.6%
Sulfate	lbs.	806,999	13.4%	32,821,182	2.9%	573,070	8.5%	140,852	7.2%
Chloride	lbs.	2,076,923	2.9%	63,893,351	19.6%	3,680,210	23.0%	227,203	8.2%
Total Dissolved Solids	lbs.	1,034,401	4.6%	199,308,956	10.3%	8,381,600	20.0%	668,783	5.8%
Total Suspended Solids	lbs.	58,032	33.7%	1,544,858	2.3%	292,754	6.6%	6,469	22.5%
Cadmium	lbs.	4.829	37.3%	79	6.5%	10	0.0%	0.00	7.4%
Chromium	lbs.	144.1	44.1%	223	6.5%	138	48.0%	0.80	38.7%
Copper	lbs.	71.6	30.0%	1,421	35.1%	229	21.1%	3.2	38.7%
Iron	lbs.	4,592	15.8%	144,214	7.2%	23,235	21.5%	254	35.5%
Lead	lbs.	24.9	39.4%	556	21.3%	102	0.0%	1.6	25.5%
Magnesium	lbs.	87,090	2.8%	3,839,391	4.0%	99,647	16.2%	10,257	5.8%
Manganese	lbs.	428.9	5.4%	8,967	6.9%	385	6.4%	8.0	15.6%
Nickel	lbs.	635.0	20.6%	2,369	16.0%	130	9.8%	4.8	47.5%
Potassium	lbs.	25,687	18.2%	2,136,258	21.0%	NA		6,649	5.6%
Zinc	lbs.	120.7	61.6%	4,677	24.1%	315	16.9%	8.9	17.3%
Phenol	lbs.	103.82	33.2%	3,247	24.7%	51	0.0%	7.2	20.2%
Fecal Coliforms	10^9 cells	1,142	31.8%	2,107,116	33.7%	22,170,330	42.5%	1,767	29.6%

error = standard error of the loading estimate. ** METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values based on data collected bi-weekly from January 5 to December 21. NA = not monitored or analyzed in 1999.

TABLE 4-7

TRIBUTARY LOADING, PERCENT OF TOTAL CONTRIBUTION TO ONONDAGA LAKE, 1999

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Onondaga County, New York

Parameter	Nine Mile Creek % of Annual Load	Harbor Brook % of Annual Load	Onondaga Creek % of Annual Load	Ley Creek % of Annual Load
5-day BOD	10.2	1.1	14.8	4.3
Total Alkalinity	28.5	2.5	35.6	7.9
Total Organic Carbon	15.9	1.1	18.8	9.4
TOC-filtered	18.6	1.2	21.8	0.0
Total Inorganic Carbon	28.1	2.6	35.6	8.0
Total Kjeldahl Nitrogen as N	6.8	0.5	7.2	2.6
Organic Nitrogen as N	9.8	1.1	18.8	4.9
Ammonia as N	5.4	0.2	2.6	1.7
Nitrate as N	13.4	1.4	15.2	1.8
Nitrite as N	6.5	0.3	9.2	1.9
Arsenic	28.1	2.1	34.2	8.1
Total Cyanide	16.2	1.2	19.8	20.1
Total Phosphorus as P	9.8	1.3	18.9	4.6
Soluble Reactive Phosphorus	8.6	1.3	11.6	4.9
Silica	19.1	15.9	28.3	6.7
Calcium	44.7	5.5	22.3	6.7
Sodium	17.2	1.3	50.4	6.5
Sulfate	34.9	4.4	27.4	5.4
Chloride	31.0	1.2	40.6	4.6
Total Dissolved Solids	32.8	2.0	36.7	5.2
Total Suspended Solids	18.4	2.5	55.1	14.6
Cadmium	28.6	2.0	29.9	13.2
Chromium	19.2	3.4	14.6	23.2
Copper	30.8	3.1	26.6	6.7
Iron	17.1	1.7	55.1	11.5
Lead	30.3	2.9	41.1	8.6
Magnesium	35.7	3.1	31.4	6.3
Manganese	25.0	1.0	37.4	16.8
Nickel	32.8	2.9	10.1	3.0
Potassium	25.7	0.8	22.3	3.9
Zinc	12.7	4.0	24.4	1.4
Phenol	33.6	1.4	21.9	21.9
Fecal Coliforms	0.9	1.2	15.8	2.0
Flow	**31.0%**	**2.3%**	**37.8%**	**9.0%**

** METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values based on data collected bi-weekly from January 5 to December 21. Calculations use the laboratory limit of detection when observations were below that limit.

*[illegible]

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TABLE 4-7 (cont.)

TRIBUTARY LOADING, PERCENT OF TOTAL CONTRIBUTION TO ONONDAGA LAKE, 1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Trib. 5A % of Annual Load	METRO Effluent ** % of Annual Load	METRO By-Pass % of Annual Load	East Flume % of Annual Load
5-day BOD	0.36	62.5	6.6	0.06
Total Alkalinity	0.63	24.0	0.8	0.06
Total Organic Carbon	0.57	52.4	1.9	0.07
TOC-filtered	0.67	55.7	1.9	0.08
Total Inorganic Carbon	0.60	24.2	0.8	0.05
Total Kjeldahl Nitrogen as N	0.17	79.4	3.3	0.05
Organic Nitrogen as N	0.35	61.9	3.0	0.07
Ammonia as N	0.08	86.9	3.0	0.05
Nitrate as N	0.65	66.8	0.6	0.10
Nitrite as N	0.24	80.7	0.6	0.66
Arsenic	0.81	26.4	0.9	0.23
Total Cyanide	0.47	42.1	2.2	0.13
Total Phosphorus as P	0.79	59.2	5.4	0.09
Soluble Reactive Phosphorus	1.89	70.8	0.7	0.24
Silica	8.91	20.2	0.7	0.12
Calcium	0.68	19.3	0.9	0.05
Sodium	0.60	23.1	1.0	0.01
Sulfate	0.65	26.5	0.5	0.11
Chloride	0.67	20.7	1.2	0.07
Total Dissolved Solids	0.11	22.1	0.9	0.07
Total Suspended Solids	0.29	7.7	1.5	0.03
Cadmium	1.52	24.8	3.3	0.00
Chromium	15.51	24.0	14.8	0.09
Copper	1.36	27.0	4.4	0.06
Iron	0.45	14.2	2.3	0.02
Lead	0.62	13.9	2.6	0.04
Magnesium	0.51	22.3	0.6	0.06
Manganese	0.90	18.9	0.8	0.02
Nickel	10.82	40.4	2.2	0.08
Potassium	0.56	46.5	NA	0.14
Zinc	1.44	56.0	3.8	0.11
Phenol	0.64	20.1	0.3	0.04
Fecal Coliforms	0.004	7.0	73.2	0.01
Flow	**0.5%**	**18.8%**	**0.5%**	**0.1%**

** METRO BOD5, NH3-N, TP, TSS based on observations made daily, METRO TKN based on observations made 5 times each 2 week period. Other values based on data collected bi-weekly from January 5 to December 21. Calculations use the laboratory limit of detection when observations were below that limit.

TABLE 4-8

REGULATORY COMPLIANCE IN ONONDAGA LAKE TRIBUTARIES, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

NM=Nine Mile Creek, OC=Onondaga Creek, LC=Ley Creek, HB=Harbor Brook, 5A=Trib 5A, and EF=East Flume.

Parameter (units)	NYSDEC Standard (Class C)	Average of 1999 measured concentrations	Observations in Compliance
pH (standard units)	Shall not be less than 6.5 nor more than 8.5	NM : 7.7 OC : 7.7 LC : 7.5 HB : 7.7 5A : 7.9 EF : 8.4	96% 100% 100% 100% 97% 52%
Dissolved Oxygen (mg/l)	Minimum daily average 5.0 mg/l, at no time shall DO be < 4.0 mg/l	NM : 10.1 OC : 10.5 LC : 8.8 HB : 9.4 5A : 6.6 EF : 7.2	100%>4, 100%>5 100%>4, 100%>5 96%>4, 96%>5 97%>4, 90%>5 97%>4, 83%>5 76%>4, 72%>5
Fecal Coliform [3] (cells/100 ml)	Percent individual observations > 200 cells. *See footnote*	NM : 390 OC : 1412 LC : 551 HB: 705 5A : 43 EF : 647	75% 18% 48% 42% 93% 62%
Ammonia-N (mg/l)	Varies with pH and temperature.	NM : 0.50 OC : 0.15 LC : 0.49 HB : 0.19 5A : 0.20 EF : 1.34	100% 100% 100% 100% 96% 17%
Arsenic * [1] (µg/l)	190 µg/l	NM : <2 OC : <2 LC : <2 HB : <2 5A : <2 EF : 6.8	100% 100% 100% 100% 100% 100%

TABLE 4-8 (continued)

NM=Nine Mile Creek, OC=Onondaga Creek, LC=Ley Creek, HB=Harbor Brook, 5A=Trib 5A, and EF=East Flume.

Parameter (units)	NYSDEC Standard (Class C)	Average of 1999 measured concentrations	Observations in Compliance
Cyanide * [1] (µg/l)	5.2 µg/l (Free CN)	NM : 2.0	100%
		OC : 2.0	100%
		LC : 8.5	75%
		HB : 2.0	100%
		5A : 2.0	100%
		EF : 5.3	75%
Nitrite-N (µg/l)	100 µg/l (Warm water fishery)	NM : 42.5	96%
		OC : 20.0	97%
		LC : 31.9	100%
		HB : 21.7	100%
		5A : 40.7	97%
		EF : 1,322	0%
Copper * (µg/l)	0.96 exp (0.8545 [ln (ppm hardness)] - 1.702) Standard Range (µg/l):		
	NM: 23.5-26.1	NM : 6.9	100%
	OC: 14.7-26.1	OC : 6.7	100%
	LC: 7.8-26.1	LC : 5.5	100%
	HB: 18.9-26.1	HB : 6.9	100%
	5A: 21.3-26.1	5A : 12.3	100%
	EF: 13.7-26.1	EF : 4.2	100%
Mercury * (µg/l)	2 µg/l	NM : 0.2	100%
		OC : 0.2	100%
		LC : 0.2	100%
		HB : 0.6	80%
		5A : 0.2	100%
		EF : 0.2	100%
Lead * (µg/l)	(1.46203 - [ln (hardness) 0.145712]) exp (1.273 [ln (hardness)] - 4.297) Standard Range (µg/l):		
	NM: 12.3-14.3	NM : 7.8	100%
	OC: 6.1-14.3	OC : 6.0	100%
	LC: 2.4-14.3	LC : 6.9	100%
	HB: 8.8-14.3	HB : 7.2	100%
	5A: 10.6-14.3	5A : 4.2	100%
	EF: 5.5-14.3	EF : 2.9	100%

TABLE 4-8 (continued)

NM=Nine Mile Creek, OC=Onondaga Creek, LC=Ley Creek, HB=Harbor Brook, 5A=Trib 5A, and EF=East Flume.

Parameter (units)	NYSDEC Standard (Class C)	Average of 1999 measured concentrations	Observations in Compliance
Cadmium * (µg/l)	0.85 exp (0.7852 [ln (ppm hardness)] - 2.715)		
	Standard Range (µg/l):		
	NM: 5.1-5.6	NM : 0.43	100%
	OC: 3.3-5.6	OC : 0.43	100%
	LC: 1.9-5.6	LC : 0.55	100%
	HB: 4.2-5.6	HB : 0.43	100%
	5A: 4.6-5.6	5A : 0.90	100%
	EF: 3.1-5.6	EF : 0.43	100%
Zinc *(1) (µg/l)	exp (0.85 [ln (ppm hardness)] + 0.50)		
	Standard Range (µg/l):		
	NM: 216-240	NM : 6:6	100%
	OC: 135-240	OC : 8.7	100%
	LC: 72-240	LC : 20.1	100%
	HB: 173-240	HB : 17.9	100%
	5A: 196-240	5A : 20.5	100%
	EF: 126-240	EF : 25.5	100%
Chromium * (µg/l)	0.86 exp (0.819 [ln (ppm hardness)] + 1.561)		
	Standard Range (µg/l):		
	NM: 450-497	NM : 0.8	100%
	OC: 285-497	OC : 1.6	100%
	LC: 157-497	LC : 2.2	100%
	HB: 363-497	HB : 1.1	100%
	5A: 409-497	5A : 11.1	100%
	EF: 267-497	EF : 3.0	100%
Iron (µg/l)	300 µg/l	NM : 790	0%
		OC : 1128	28%
		LC : 1348	7%
		HB : 815	35%
		5A : 777	0%
		EF : 466	69%

TABLE 4-8 (continued)

NM=Nine Mile Creek, OC=Onondaga Creek, LC=Ley Creek, HB=Harbor Brook, 5A=Trib 5A, and EF=East Flume.

Parameter (units)	NYSDEC Standard (Class C)	Average of 1999 measured concentrations	Observations in Compliance
Nickel (µg/l)	0.997 exp (0.846 [ln (ppm hardness)] + 0.0584)		
	Standard Range (µg/l):		
	NM: 135-150	NM : 37.9	100%
	OC: 85-150	OC : 18.8	100%
	LC: 46-150	LC : 15.4	100%
	HB: 109-150	HB : 35.4	100%
	5A: 123-150	5A : 62.5	75%
	EF: 79-150	EF : 22.9	100%

(1) : Standard value applies to dissolved fraction, though currently only acid soluble, total recoverable fraction is measured within the monitoring program. Standard values for all other metals apply to acid soluble, total recoverable fraction.

(2) :Standard values are derived from NYSDEC Ambient Water Quality Standards and Guidance Values, 1993, for Class B and C surface waters and 6NYCRR Part 703, with Jan. 1994 updates for bacteria and zinc; and 1998 updates for metals.

3) :The bacteria data presented compare individual measurements to the standard of 200 cells/100mL. Compliance is assessed as the geometric mean of a minimum of 5 samples a month. Therefore, the table represents the worst case. Compliance would always be greater than or equal to percentages noted.

* Averages derived from observations made during quarterly sampling. All other averages derived from observations made during the bi-weekly sampling program. Calculations use the laboratory limit of detection when observations are below that limit (see Table 3-4).

Compliance calculations are made using a maximum hardness value of 350 ppm, which is the maximum value allowed by NYSDEC for these calculations.

1999 Average Hardness for tributaries (calculated from Ca and Mg concentrations) is as follows (units ppm).
NM-997
OC-456
LC-385
HB-791
SA-399
EF-381

TABLE 4-9

METRO SPDES PERMIT LIMIT EXCEEDANCES, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

SPDES PERMIT LIMITS	TOTALS
FLOW	0
BOD5 (30 Day) Concentration	0
BOD5 (30 Day) Loading	0
BOD5 (7 Day) Concentration	0
BOD5 (7 Day) Loading	0
BOD5 (% Removal)	0
SUSPENDED SOLIDS (30 Day)	0
SUSPENDED SOLIDS (7 Day)	0
FECAL COLIFORM (30 Day)	0
FECAL COLIFORM (7 Day)	0
pH	0
SETTLEABLE SOLIDS	3
T-PHOSPHORUS	0
CYANIDE	0
TOTAL RESIDUAL CHLORINE	0
BYPASS SETTLEABLE SOLIDS	0
CADMIUM	1
LEAD	4
ZINC	0
CBOD (5 Day)	0
TOTAL	**8**

TABLE 4-10

SUMMARY OF TEN YEAR TRENDS IN FLOW-ADJUSTED CONCENTRATION (C) AND LOAD (L)
ONONDAGA LAKE TRIBUTARIES
1990 - 1999 MONITORING DATA

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Metro		Bypass		Allied (East Flume)		Trib 5A (Crucible)		Harbor (Hiawatha)		Ley Creek		Nine Mile		Onondaga Cr. (Kirkpatrick)		Harbor (Velasko)		Onondaga (Dorwin)	
	C	L	C	L	C	L	C	L	C	L	C	L	C	L	C	L	C	L	C	L
T-Alk													D	D	D	D	D		D	D
BOD - 5									I						I	I				
Ca													D	D						
Cl																				
TKN																				
Fecal Coli																				
Na																				I
NH3-N																			I	I
NO_2-N																	D			
NO_3-N	I	I																	I	I
SRP	D	D															D			
TIC													D	D	D	D	D		D	D
TKN																				
TN																			I	I
TOC	D	D										D								
TP	D	D																		
TSS																				

C Flow-adjusted concentration
L Flow-adjusted load
D Decreasing trend based on ten years of data. Probability that trend is due to chance is less than 5%
I Increasing trend based on ten years of data. Probability that trend is due to chance is less than 5%

TABLE 4-11

RESULTS OF WHOLE EFFLUENT TOXICITY TESTING OF METRO EFFLUENT
JANUARY AND APRIL 1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Date	**January 26 - 28**		**April 28- 30**	
Test Organism	*Ceriodaphnia dubia*	*Pimephales promelas*	*Ceriodaphnia dubia*	*Pimephales promelas*
LC_{50}	> 100% effluent	> 100% effluent	> 100% effluent	> 100% effluent
Percent Mortality in 50% Effluent after 48 hrs	0 %	5% (not statistically significant)	0 %	0 %
Percent Mortality in 100% Effluent after 48 hrs	0 %	5% (not statistically significant)	0 %	5 %
Effluent total ammonia, mg/l	0.3		14.2	
Effluent unionized ammonia	0.01		0.54	

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CHAPTER 5

1999 STORM EVENTS

5.1 Introduction: Scope of the Storm Event Monitoring Effort

As part of the Ambient Monitoring Program, Onondaga County is sampling selected tributaries to Onondaga Lake during storms. The storm event program is designed to collect multiple samples at short time intervals during intense rainstorms. The collected data will support efforts to quantify the annual load of pollutants delivered to Onondaga Lake and determine the contribution of stormwater runoff and Combined Sewer Overflows (CSOs) to annual loading.

Onondaga Creek, the largest hydrologic inflow to the lake, is the primary focus of the storm event program. Fifty-three CSOs discharge to the creek and the engineering controls to remediate these discharges are underway. Implementation of all the control actions is phased over the 15-year program of improvements to the wastewater collection and treatment system. Since the CSO-related pollutants are delivered to Onondaga Creek during wet weather, the storm event monitoring program can provide data to document improvements in water quality brought about by the remedial actions.

A limited storm event monitoring program is also being conducted on Harbor Brook and Ley Creek. These tributaries receive CSOs (19 on Harbor Brook and 2 on Ley Creek). The second largest tributary to Onondaga Lake, Nine Mile Creek, does not receive CSOs. Limited storm event monitoring of Nine Mile Creek will help partition phosphorus in stormwater runoff from urban and non-urban sources.

The storm event monitoring program includes sampling during the three-year period from 1999 – 2001 to quantify baseline conditions. Another series of storms will be monitored in 2005 following completion of all interim measures and in 2008 following completion of the Midland Ave. regional treatment facility. A final series of storm event monitoring is scheduled for 2012 following completion of the Clinton St. regional treatment facility. The monitoring schedule may be modified based on any changes to the construction schedule or milestone dates for completing construction.

Stream water quality during a storm event is highly variable. The intensity of rainfall, time since last rainfall, antecedent snowpack, street sweeping practices, farming practices, and a host of other parameters influence the quality of the first flush and the total loading of pollutants from a particular storm. In tributaries with CSOs, water quality during storms is even more variable as it also depends on antecedent condition in the collection system. Mathematical modeling verified by monitoring data is consequently an important tool to predict the effectiveness of stormwater management facilities, particularly for CSOs.

A number of models to estimate storm-related loading and lake response have been developed for this system. Models were used to estimate the effectiveness of the selected improvements to the wastewater collection and treatment system. New York State Department of Environmental Conservation (NYSDEC) plans to convene a technical committee to define additional modeling approaches for the tributaries. The locations, sampling frequency, and parameter list currently in place for the tributary storm event program may be modified once model selection is complete.

Sampling locations are selected to be upstream and downstream of major point and nonpoint sources. CSO discharge points are bracketed. The goal is to initiate sampling within 2 hours of the beginning of a storm of sufficient intensity to trigger operation of the CSO network. Real-time streamflow measurements and rain gauges are used to determine when to initiate a storm event. Additional information is provided by the weather forecasts. Samples are collected every two hours for the first day and at four hour intervals on subsequent days.

5.2 1999 Sampling Program

Three storm events were monitored during 1999 as the first year of the baseline monitoring program. The relationship of the storm events to the 1999 rainfall and streamflow records from April through October is displayed in Figure 5-1. Storm sampling was conducted April 11 – 14, June 29 – July 2, and October 10 – 13.

Sampling locations are summarized in Table 5-1. Water samples were collected at four points along Onondaga Creek and at two points on Harbor Brook and Ley Creek. Samples were collected from mid-stream using a stainless steel bucket in a dip sampling technique. Sample bottles were filled directly from the bucket. Appropriate preservatives were added in the field. Samples were analyzed for total suspended solids (TSS), total phosphorus (TP), total Kjeldahl nitrogen (TKN), and chloride. Water samples were analyzed for the presence and density of three classes of indicator bacteria: fecal coliform, E. coli, and Enterococcus.

5.3 1999 Results

Concentration and Loading Estimates, Onondaga Creek

The average and flow-weighted average concentrations of water quality constituents are summarized in Table 5-2. Data from all three storm events are presented. For the two stations on Onondaga Creek with flow monitoring (Dorwin Ave. and Spencer St.) constituent loading is tabulated as well.

Water quality was highly variable over the course of each storm, as illustrated in Figure 5-2. These plots of total P and total suspended solids for the April and June events (two stations) represent a subset of the extensive data set collected over the 1999 storm event program. From these plots it is evident that the hydrographs for the upstream and downstream segments of the creek are quire different. The flow measured at Spencer St., the downstream station, peaked early during each of the storms at a very high flow value. This pattern is the result of the CSO discharges to the lower reaches of Onondaga Creek. A large volume of water from the wastewater collection system can potentially be discharged to the creek within a very short time. This flow regime presents a challenge to the monitoring program to capture the critically important first flush when a slug of material is transported downstream.

Histograms of the distribution of sample concentrations monitored at the Onondaga Creek sites are plotted in Figure 5-3. Concentrations of total P and suspended solids are highly correlated in the upstream stations of this system (Figure 5-4). The relationship shifts at the Spencer St. station, downstream of the CSOs. The shift may indicate the introduction of soluble fractions of phosphorus into the stream from the combined sewer discharges. The Inner Harbor site is located where the stream gradient drops and velocity slows, creating a depositional reach along lower Onondaga Creek. The TSS:TP regression in this stream reach is altered as well.

Bacteria data were also variable over the course of the storms (Figure 5-5). Three classes of bacterial indicators were monitored: fecal coliforms, Enterococcus, and E. coli. The mean, maximum and minimum data measured over the 1999 storm events are plotted in Figure 5-6. As expected, concentrations of bacteria are elevated downstream of the CSO discharges.

Concentration and Loading Estimates, Ley Creek

Average and flow-weighted average data collected at the two Ley Creek stations are summarized in Table 5-3. Loads are estimated for the most downstream station, Park St., near the confluence of Onondaga Lake. The flow gauge is located in a low-gradient segment of the stream subject to backwater influence from Onondaga Lake and USGS rates flow estimates from this gauging site as fair.

Similar to the results on Onondaga Creek, water quality was variable over the course of the storm events. Only two CSOs discharge to Ley Creek so the peak flows are not observed as rapidly following onset of the

storm. Figure 5-7 plots the hydrograph and concentrations of TP and TSS. The histograms of upstream/downstream measurements (Figure 5-8) demonstrate the impact of the urban corridor, including CSOs. TP and TSS are correlated in the Ley Creek system as measured at both stations, indicating the importance of particulate phosphorus to the total load. The TP:TSS regression plot of the Ley Creek data set is included as Figure 5-9. Bacteria concentrations tend to be elevated downstream of the urban/CSO corridor on this stream as well (Figure 5-10).

3 Concentration and Loading Estimates, Harbor Brook

Data from the 1999 storm event effort on Harbor Brook are presented in the same sequence of tables and graphs (Table 5-4, summary of loads and concentrations; Figure 5-11, plotted changes in water quality over time and in relation to streamflow; Figure 5-12, histograms of TP and TSS concentration at the two sampling sites; Figure 5-13, regression of TP and TSS; and Figure 5-14, bacteria concentrations measured during the April storm event).

5.4 Discussion and Recommendations

1999 was the first year of a three-year program to characterize baseline water quality and estimate CSO loads during wet weather. The baseline data will provide a benchmark against which the effectiveness of improvements to the CSO collection and treatment system can be quantified. Since baseline monitoring will continue through 2001, it is important to identify areas of improvement to the data collection and analysis program. These recommendations are provided as a basis for discussion and may be modified in future drafts of the 1999 annual report.

(1) Begin sampling earlier in the storm.

Sampling generally began after the rising limb of the hydrograph had passed. The sampling regime for the April storm was the best of the three events but the early part of the storm was not sampled. With so many CSOs active on Onondaga Creek it is essential to sample the downstream sites as early as possible.

(2) Consider automatic sampling devices to capture the first flush

This recommendation follows as a means to overcome the barriers that prevent the sampling team from capturing the first flush. The samples may not be able to be analyzed for coliform bacteria due to holding time constraints. However, the early portion of the storm record can be analyzed for TSS and TP, which will provide better data for storm-related transport of phosphorus and suspended sediment. This is a key issue related to partitioning of point and nonpoint source phosphorus.

Another option is to track an easily measured surrogate parameter that is directly correlated to the parameters of interest (TP, TSS, and bacteria). This is an active area of research in EPA's wet weather program with a focus on remote measuring devices and telemetry. To date, EPA has not issued their findings and recommendations.

(3) Measure field parameters during events

The tributaries to Onondaga Lake have a fairly unique chloride and specific conductance profile. Recommendations that EPA develops for remote measurements of CSO and wet weather indicators may not be optimal for this system. To determine if field parameters are correlated with analytical parameters measured during storm events on the tributaries to Onondaga Lake the field teams should measure DO, pH, redox, and specific conductance during sample collection. An option is to deploy in-situ sondes to continuously recorded field data at 15-minute intervals at the downstream locations of the tributary.

(4) Document CSO overflows during storm events

The timing and duration of CSO discharges is very important in interpreting the data. Only discharges from the treatment facilities have an estimated overflow rate and duration. In the absence of monitoring data, consider having the field team visually document which overflows are active during the event.

(5) Document the criteria for defining a storm event

The decision to initiate storm event monitoring commits the AMP team and environmental laboratory to a labor intensive and costly exercise. While predicting the course of a storm will always be subject to uncertainty, well defined criteria will help in the decision making process.

An "ideal" storm would be characterized by:

- Antecedent dry conditions with a recent tributary monitoring event to quantify pre-storm conditions
- Intense rainfall throughout the subwatershed
  Overflows of the combined sewers with documented loads

The program should try to capture a storm during spring or early summer to maximize input from agricultural nonpoint sources.

The SWMM model could be applied to rainfall events of different intensity to refine the definition of a storm event.

(6) Simplify the analytical program by using only fecal coliform bacteria as an indicator of the potential presence and abundance of pathogens in the stream samples.

To date, the program has analyzed for three classes of indicator bacteria: fecal coliform, Enterococcus and E. coli. Abundance of these bacteria in the Onondaga Lake tributaries is well correlated as evident from Figures 5-6, 5-10, and 5-14. New York State relies on fecal coliform bacteria in their ambient water quality standards to indicate the potential presence and abundance of pathogens. The other classes of bacteria are in used in federal criteria to indicate suitability of water for bathing and other primary contact recreation. The streams are not classified or used for primary contact recreation.

Analysis for these indicator organisms is expensive and time consuming. The laboratory has had difficulty identifying a reliable supply of the necessary growth media for Enterococcus.

(7) The program is not designed to target every storm. Some large or intense storms may not be sampled for various reasons. When storms of sufficient intensity to trigger the CSOs occur during the summer recreational period (June – August), the County should consider implementing near-shore bacteria monitoring even if the storm events were not captured. This will provide an expanded data set for a bacteria model, as the loads from the tributaries can be modeled.

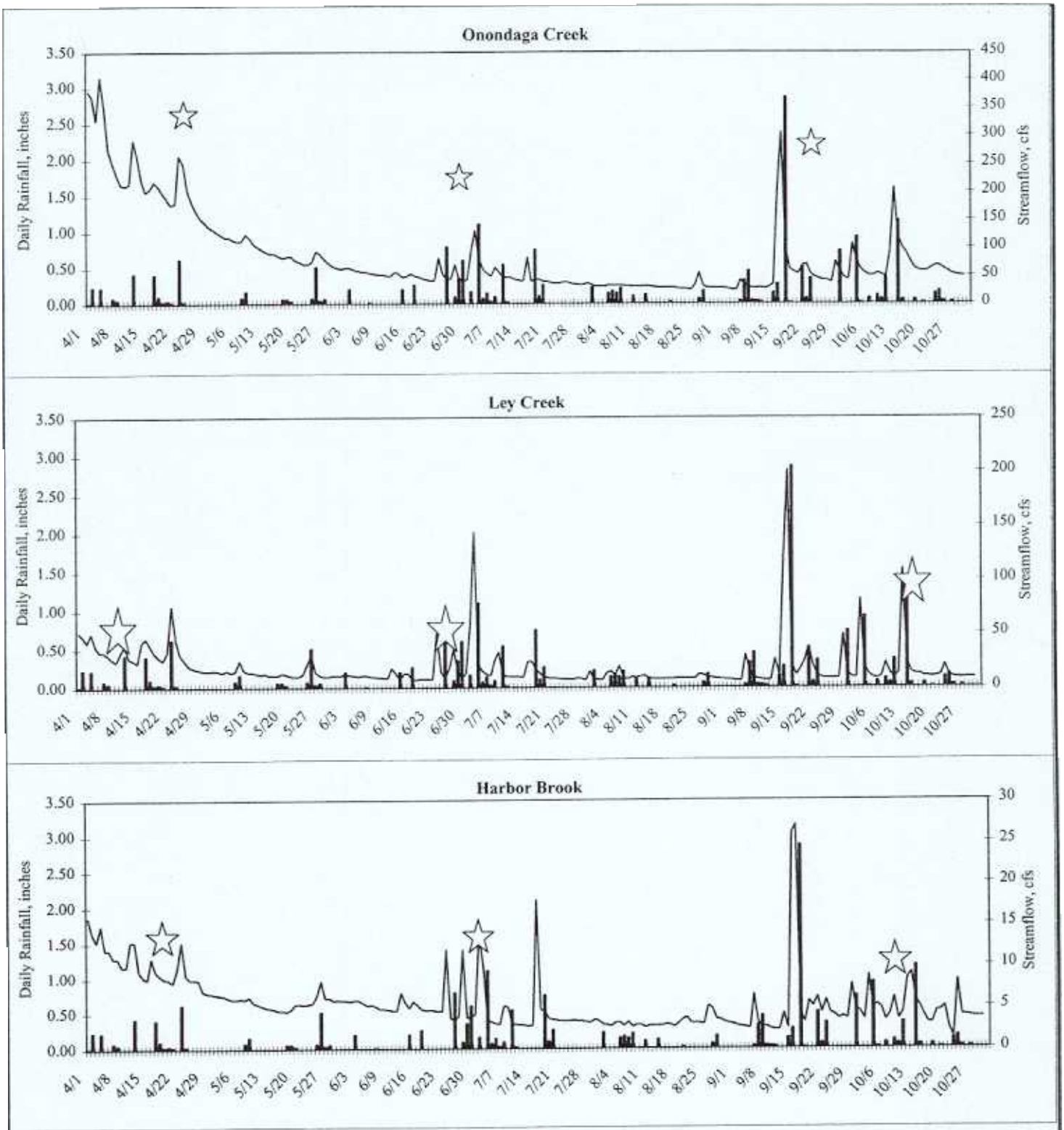

FIGURE 5-1: Rainfall and streamflow conditions in tributaries to Onondaga Lake, April - October 1999. Stars designate storm sampling events (April 11 - 14, June 29 - July 2, and October 10 - 13, 1999.)

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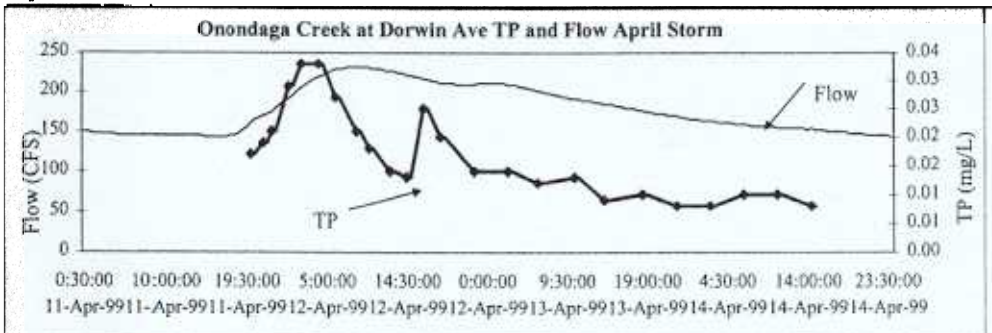
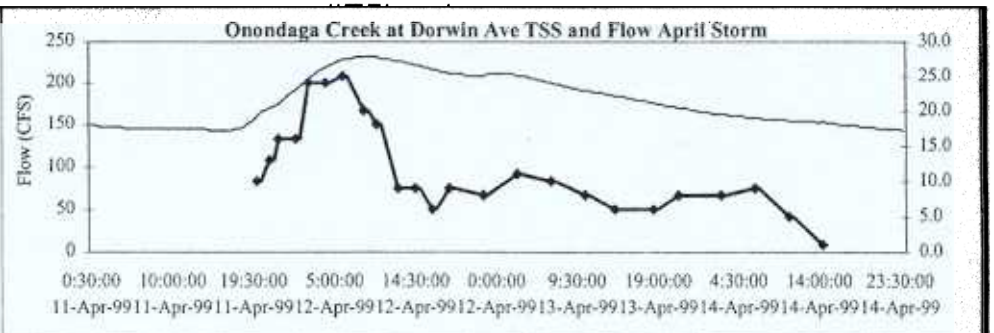
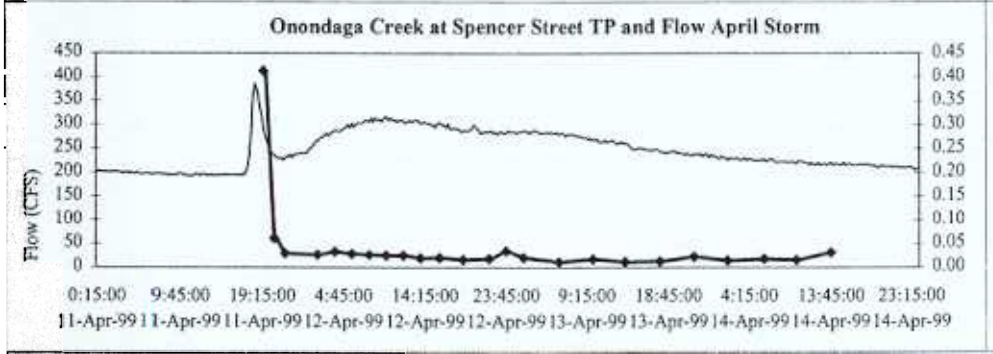
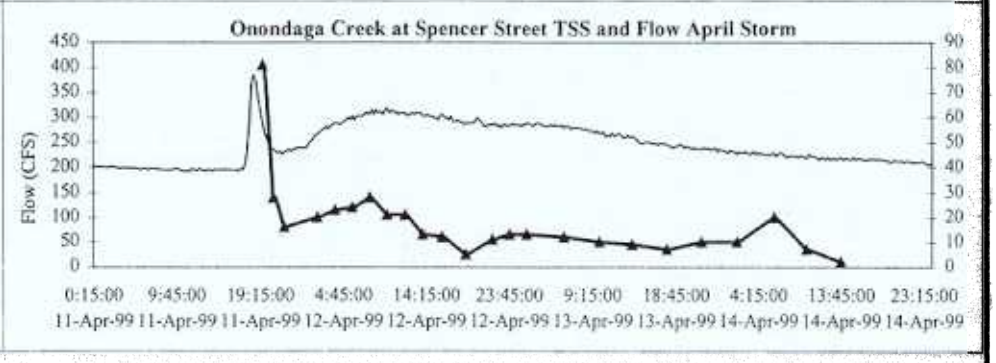
April Event

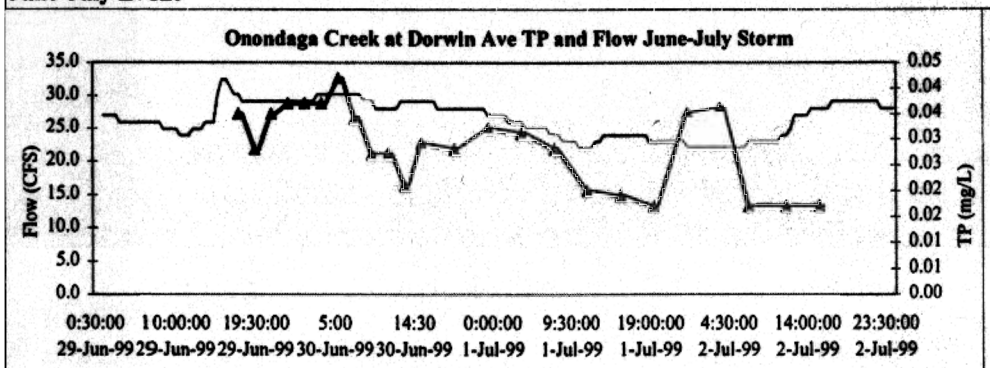


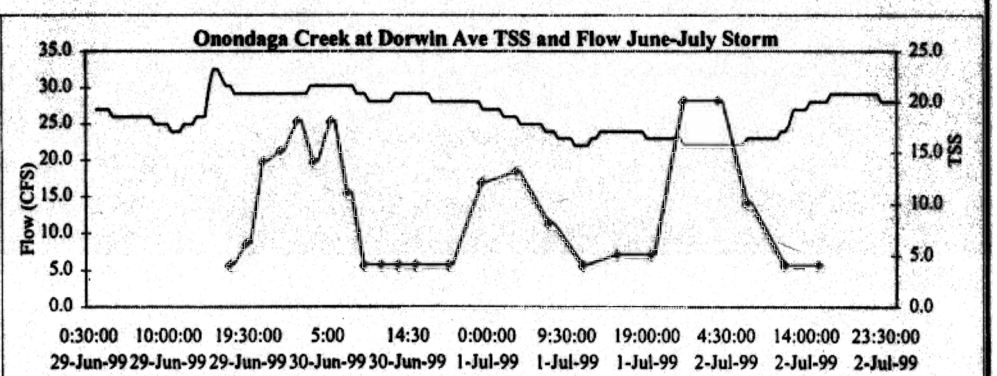


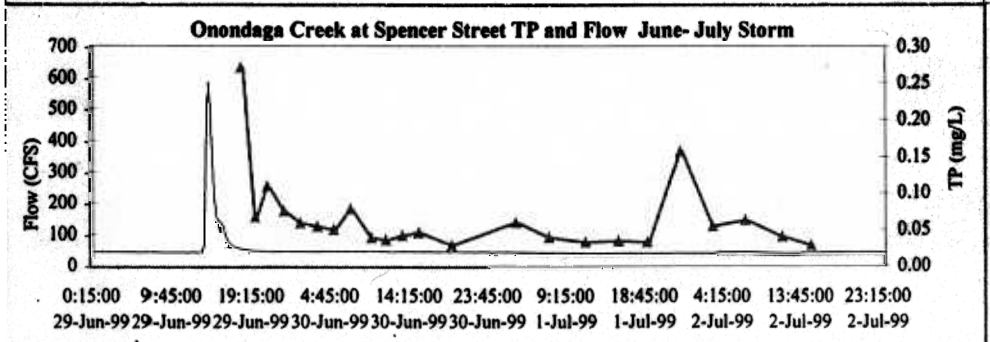




June-July Event







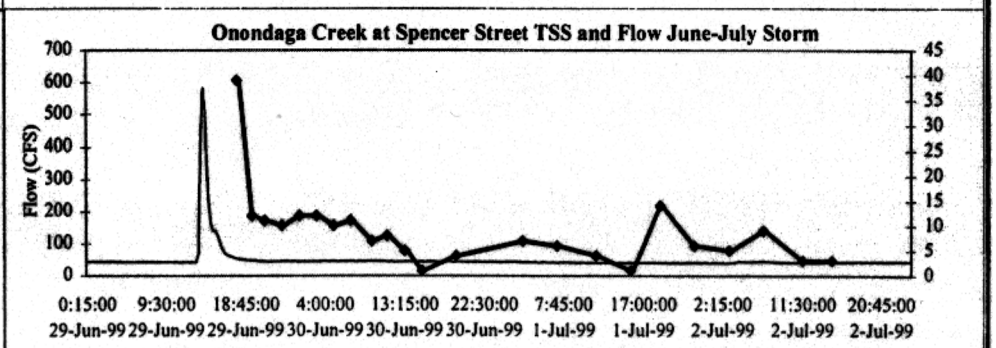


FIGURE 5-2: Representative hydrographs and concentration plots for two water qualty parameters (Total P and Total Suspended Solids). Onondaga Creek, Dorwin Ave. (upstream of CSO) and Spencer St (downstream of CSO). Storm event data from April 11 - 14, 1999 and June 29 - July 2, 1999

April Event

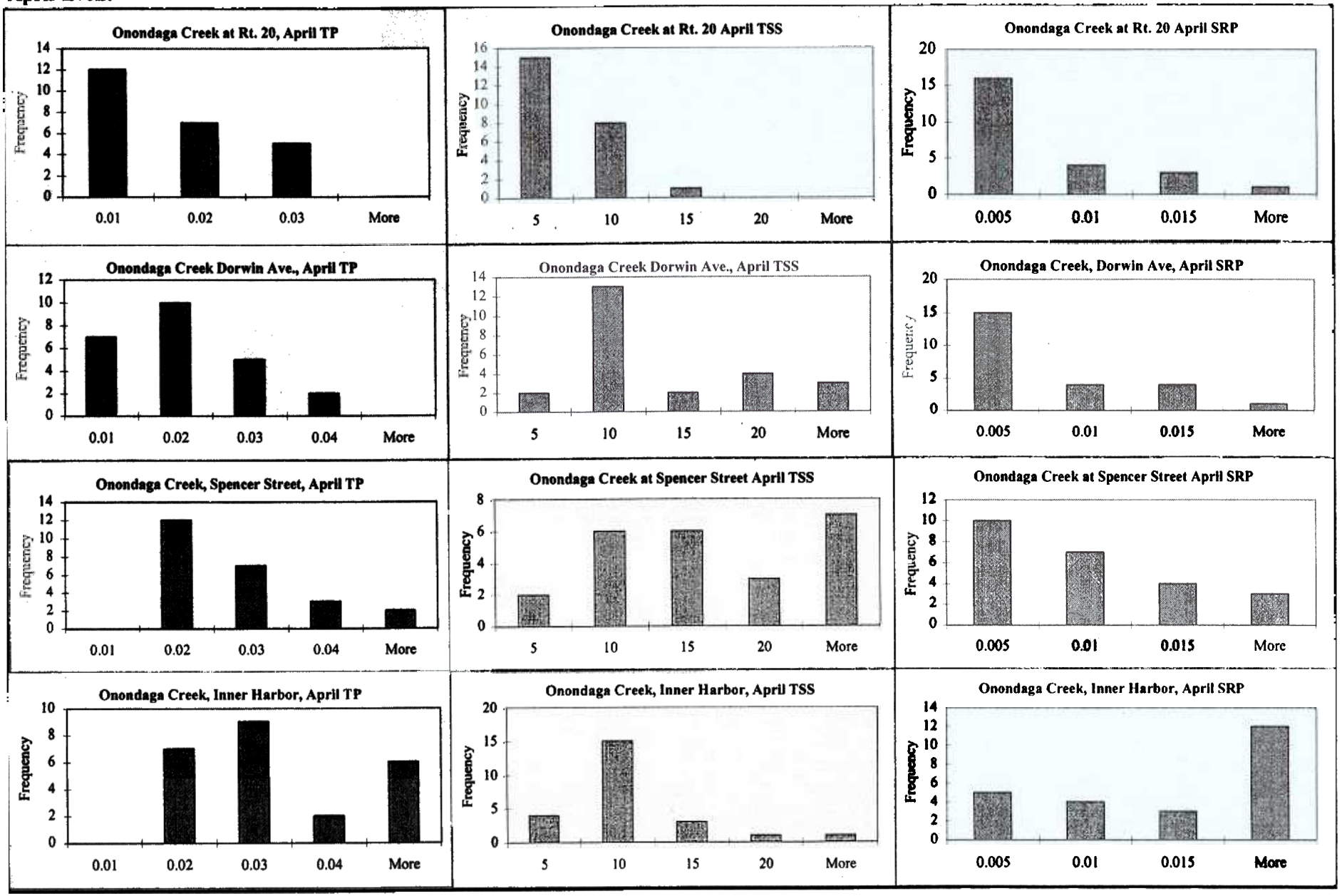


Figure 5-3 A: Histograms of TP, TKN and TSS measured at four stations along Onondaga Creek, April 1999

June-July Event

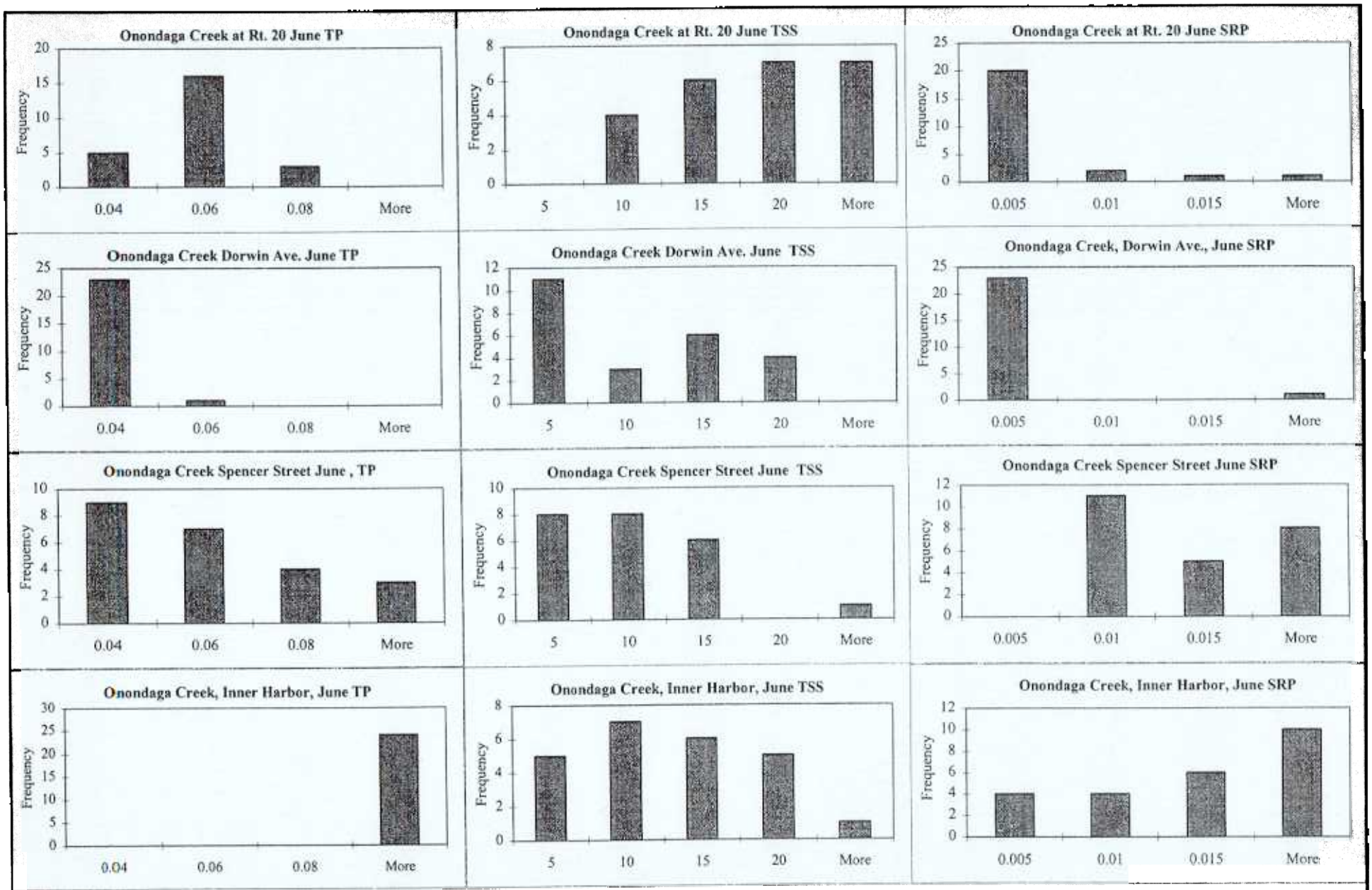


Figure 5-3 B: Histograms of TP, TKN and TSS measured at four stations along Onondaga Creek, June - July 1999

October Event

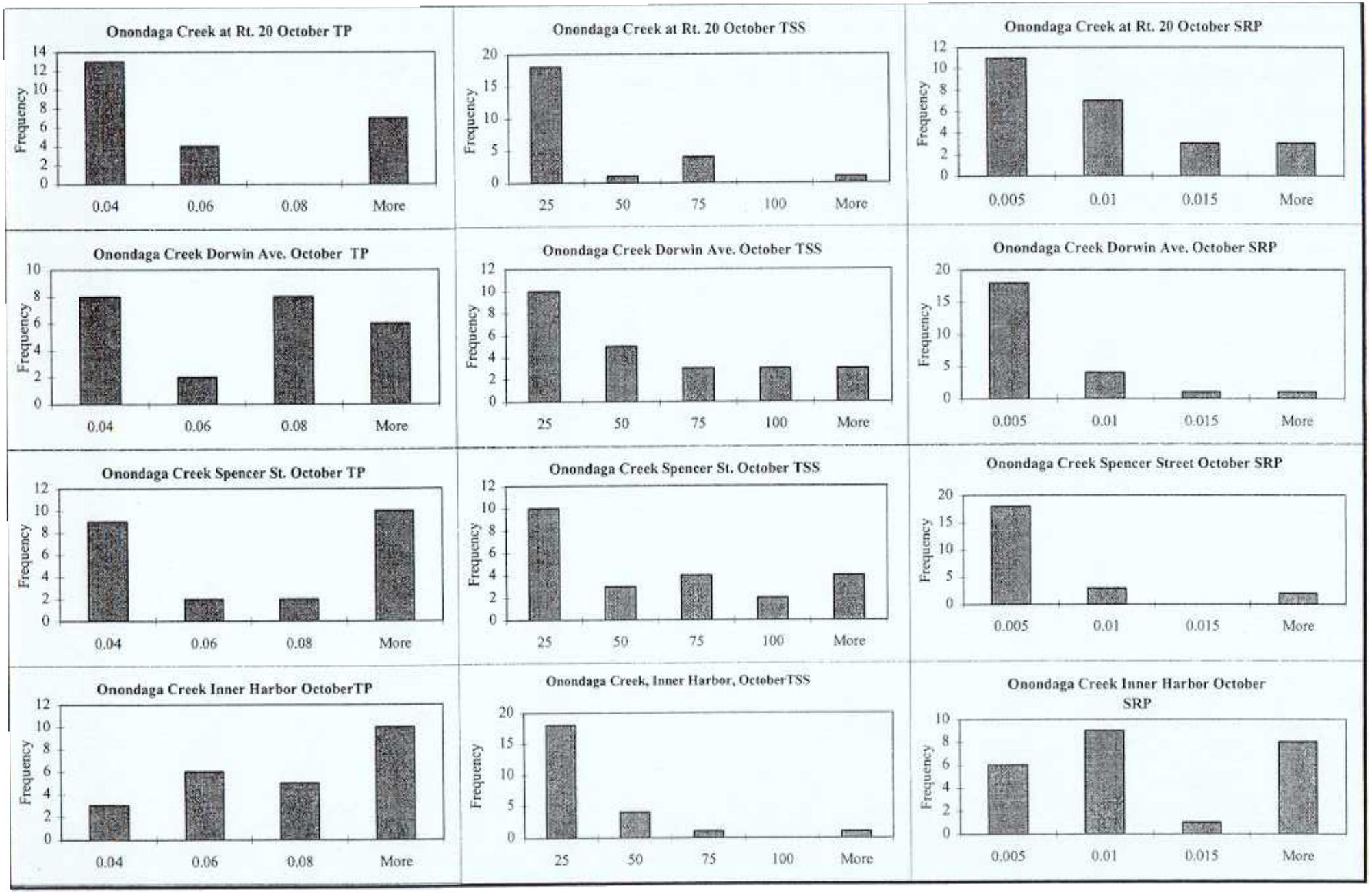


Figure 5-3 C: Histograms of TP, TKN and TSS measured at four stations along Onondaga Creek, October 1999

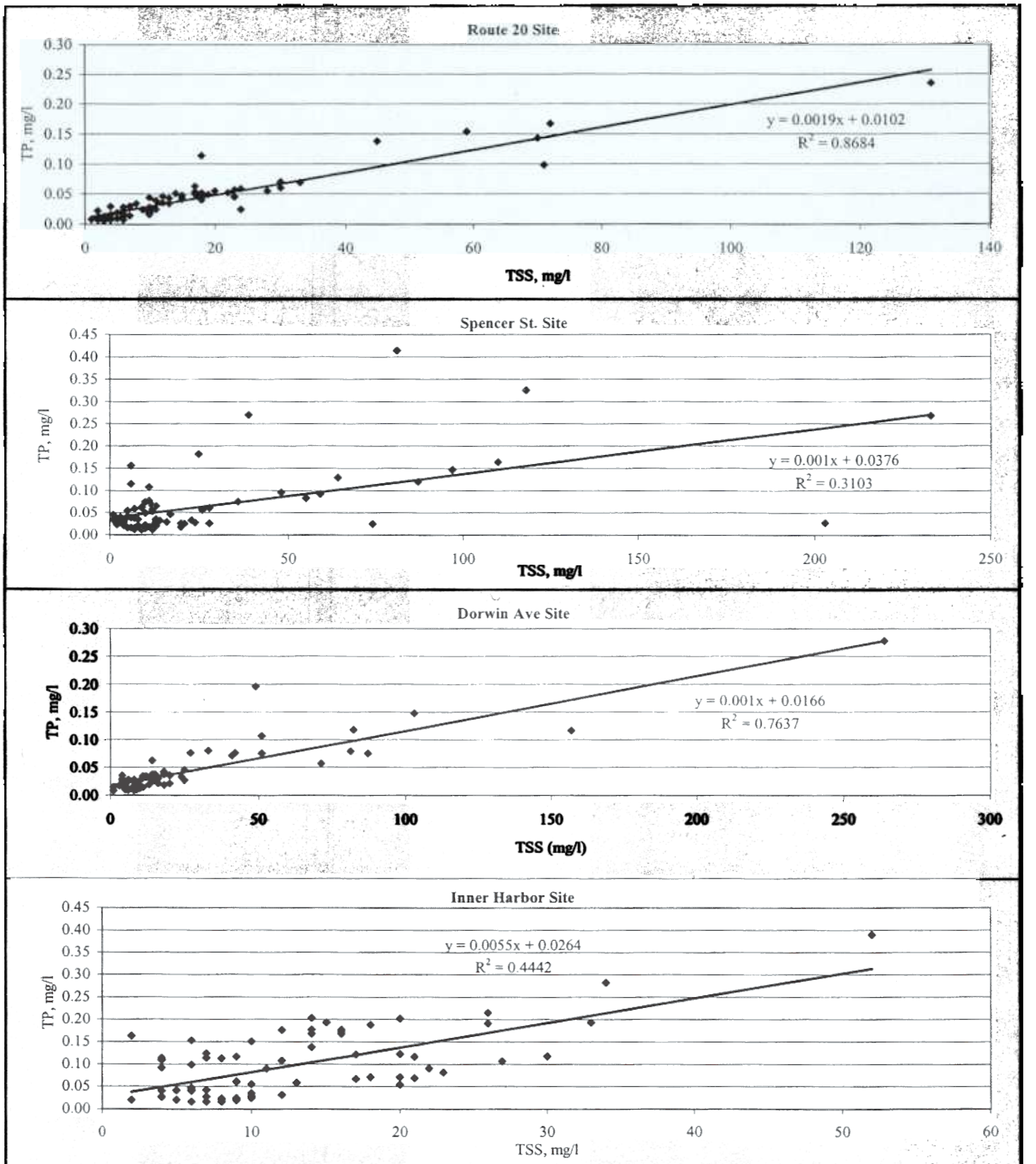


FIGURE 5-4: **Regression of Total P and Suspended Sediment in Onondaga Creek storm sampling stations. Plots depict pooled samples from 1999 storm events (April, June - July and October).**

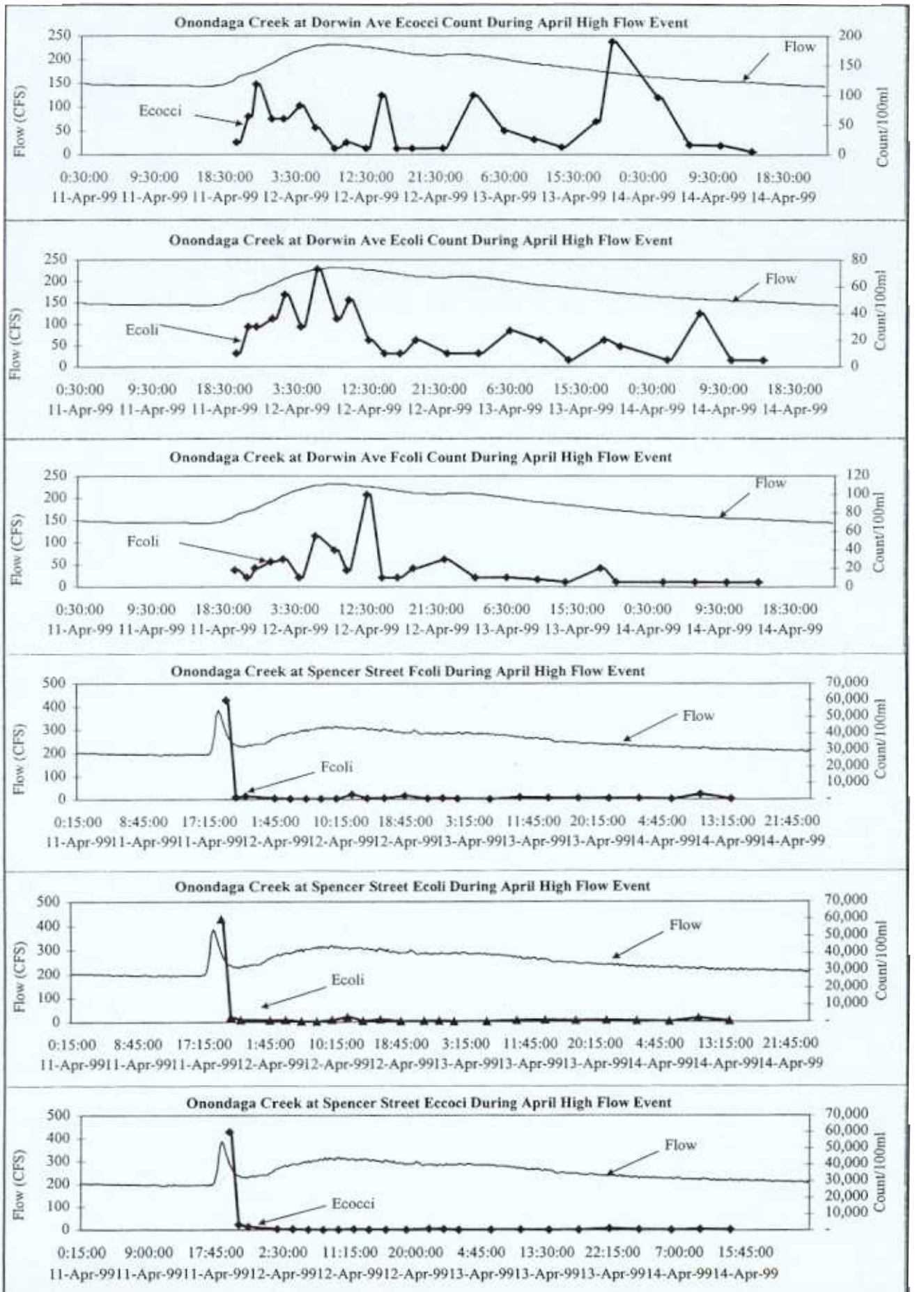
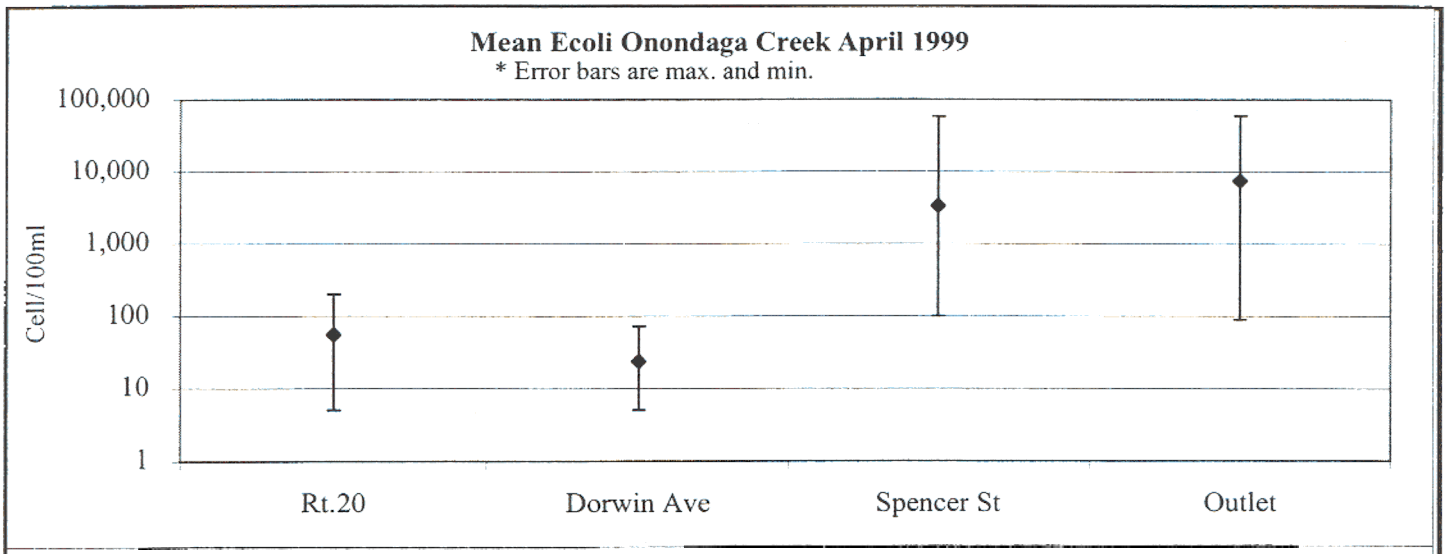
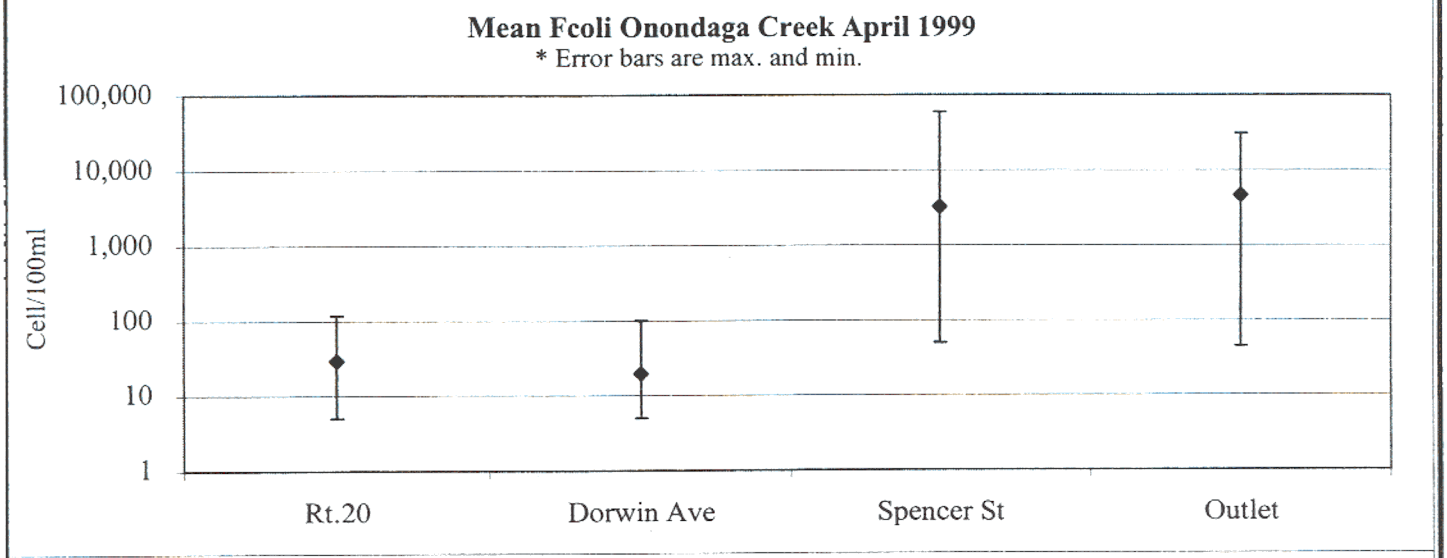


Figure 5-5: Concentrations of three classes of indicator bacteria over April 1999 storm event, Onondaga Creek

Fig 5-5 bacteria, On Cr April





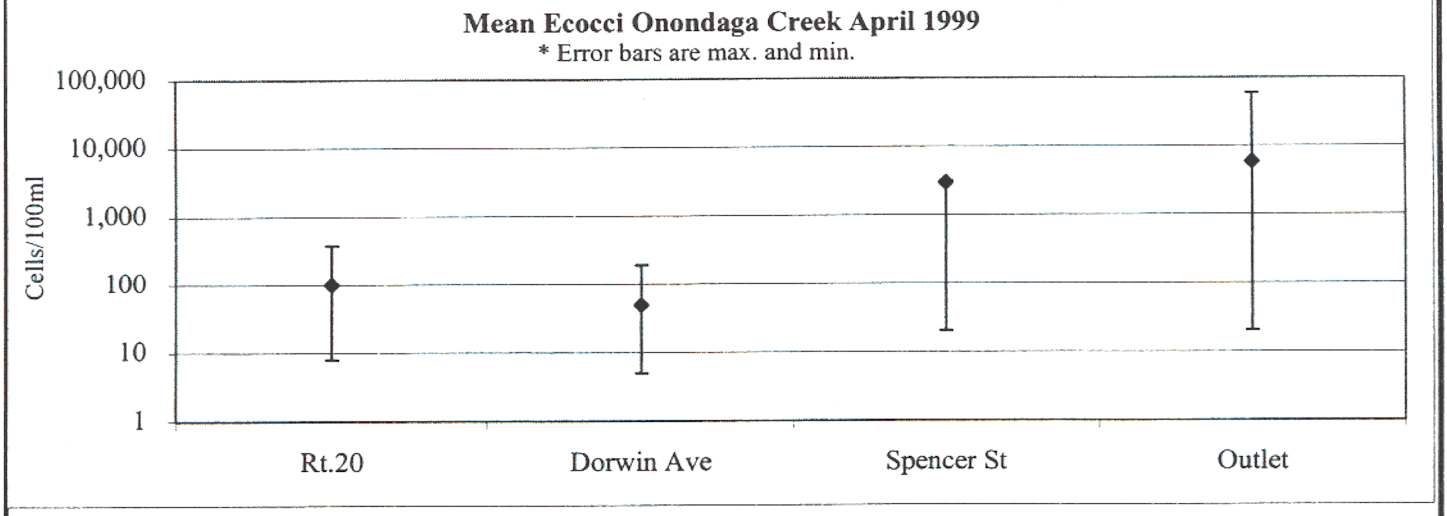


Figure 5-6. Mean, maximum and mimimum of indicator bacteria measured in Onondaga Creek

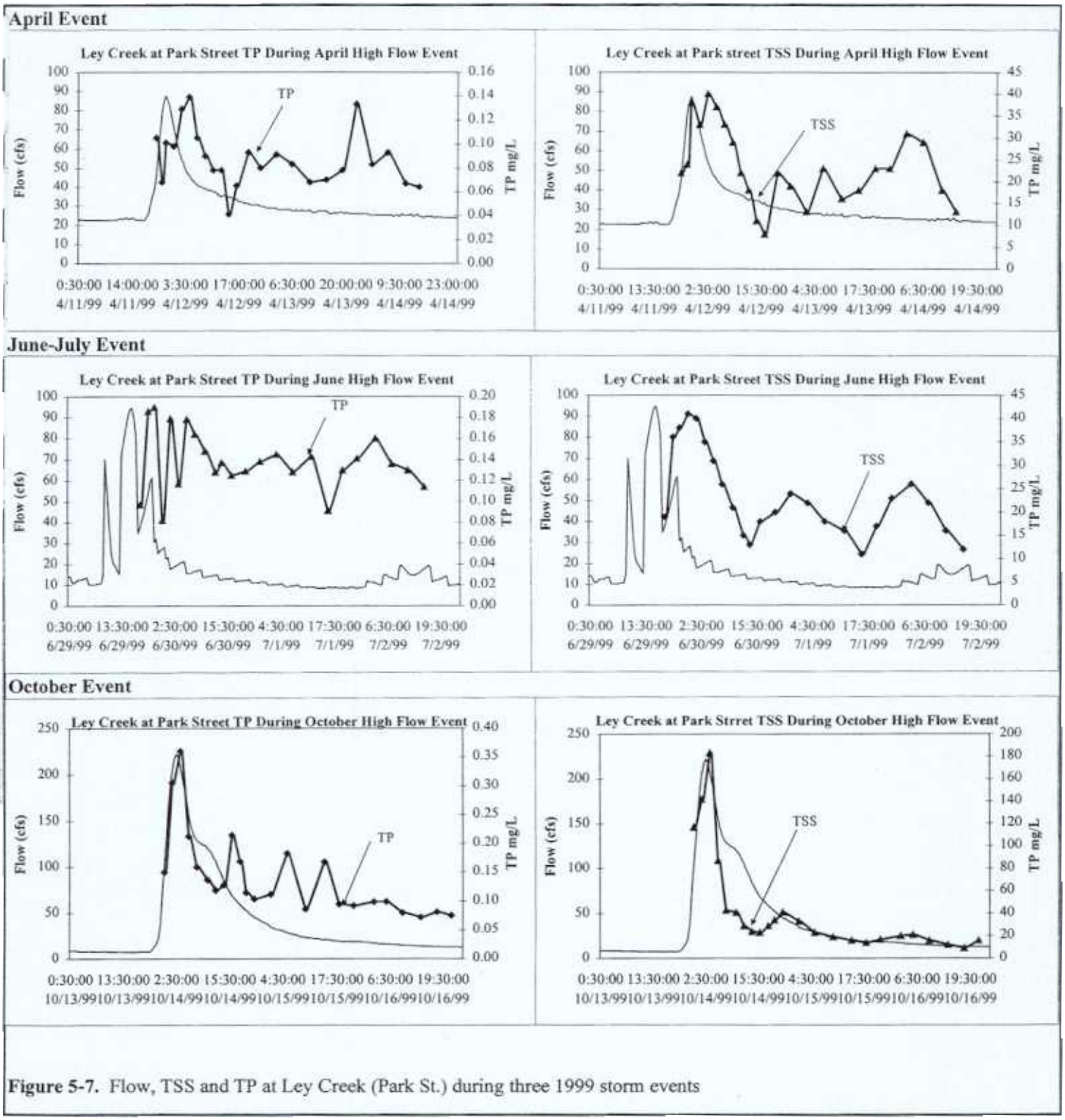


Figure 5-7. Flow, TSS and TP at Ley Creek (Park St.) during three 1999 storm events

Fig 5-7 Ley Cr flow_TP_TSS

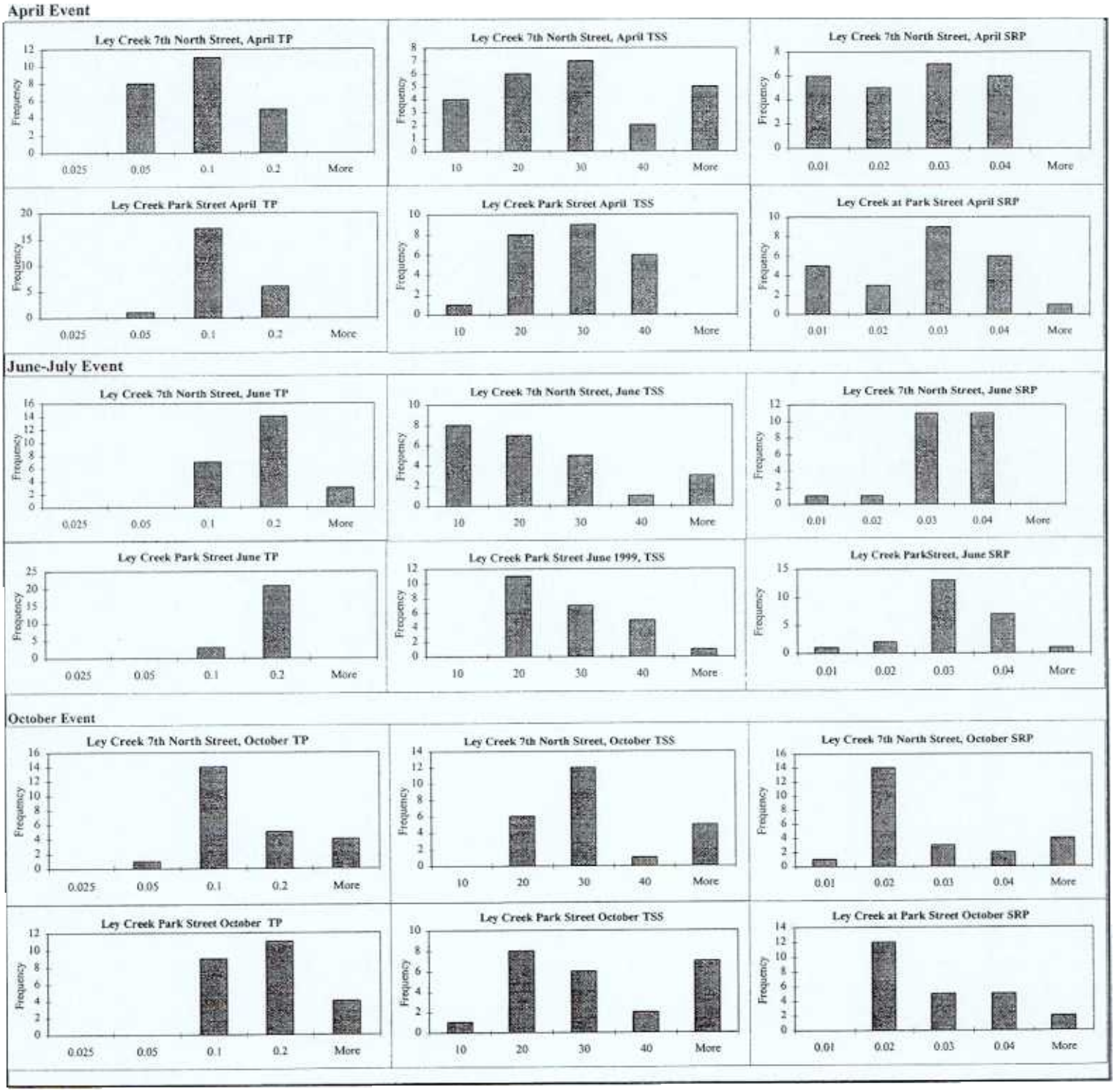
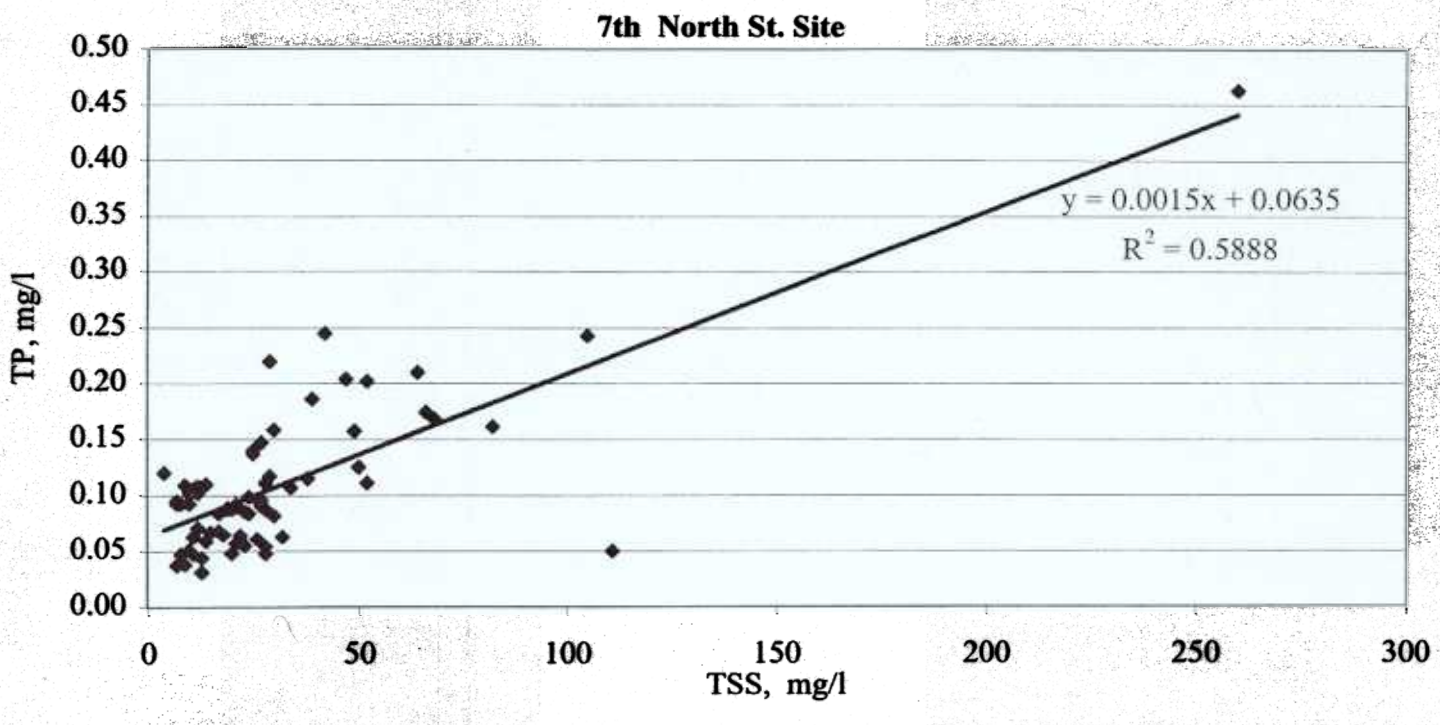


Figure 5-8: Histograms of TP, TKN and TSS measured at two stations along Ley Creek, April, June - July and October 1999



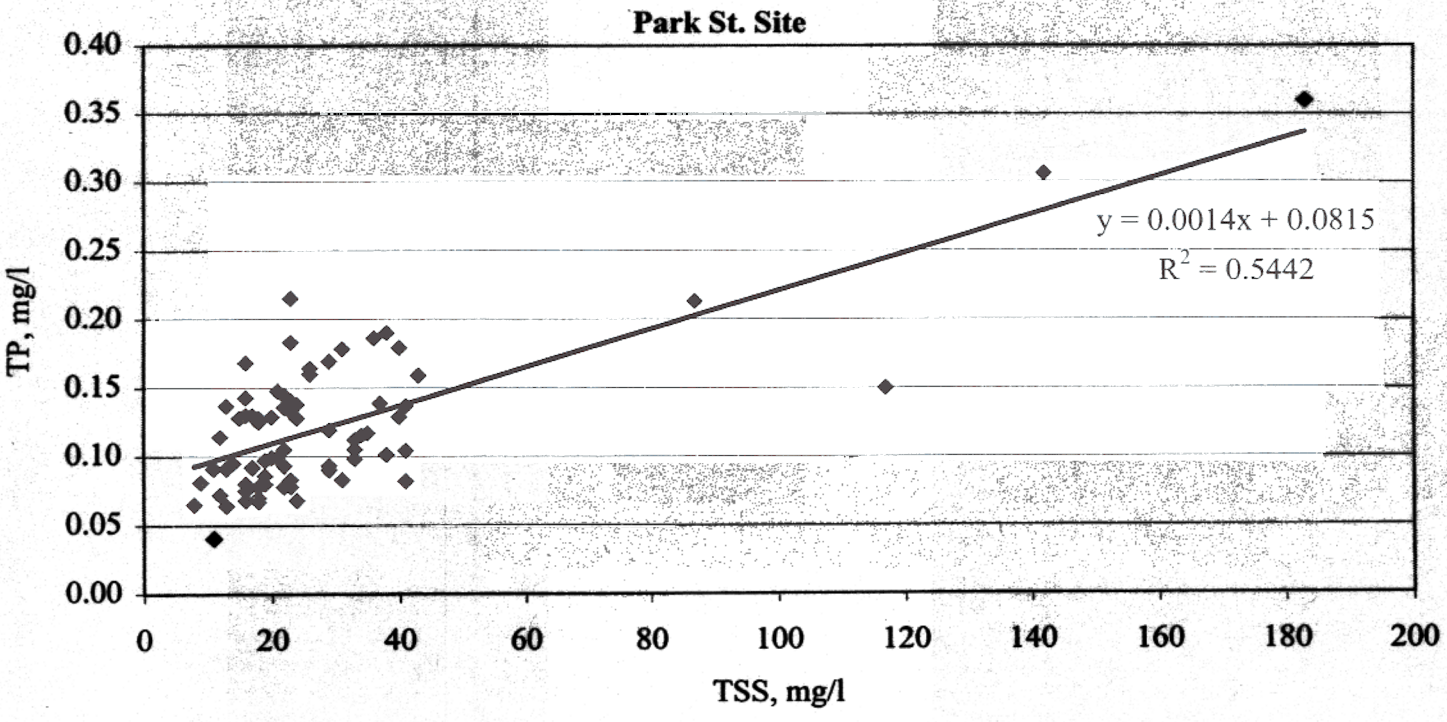
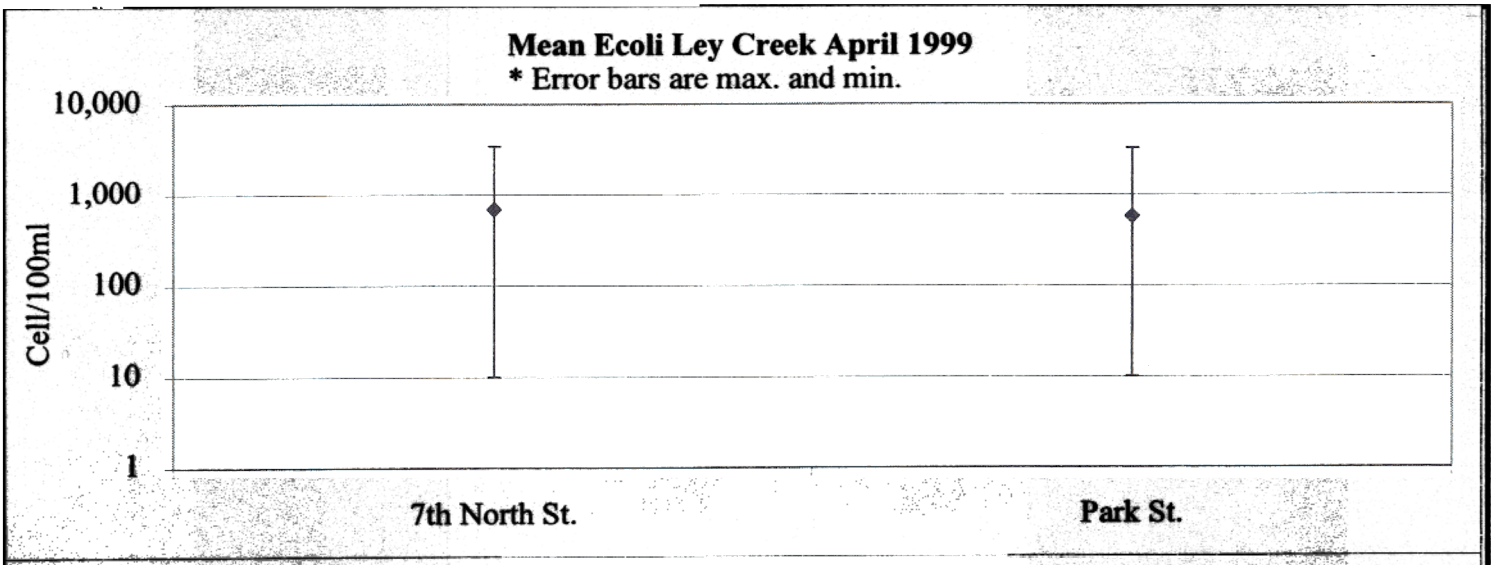
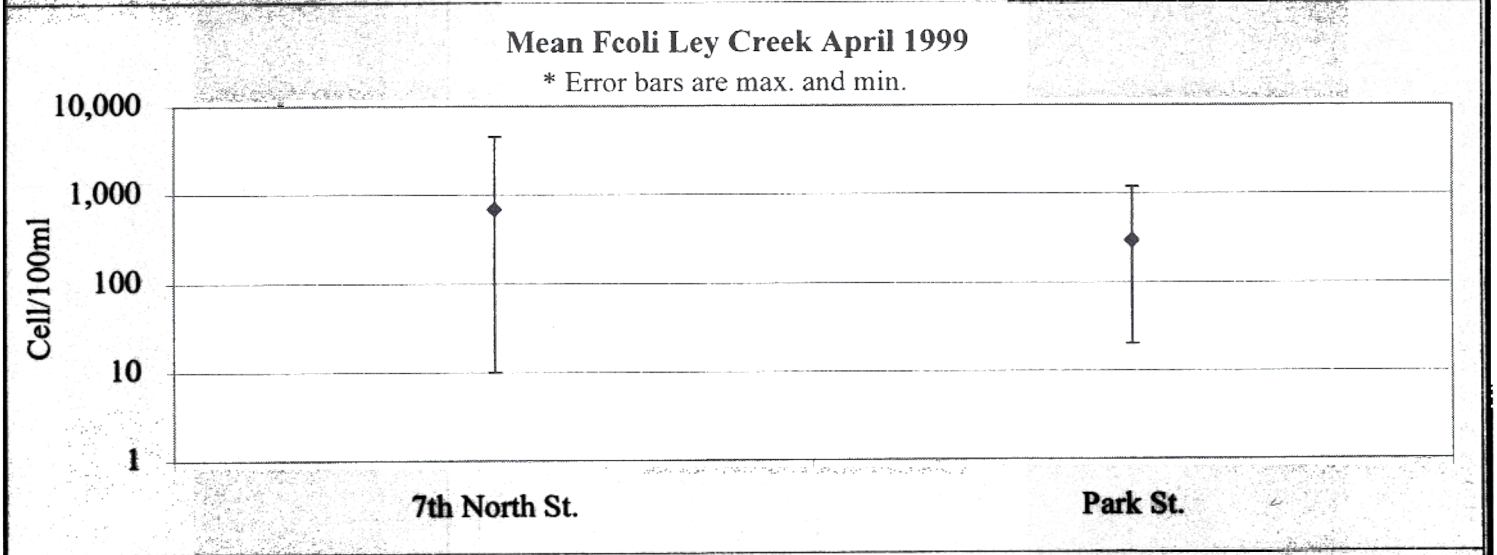


FIGURE 5-9: Regression of Total P and Suspended Sediment in Ley Creek storm sampling stations. Plots depict pooled samples from 1999 storm events (April, June - July and October).





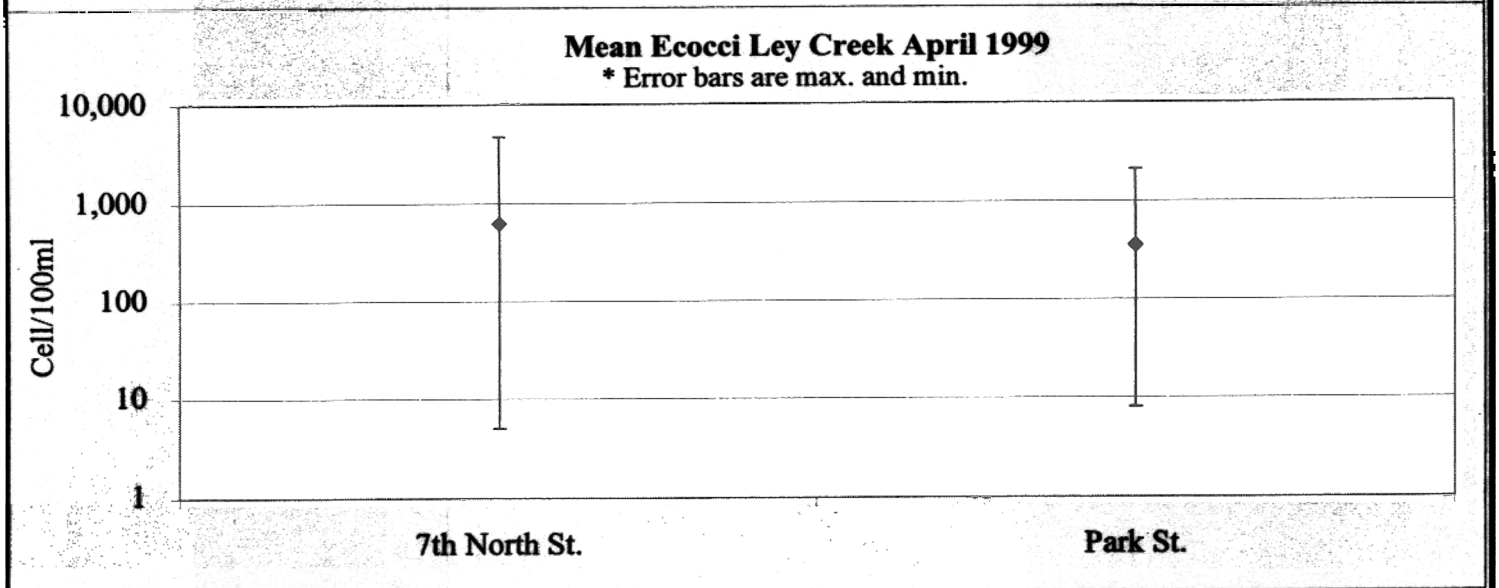
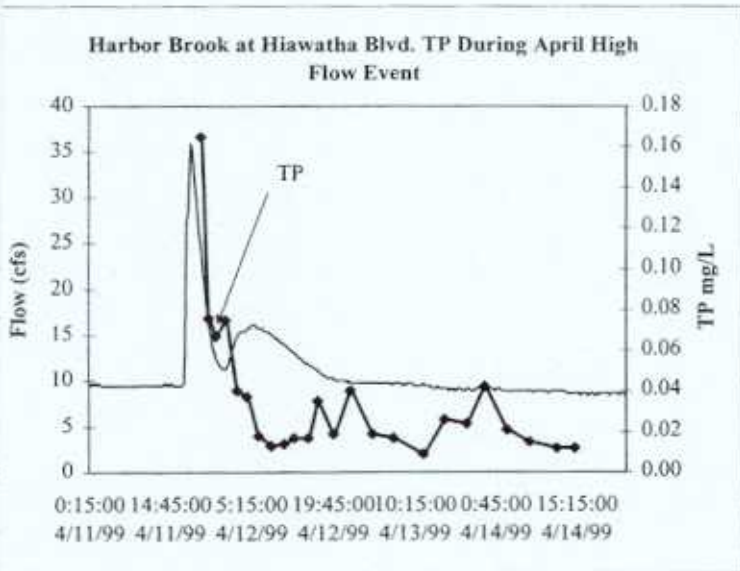
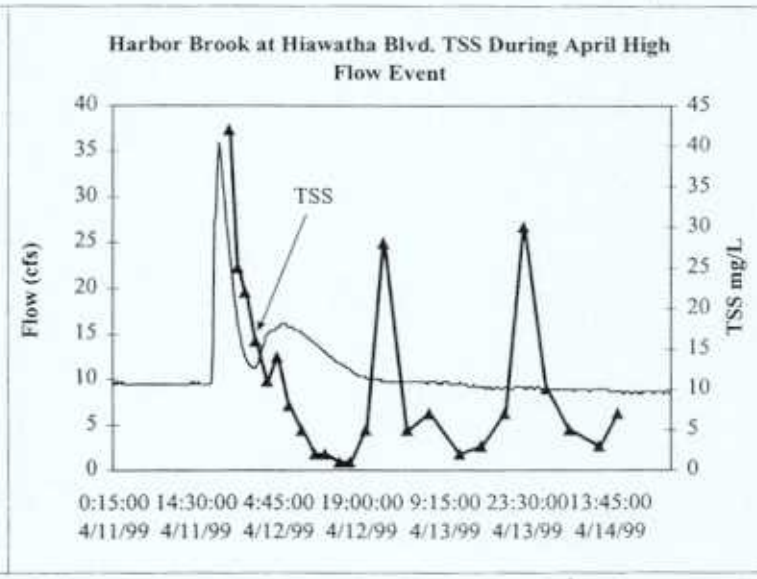


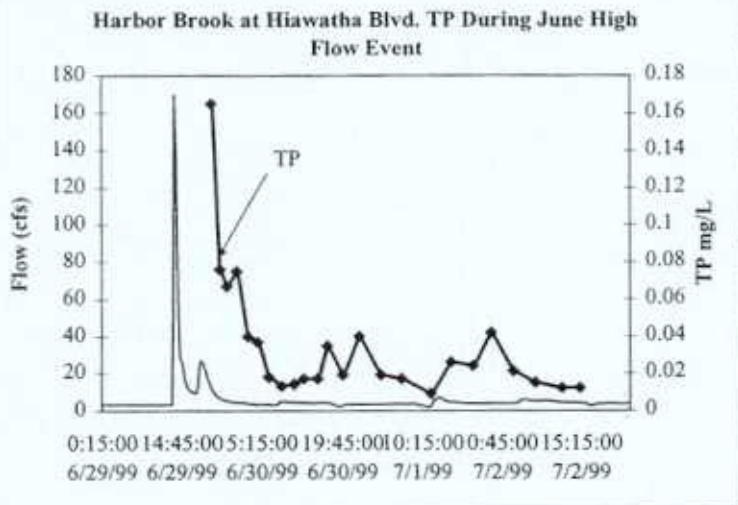
Figure 5-10: Mean, maximum and minimum concentration of three classes of indicator bacteria, Ley Creek

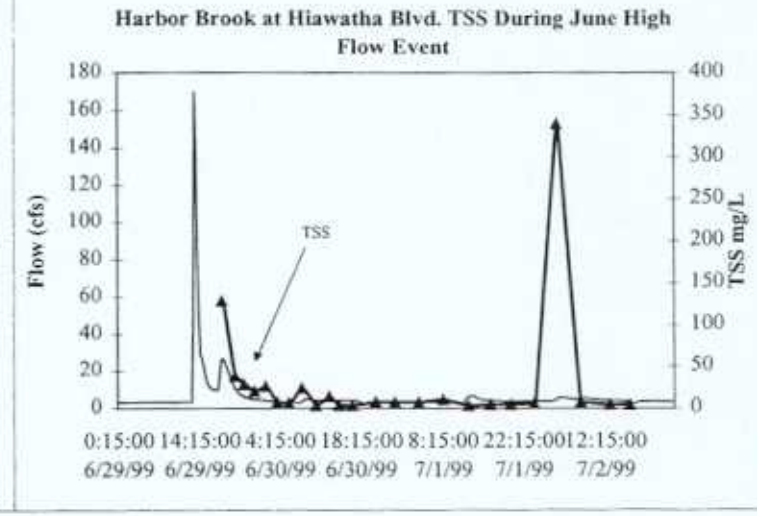
April Event



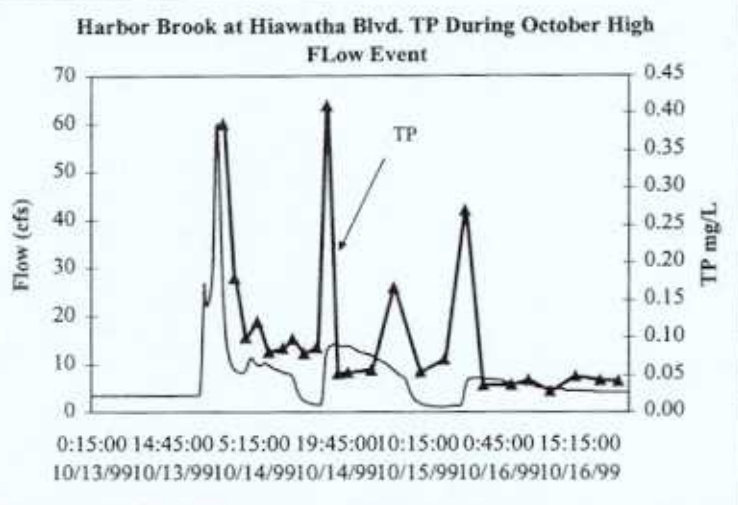


June-July Event





October Event



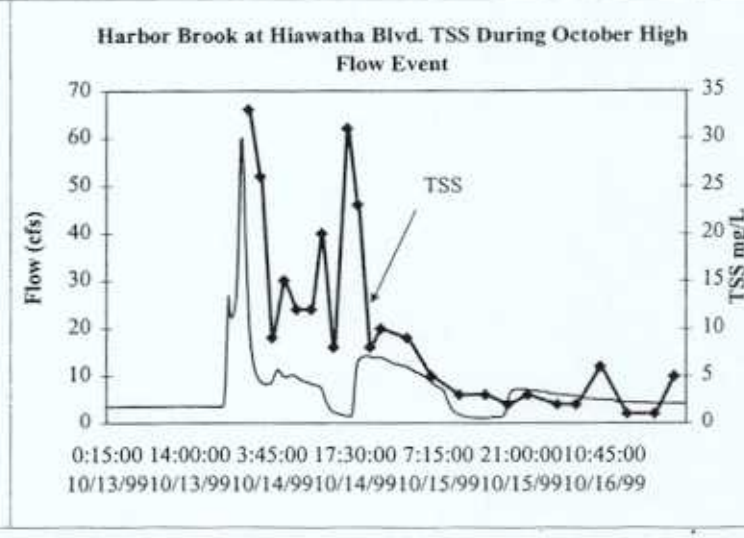


Figure 5-11: Flow, TP and TSS concentrations on Harbor Brook during 1999 storm events

Fig 5-11 Flow_TP_TSS harbor

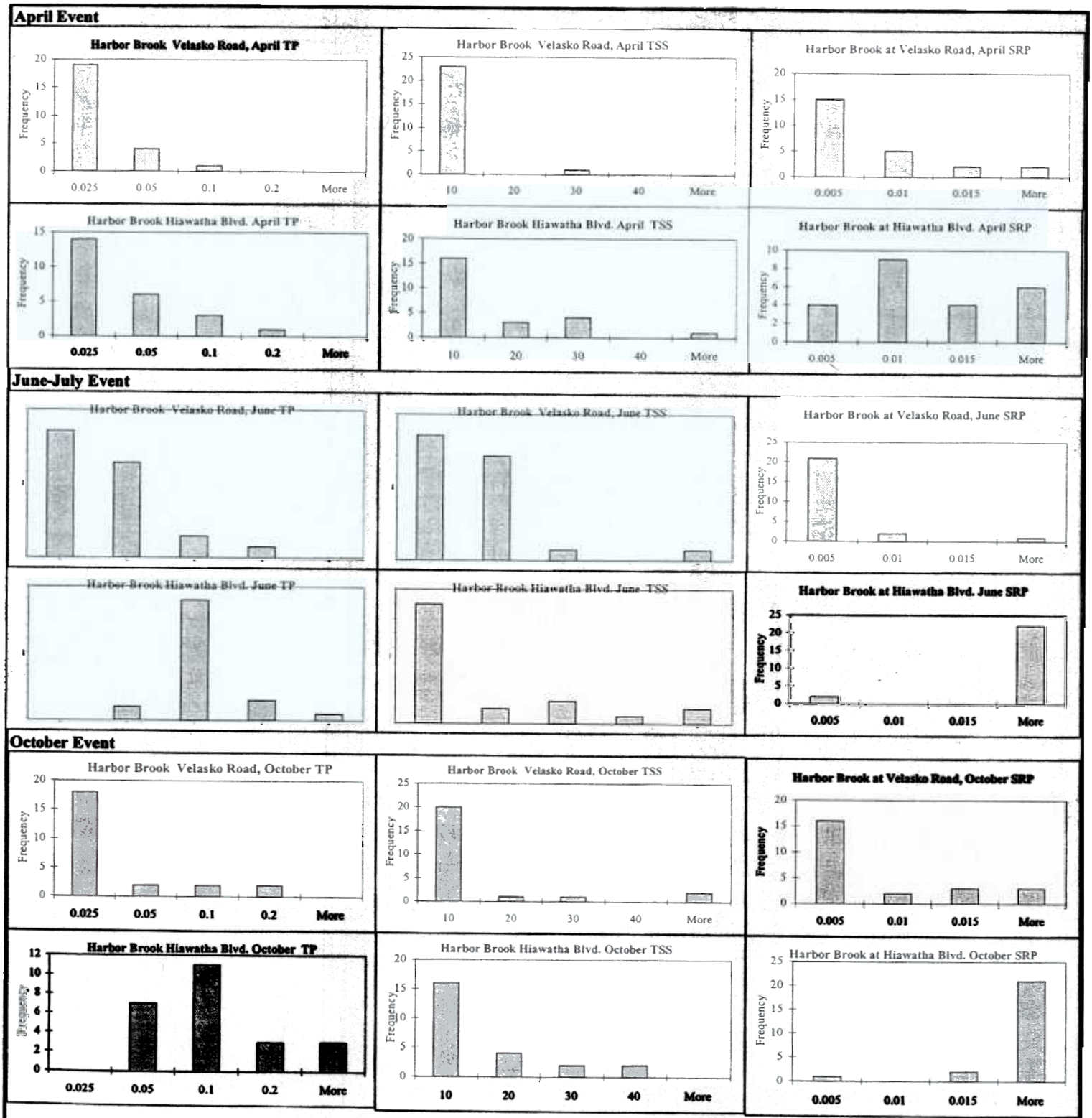


Figure 5-12: Histograms of TP, TKN and TSS measured at two stations along Harbor Brook April, June - July and October 1999.

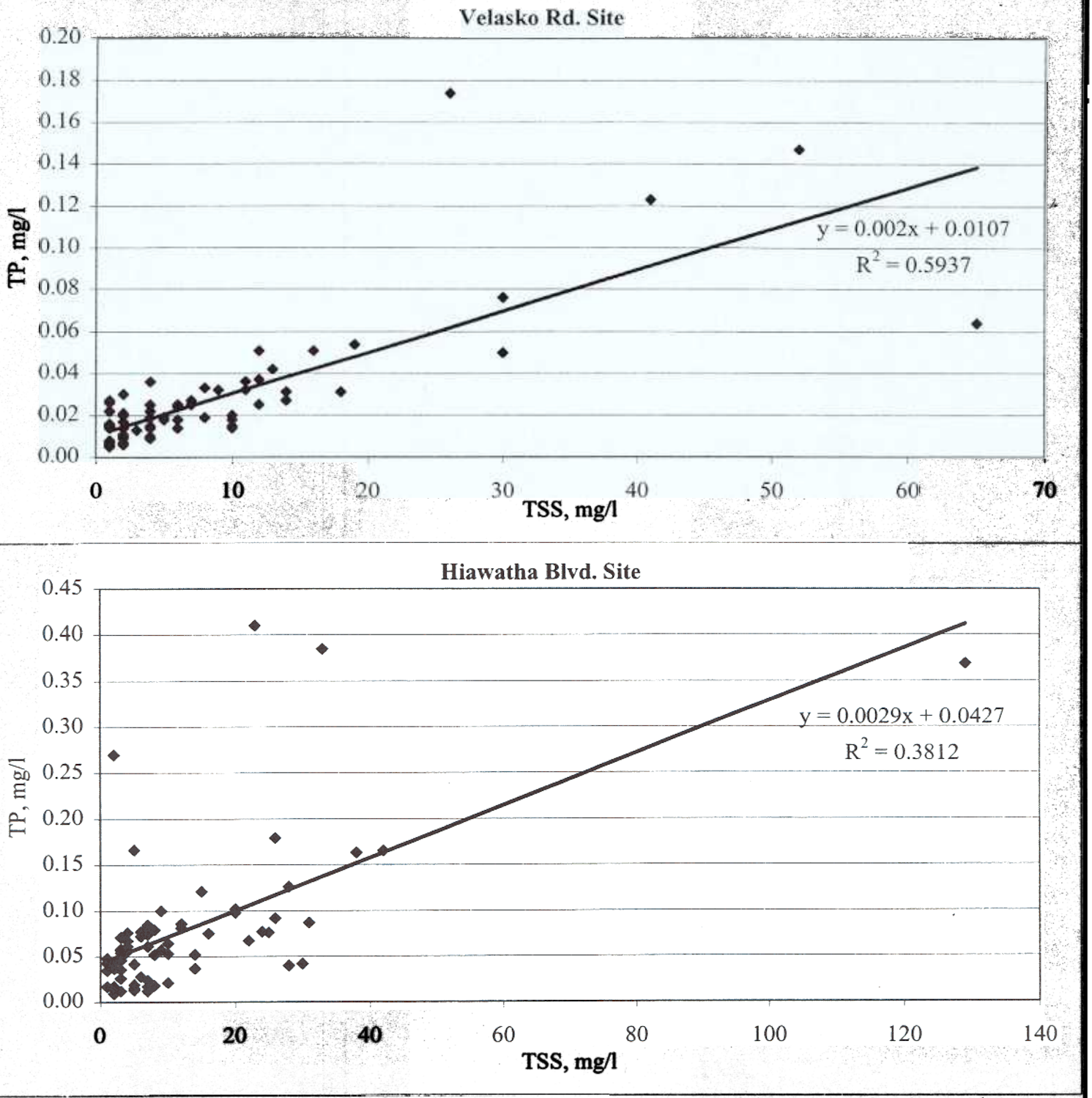


FIGURE 5-13: Regression of Total P and Suspended Sediment in Harbor Brook storm sampling stations. Plots depict pooled samples from 1999 storm events (April, June - July and October).

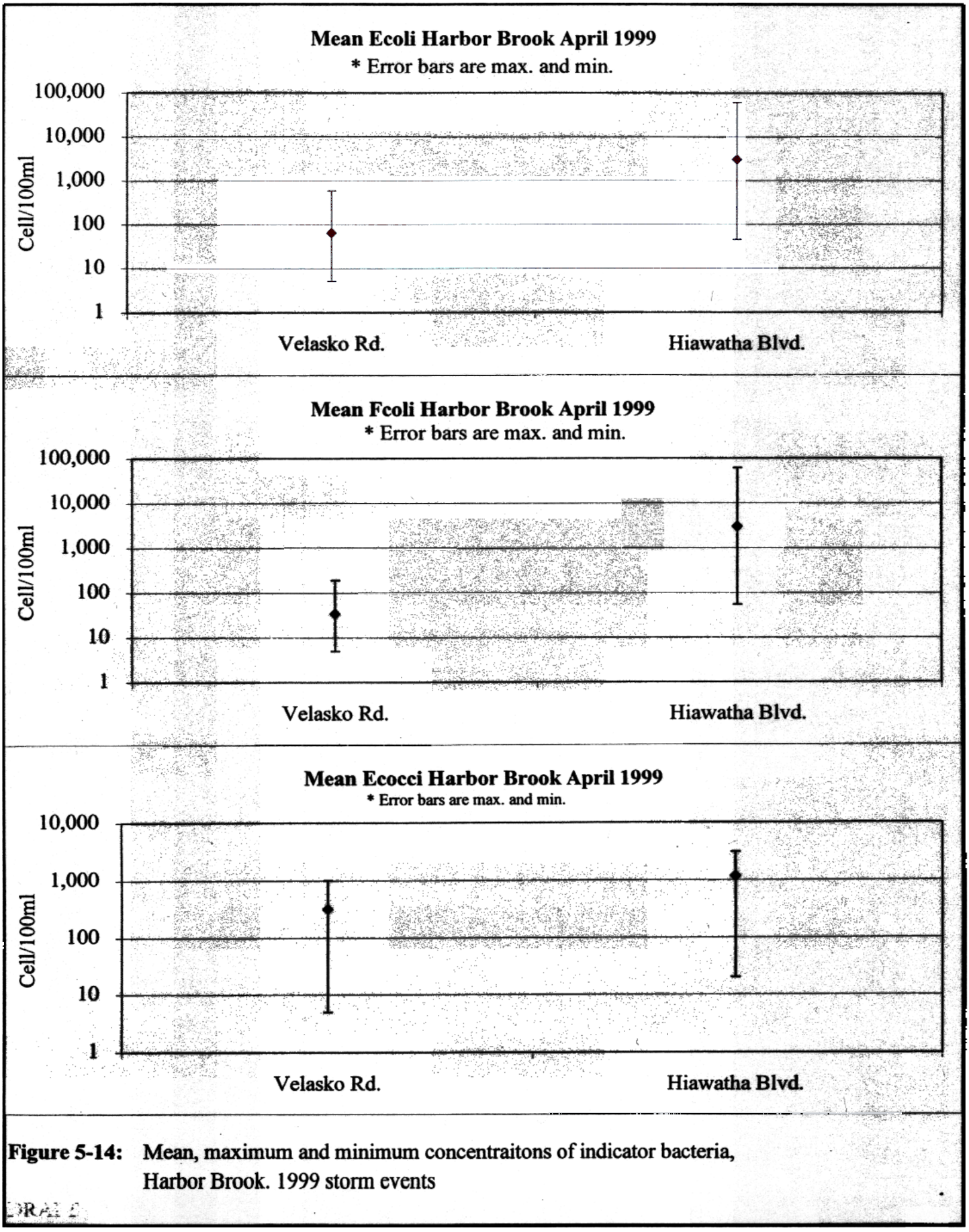


Figure 5-14: Mean, maximum and minimum concentraitons of indicator bacteria, Harbor Brook. 1999 storm events

TABLE 5-

Sampling Stations, Storm Event Program
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Stream	Site designation	Description
Onondaga Creek	Rt. 20	Downstream of mudboils, rural land use
	Dorwin Ave.	Low-moderate density residential land use, upstream of CSOs. Gauged site
	Spencer St.	Urban land use. Downstream of CSOs. Gauged site
	Inner Harbor	Near confluence with Onondaga Lake. Urban land use. Low-gradient segment dredged for navigation.
Ley Creek	Seventh North St.	Urban area, upstream of CSO discharges
	Park St.	Urban area, downstream of CSO discharges. Gauged site.
Harbor Brook	Velasko Rd.	Urban area, upstream of CSO discharges. Gauged site
	Hiawatha Blvd.	Urban area, downstream of CSO discharges. Gauged site.

TABLE 5-2
Summary of 1999 Storm Event Data, Onondaga Creek

Onondaga Lake 1999 Annual Report
Onondaga County, New York

STORM 1: APRIL 11 - 14, 1999	Rt 20	Dorwin Ave	Spencer St.	Inner Harbor
Total Phosphorus				
Avg.concentration (mg/l)	0.013	0.017	0.039	0.071
Flow-weighted average (mg/l)	n/a	0.015	0.062	n/a
Estimated load (kg/day)	n/a	8.3	26.7	n/a
Total Suspended Solids				
Avg.concentration (mg/l)	5.3	11.6	17.3	9.1
Flow-weighted average (mg/l)	n/a	10.6	20.9	n/a
Estimated load (kg/day)	n/a	1915	11771	n/a
TKN				
Avg.concentration (mg/l)	0.213	0.239	0.339	0.497
Flow-weighted average (mg/l)	n/a	0.230	0.429	n/a
Estimated load (kg/day)	n/a	116	228	n/a
Chloride				
Avg.concentration (mg/l)	149	94	174	536
Flow-weighted average (mg/l)	n/a	95	185	n/a
Estimated load (kg/day)	n/a	44878	114316	n/a
Fecal Coliform				
Avg.concentration (cells/100 ml)	30	20	3296	4709
Flow-weighted average (cells/100 ml)	n/a	16	6543	n/a
Estimated load (10^10 cells/day)	n/a	10	2277	n/a
E. Coli				
Avg.concentration (cells/100 ml)	56	24	3331	7462
Flow-weighted average (cells/100 ml)	n/a	21	6313	n/a
Estimated load (10^10 cells/day)	n/a	12	2306	n/a
Enterococci				
Avg.concentration (cells/100 ml)	100	49	2959	5812
Flow-weighted average (cells/100 ml)	n/a	52	6313	n/a
Estimated load (10^10 cells/day)	n/a	23	2045	n/a

TABLE 5-2 continued
Summary of 1999 Storm Event Data, Onondaga Creek

Onondaga Lake 1999 Annual Report
Onondaga County, New York

STORM 2: JUNE 29 - JULY 2, 1999	Rt 20	Dorwin Ave	Spencer St.	Inner Harbor
Total Phosphorus				
Avg.concentration (mg/l)	0.049	0.029	0.064	0.151
Flow-weighted average (mg/l)	n/a	0.028	0.072	n/a
Estimated load (kg/day)	n/a	1.9	6.9	n/a
Total Suspended Solids				
Avg.concentration (mg/l)	18.1	9.4	8.7	11.3
Flow-weighted average (mg/l)	n/a	9.3	9.5	n/a
Estimated load (kg/day)	n/a	612	981	n/a
TKN				
Avg.concentration (mg/l)	0.469	0.372	0.570	2.168
Flow-weighted average (mg/l)	n/a	0.363	0.615	n/a
Estimated load (kg/day)	n/a	24	62	n/a
Chloride				
Avg.concentration (mg/l)	734	327	666	689
Flow-weighted average (mg/l)	n/a	322	660	n/a
Estimated load (kg/day)	n/a	21232	70978	n/a
Fecal Coliform				
Avg.concentration (cells/100 ml)	961	320	77275	76825
Flow-weighted average (cells/100 ml)	n/a	148	27077	n/a
Estimated load (10^10 cells/day)	n/a	9	2404	n/a
E. Coli				
Avg.concentration (cells/100 ml)	740	95	12815	11977
Flow-weighted average (cells/100 ml)	n/a	107	17876	n/a
Estimated load (10^10 cells/day)	n/a	6	1515	n/a
Enterococci				
Avg.concentration (cells/100 ml)	370	70	4464	3562
Flow-weighted average (cells/100 ml)	n/a	85	6315	n/a
Estimated load (10^10 cells/day)	n/a	5	532	n/a

TABLE 5-2, CONTINUED
Summary of 1999 Storm Event Data, Onondaga Creek

Onondaga Lake 1999 Annual Report
Onondaga County, New York

STORM 3: OCTOBER 10 - 13, 1999	Rt 20	Dorwin Ave	Spencer St.	Inner Harbor
Total Phosphorus				
Avg.concentration (mg/l)	0.065	0.077	0.128	0.099
Flow-weighted average (mg/l)	n/a	0.028	0.109	n/a
Estimated load (kg/day)	n/a	5.1	62.7	n/a
Total Suspended Solids				
Avg.concentration (mg/l)	7.8	52.1	88.2	6.7
Flow-weighted average (mg/l)	n/a	10.4	68.3	n/a
Estimated load (kg/day)	n/a	1871	45293	n/a

[redacted]

TABLE 5-4

Summary of 1999 Storm Event Data, Harbor Brook

Onondaga Lake 1999 Annual Report

Onondaga County, New York

	STORM 1 *April 11 - 14*		*STORM 2* *June 29 - July 2*		*STORM 3* *October 10 - 13*	
	Velasko Rd.	Hiawatha Blvd.	Velasko Rd.	Hiawatha Blvd.	Velasko Rd.	Hiawatha Blvd.
Total Phosphorus						
Avg.concentration (mg/l)	0.016	0.035	0.033	0.089	0.033	0.109
Flow-weighted average (mg/l)	N/A	0.045	N/A	0.117	N/A	0.167
Estimated load (kg/day)	N/A	1.2	N/A	1.9	N/A	2.8
Total Suspended Solids						
Avg.concentration (mg/l)	3.6	10.9	1.4	29.3	6.2	10.4
Flow-weighted average (mg/l)	N/A	13.9	N/A	51.1	N/A	14
Estimated load (kg/day)	N/A	368	N/A	651	N/A	259
TKN						
Avg.concentration (mg/l)	0.194	0.265	0.287	0.674	0.323	0.483
Flow-weighted average (mg/l)	N/A	0.318	N/A	0.746	N/A	0.669
Estimated load (kg/day)	N/A	9	N/A	10.7	N/A	11.4
Chloride						
Avg.concentration (mg/l)	202	221	280	242	235	181
Flow-weighted average (mg/l)	N/A	222	N/A	232	N/A	163
Estimated load (kg/day)	N/A	6334	N/A	2770	N/A	2931
Fecal Coliform						
Avg.concentration (cells/100 ml)	35	2991	2750	11206	979	14791
Flow-weighted average (cells/100 ml)	N/A	7516	N/A	11954	N/A	36103
Estimated load (10^10 cells/day)	N/A	1.68E-05	N/A	213	N/A	5.27E-05
E. Coli						
Avg.concentration (cells/100 ml)	65	3036	1194	6826	705	5445
Flow-weighted average (cells/100 ml)	N/A	7476	N/A	6580	N/A	14529
Estimated load (10^10 cells/day)	N/A	1.70E-05	N/A	117	N/A	2.00E-05
Enterococci						
Avg.concentration (cells/100 ml)	322	1164	2816	4125	3850	5462
Flow-weighted average (cells/100 ml)	N/A	2358	N/A	3537	N/A	13810
Estimated load (10^10 cells/day)	N/A	5.58E-06	N/A	64	N/A	1.92E-05

CHAPTER 6

LAKE RESULTS

6.1 INTRODUCTION

Onondaga Lake was monitored biweekly between April and December 1999 for a comprehensive suite of water quality parameters. No winter sampling event was conducted, due to the warm winter and unreliable ice cover. Physical attributes of the lake, such as temperature and Secchi disk transparency, were monitored to document development of thermal stratification and changes in water clarity. Chemical parameters indicating the lake's trophic status, compliance with ambient water quality standards, ionic balance, nitrogen cycling, forms of organic and inorganic carbon, and content of heavy metals were measured and assessed. Biological parameters, including bacteria, phytoplankton, dreissenid veligers, and zooplankton were monitored. Samples were collected at various depths and locations in the lake depending on specific objectives.

The 1999 lake water quality results are summarized in Tables 6-1 and 6-2. Volume-weighted means and medians are presented for both the entire sampling period (early April through December, designated as the ice-free period) and the summer recreational season (mid-May through mid-September, designated as the growing season). Epilimnetic and hypolimnetic results are tabulated separately. In Tables 6-3 and 6-4, 1999 results are compared to annual results over the past decade. Table 6-5 summarizes the number of measurements below the analytical limit of detection for selected parameters. Results of the 1999 monitoring program are discussed in the following sections.

6.2 THERMAL CHARACTERISTICS AND MIXING

Onondaga Lake waters were completely mixed in the spring of 1999, as evident in the isothermal conditions measured through the end of April (Figure 6-1, top, and Figure 6-2). The upper waters began to warm rapidly in 1999, and by mid-May the lake had stratified into its characteristic layers (epilimnion, metalimnion, and hypolimnion). The upper mixed layer of Onondaga Lake reached its maximum temperature in late July. By early September the lake began to lose heat; and the epilimnion began to deepen. Isothermal conditions were evident by late October. The temperature of the entire water column continued to decrease through the end of the monitoring period in mid-December.

6.3 DISSOLVED OXYGEN

The concentration of dissolved oxygen (DO) measured at South Deep Station over the 1999 field sampling period is plotted in Figure 6-1 (bottom). Note that the DO concentration throughout the water column was high (100 percent of air saturation) when measured during the first sampling event of the spring. As the lake began to warm and thermally stratify, DO in the lower waters decreased. Decomposition of organic material in the sediments depleted the DO resources of the lower waters.

The slope of the decline in DO content of the lower waters was comparable to that of recent years (Figure 6-3). Onondaga Lake did not completely mix in the spring of 1993 and 1994 and dissolved oxygen concentrations in the hypolimnion were not replenished by exchange with the atmosphere. With the failure of spring mixing it was not possible to estimate the DO depletion rate for those years.

A quantitative measure of the rate of decline in hypolimnetic DO is the areal hypolimnetic oxygen deficit (AHOD). This metric is calculated as the product of the slope of the DO depletion plot (in units of $g \cdot m^{-3} \cdot d^{-1}$) and the mean depth of the hypolimnion during the calculation period (Wetzel and Likens 1991). This calculation is made using biweekly DO profile data collected at 0.5 meter intervals at the South Deep station. The depletion rate is calculated from profiles collected when the lake is stratified but average DO in the lower waters remains above 2 mg/l. In recent years, data from late May into June or early July met these criteria. Volume-averaged DO is calculated using measured DO concentrations at depths of 9 m and below, multiplying the concentration at each depth stratum by its proportional contribution to lake volume, and dividing the sum by the lake volume at 9 m and below.

Effler calculated AHOD in Onondaga Lake between 1989 - 1991 and reported a range of 1.1 - 1.87 $g \cdot m^{-2} \cdot d^{-1}$, mean value 1.47 $g \cdot m^{-2} \cdot d^{-1}$ (Effler 1994, pg. 352). The result for 1999 (1.249 $g \cdot m^{-2} \cdot d^{-1}$) is within this historical range. Much of the interannual variability in this parameter is due to meteorological conditions, which greatly affect the magnitude of vertical mixing.

The depth of the upper mixed layer fluctuates in response to wind-driven seiches, as evident from comparing profiles collected on June 29, July 13 and July 27. Low dissolved oxygen conditions extended from the lake sediments to a water depth approaching 5 or 6 meters from the surface during this period. This low oxygen zone is also associated with warm water and restricts the habitat available for fish species. Because only the shallow water depths retain sufficient dissolved oxygen throughout the summer to support aquatic life, the fish community is restricted to warm water species.

A quantitative estimate of the annual time duration and volume of anoxia in Onondaga Lake can be used as a basis of comparison of yearly oxygen resources. The volume of Onondaga Lake water and the time duration of DO at two concentrations (0 mg/l and 2 mg/l) are plotted in Figure 6-4, which includes data from 1992 – 1998 for comparison. This analysis suggests improving conditions in 1999. The number of days of anoxia (0 mg/l DO) and low DO (2 mg/l) are approximate, since the time interval between the dissolved oxygen profiles on which the calculations can be as long as 14 days.

In Onondaga Lake, the DO status of the upper waters during fall mixing is another important indicator of overall water quality. In 1999, the characteristic DO sag in the upper waters was evident as lake waters cooled and the upper mixed layer deepened. Anoxic lower waters were entrained higher in the water column and DO content of the water column was depleted to meet the chemical oxygen demand of the reduced species (such as hydrogen sulfide) that had accumulated in the lower waters during stratification. However, the average DO concentration in the upper waters remained above the state ambient water quality standard for Class B and C waters (5 mg/l daily average, 4 mg/l instantaneous concentration) based on the County's focused sampling program (Figure 6-5). The County obtained DO profiles on 16 sampling days between October 5 and November 3, 1999 during this critical fall mixing period. The 1999 fall mixing DO conditions were improved in 1999 as compared with recent years (Figure 6-6). As in the AHOD estimates, a great deal of interannual variability in fall DO is associated with meteorological conditions such as wind speed and air temperature.

The DO concentration in Onondaga Lake water was measured eight times over a 24-hour cycle on two occasions in summer 1999, June 14th and August 4th. Phytoplankton abundance had reached bloom levels on both days; chlorophyll *a* concentrations were 32 and 38 µg/l. Fluctuations in DO and pH at depths of 1 and 3 meters in the upper mixed layer are plotted in Figure 6-7. The magnitude of DO fluctuation ranged up to approximately 2 mg/l with highest concentrations late in the afternoon and minimum levels at dawn. This fluctuation reflects addition of DO through photosynthesis during daylight hours. Dissolved oxygen remained supersaturated throughout the 24-hour cycle during both days of monitoring. The diurnal pH fluctuation in the upper waters of approximately 0.3 standard units reflects the uptake of carbon dioxide during photosynthesis during daylight hours and the consequent shift in the calcium carbonate equilibrium in the lake waters.

In April 2000, Onondaga County installed a buoy at the South Deep station with the capability of continually monitoring water quality parameters at short (15 minute) intervals and relaying the data to a computer on shore through telemetry. Upstate Freshwater Institute and a number of cooperating research and educational organizations have also deployed equipment to monitor and report water quality conditions in the lake and river. These data will greatly enhance our understanding of the magnitude and significance of short-term fluctuations in dissolved oxygen, temperature, pH and other water quality parameters.

6.4 MAJOR IONS

Concentrations of sodium, chloride, and calcium decreased in Onondaga Lake in response to the April 1986 closure of the AlliedSignal chlor-alkali facility (Figure 6-8). The short hydraulic retention time (fast flushing rate) of Onondaga Lake led to this rapid decline in ambient concentration in response to the sudden change in external loading. Variability in concentrations in recent years reflects annual precipitation; concentrations tend to be higher during dry years such as

1995, 1997, 1998 and 1999. An additional complication is introduced by the installation of the aquifer depressurizing wells in the Tully Valley which discharge to Onondaga Creek. The depressurizing wells discharge an average total of 350 gallons per minute of brackish to salty water. While the flow from the depressurizing wells is low compared with the natural tributaries and METRO (350 gpm is equivalent to 0.5 mgd or 0.74 cfs), the chloride load to the lake from this source may be detectable. There is some evidence that chloride concentrations in the regional aquifer are increasing due to mixing between groundwater strata induced by solution mining in the Tully Valley (W. Kappel, USGS personal communication January 2000). Groundwater discharge zones exist along the lower reaches of Onondaga Creek, and this increased salt load will eventually make its way to the lake waters.

Prior to the closure of AlliedSignal, differences in ionic composition of the hypolimnion and epilimnion were more evident. Note that the concentrations of sodium and chloride and the specific conductance of the hypolimnion were slightly higher than concentrations in the epilimnion during 1993 and 1994, two years when the lake did not completely mix in the spring. The ionic balance of the lake waters has changed significantly since the closure of the AlliedSignal facility (Figure 6-9). Both the total amount of dissolved salts and the percentage contribution of calcium to the cations has decreased. The composition of Onondaga Lake water has become more comparable to other regional lakes with the elimination of point source loading from the chlor-alkali facility (Table 6-6).

6.5 NITROGEN SPECIES

The 1999 volume-weighted concentrations of total Kjeldahl nitrogen (TKN) and ammonia-nitrogen (NH_3-N) were below the ten-year average, as shown in Tables 6-1 and 6-2. This decrease in annual average concentration largely reflects lower concentrations during the summer months, now that operations and equipment at the METRO facility have been modified to support conversion of ammonia into nitrate (in the biological process of nitrification) prior to discharging wastewater to the lake. As discussed in Chapter 5, the annual period of nitrification of METRO effluent continues to expand and wastewater ammonia levels were low from early June through late November.

The existing New York State ambient water quality standard for Class B and C waters was exceeded from the beginning of the monitoring period in late March through July (Figure 6-10). This standard is designed to protect the aquatic community from chronic toxicity conditions. Ammonia concentrations in the upper waters have continued to decline in response to the reduction in ammonia loading from METRO. The concentration in the lower waters is plotted as Figure 6-11.

Histograms of the frequency and magnitude of exceedances of the state Class B and C standard in the lake's upper waters from 1995 – 1999 are displayed in Figure 6-12. The histogram plots delta ammonia N, defined as the difference between measured ammonia concentrations and the ambient water quality standard applicable to measured pH and temperature conditions. Observations of zero or less indicate compliance, observations greater than zero indicate exceedances. A shift towards compliance is evident in the data series.

In December 1999, EPA issued revised ambient water quality criteria for ammonia in fresh water. Criteria are defined as the maximum concentration of substances that will do no harm to the aquatic ecosystem (i.e. water quality conditions will support the resource's designated best use). States may adopt criteria as standards or may adopt more stringent standards. New York is currently examining the new federal criteria and evaluating the need to revise their standards. The federal criteria are plotted in Figure 6-13 along with the current NYS standards and measured concentrations. The federal criteria are consistently higher (less stringent) than the state standard. This revision is based on the latest research quantifying the effect of ammonia on sensitive life stages of aquatic organisms. When the 1999 data are compared with the federal criteria, the compliance picture is very different. With the exception of early spring conditions at the lake surface (0-meter sample), ammonia concentrations in 1999 met the federal criteria for protection of aquatic life.

Nitrite-nitrogen (NO_2-N) concentrations in the upper waters were lower in 1999 than measured in any previous year, continuing the trend reported in the 1998 annual report. This is a direct reflection of more complete nitrification of the treated wastewater prior to discharge. Concentrations of exceeded the ambient water quality standard (0.1 mg/l), promulgated to protect a warm water fish community in the lake's upper waters (Figure 6-14) and lower waters (Figure 6-15). Consistent with the concentration data, the margin and duration of the standard violation were less in 1999.

Concentrations of nitrite in the upper and lower waters increased dramatically in the late fall, after stratification had broken down. Cooler wastewater temperatures decreased the efficiency of nitrification at METRO by the end of the year.

As discussed in Chapter 3, METRO effluent is the major external source of the nitrogen species TKN, NH_3-N, and NO_2-N. Effluent nitrification began in June 1999, once wastewater temperatures were high, and persisted through the end of the year. The pattern of nitrogen species measured in Onondaga Lake reflects the effectiveness of ammonia conversion at METRO (Figure 6-16).

6.6 PHOSPHORUS AND PRODUCTIVITY

Phosphorus (P) is the limiting nutrient for phytoplankton in Onondaga Lake. However, ambient concentrations are currently elevated; temperature and light limit phytoplankton growth (Connors, Auer, and Effler 1996). The concentrations of P measured in the upper and lower waters of this eutrophic, dimictic lake during the 1999 monitoring program are graphed in Figure 6-17. Note the decrease in concentrations in the upper waters after thermal stratification developed, indicating that the rate of P uptake and subsequent loss to the lower waters exceeded the rate at which P is supplied from METRO and the tributaries. The P concentration in the lower waters increased rapidly once thermal stratification developed; there is not sink of phosphorus from algal uptake below the photic zone. The increase in TP concentration over time in the lower waters results from algal decomposition and release from the lake sediments.

Total P (TP) in the lake's upper waters (volume average calculation, May 15 – Sept. 15) averaged 61 µg/l during 1999. To assess compliance with the NYSDEC guidance value for TP in lakes, samples were collected at a depth of one meter at biweekly intervals, June through September. The average TP concentration in this data set was 55 µg/l, which exceeds the New York State guidance value for phosphorus in water of 20 µg/l. This statewide guidance value is based on perceived suitability of water for recreational use.

Chlorophyll *a* concentration in the upper waters averaged 23.5 µg/l between mid-May and mid-September, 1999. There is a tremendous amount of seasonal variability in this parameter. Weekly measurements were obtained in 1999 to better capture the short-term variability. The summer of 1999 was characterized by high algal abundance late June through August. The 1999 chlorophyll data were within the range of historical data, particularly given the high standard error of the mean (Figure 6-18).

The pattern of chlorophyll *a* concentration measured in recent years over the ice-free monitoring season is plotted in Figure 6-19. Note the variability from year to year in the magnitude of spring phytoplankton blooms, the timing of clearing events, and the timing and magnitude of summer phytoplankton blooms.

Secchi disk transparency measured during the summer 1999 is plotted in Figure 6-21. After mid-July, water transparency was reduced as algal abundance increased. Compliance with the swimming safety guidance value of 1.2 m (4 feet) was achieved on only seven of 13 weekly sampling events at South Deep during the recreational season (June, July, and August). Secchi disk transparency was also monitored at a network of nearshore stations in order to evaluate the lake's suitability for water contact recreation in shoreline park areas. Data from Maple Bay, Onondaga Lake Park, and Willow Bay are plotted in Figure 6-21. These results demonstrate more consistent compliance with the swimming safety guidance at the nearshore stations. An interesting feature of the nearshore data set is the differences in transparency measured on the same date. Particularly in July and August, this reflects the impact of the prevailing winds in concentrating algal blooms along the eastern and more southern shorelines.

Phosphorus, chlorophyll *a*, and Secchi disk transparency are three common indicators of lake trophic status. Values of the three parameters measured over the previous twelve (12) years are plotted in Figure 6-22. Note the inverse scale for Secchi disk transparency (higher measurements are associated with clearer water and a lower abundance of algae). This graph illustrates the high year-to-year variability in trophic status indicators in Onondaga Lake, as well as the lack of strong correlation between the three parameters.

6.7 INDICATOR BACTERIA

NYSDEC has ambient water quality standards for maximum density of indicator bacteria in surface waters. For Class B waters the standards are developed to protect contact recreational uses including swimming. There are a wide variety of disease-causing bacteria, viruses, parasites, and other microorganisms that can enter the water and be transmitted to humans. Some are indigenous to natural waters. Others are carried from wastewater sources including treated wastewater, septic systems and runoff from animal and wildfowl areas. Infected swimmers themselves are also a source of pathogens.

The ideal way to determine potential health hazards is to test directly for disease-causing organisms. Unfortunately, detection of these organisms requires very complex procedures and equipment. In addition, there are hundreds of different kinds of pathogens; to test for each one would be impractical. Most public health officials, therefore, simply test for the presence of an *indicator organism*. The relative abundance of the indicator organism in a sample can serve as a warning of the likely presence of other, more dangerous pathogens in the water. Public health officials usually monitor for the presence of one or more indicator organisms as part of a regular sampling program.

EPA is actively investigating the relationship between indicator organisms and the potential for water-borne disease. The EPA mission includes developing guidance on the maximum level of pollution acceptable for various uses of water. In 1986, EPA issued criteria for maximum levels of indicator organisms present in waters used for full-body contact recreation. Criteria reflect the best professional judgment of the scientific community.

Waterbody	Federal Criteria
Freshwater	33 enterococcus bacteria /100 ml (geometric mean)
	126 *E. coli* bacteria /100 ml (geometric mean)
Marine water	35 enterococcus bacteria /100 ml (geometric mean)
	104 enterococcus bacteria /100 ml (instantaneous)

States have the option of adopting the federal criteria for sanitary quality of bathing beaches or utilizing other indicators. The indicator organisms most often used to indicate sanitary conditions at bathing beaches are fecal coliform bacteria and enterococcus bacteria. New York uses the concentration of fecal coliform bacteria to indicate suitability for water contact recreation. NYCRR Parts 701.19 and 701.20 stipulate as follows for fresh surface waters:

> "The monthly median coliform value for 100 ml of sample shall not exceed 2400 from a minimum of five examinations, and provided that not more than 20 percent of the samples shall exceed a coliform value of 5000 for 100 ml of sample and the monthly geometric mean fecal coliform value for 100 ml of sample shall not exceed 200 from a minimum of five examinations. The standard shall be met during all periods when disinfection is practiced"

Coliforms belong to the enteric bacteria group, Enterobacteriaceae, which is comprised of various species found in the environment and in the intestinal tract of warm-blooded animals. Fecal coliforms are the part of the coliform group that is derived from the feces of warm-blooded animals. The fecal test differentiates between coliforms of fecal origin and those from other sources. Enterococci are a subset of the fecal coliform group. Like fecal coliforms, they indicate fecal contamination by warm-blooded animals. They are useful because they are found only in certain animals. Examination of the ratio of fecal coliform to enterococcus can, therefore, indicate whether the bacterial pollution is from humans or animals.

The concentration of fecal coliform bacteria measured at South Deep is plotted in Figure 6-25. Concentrations in the upper waters were low during the period that the SPDES permit for METRO requires chlorination of the facility's effluent (April 1 to October 15). Bacteriological quality at the South Deep station met the state's ambient water quality

standards for water contact recreation (Class B waters). Concentrations of fecal coliforms were low throughout the period of disinfection when the standard must be met.

The 1999 Clean Water Action Plan addressed the issue of water quality for primary contact recreation and strongly encouraged the states and tribes to adopt the federal criteria for bacteria levels as ambient water quality standards. Because of the increasing emphasis placed on alternative indicators of sanitary quality of waters used for swimming, the County began in 1999 to measure three classes of bacteria in the nearshore waters of Onondaga Lake: fecal coliforms, E. coli and Enterococci. Sampling was conducted in conjunction with the three storm events (April, June-July, and October). Additional samples were collected at an approximately weekly frequency at three potential bathing beach sites (Maple Bay, Willow Bay, and Onondaga Lake Park). These data are plotted in Figure 6-24. Following storms, ambient criteria and standards were exceeded at stations near the mouths of tributaries with CSO discharges. It is interesting to compare the spatial differences in bacteria concentrations in the lake. The frequency of violations decreased with distance from the sources on the southern end. The highest compliance frequency with Class B Standards was calculated using fecal coliform bacteria (Table 6-7). That is E. Coli and Enterococci data indicate the potential presence of pathogens at concentrations adversely affecting human health in samples where the F. Coli indicator would not.

COMPLIANCE WITH NEW YORK STATE AMBIENT WATER QUALITY STANDARDS AND GUIDANCE VALUES

Compliance of Onondaga Lake's upper and lower waters with applicable ambient water quality standards is summarized in Table 6-8. The lake is Class B in the northern basin and Class C in the southern basin. Water quality in both classes must be suitable for fish survival and propagation. Class B waters are be suitable for primary water contact recreation (such as swimming). Class C waters are to be suitable for secondary water contact recreation (such as boating).

Similar to previous years, Onondaga Lake waters were not in compliance with ambient water quality standards for ammonia N, DO, the TP guidance value, nitrite N, and total dissolved solids. The findings of monitoring for indicator bacteria are discussed above.

The annual lake monitoring program has consistently collected data at the deepest point of Onondaga Lake, located in the southern lake basin. This single station is considered to be representative of conditions lakewide. In order to evaluate the extent to which spatial heterogeneity might have developed, a second station is sampled four times each year in conjunction with South Deep Station to provide a basis for comparison. The second station, North Deep, is the deepest point in the northern lake basin. The results of the 1999 paired sampling events are presented in Appendix A. As in previous years, the differences between the stations is insignificant, and therefore, the South Deep Station is considered to be representative of lakewide conditions.

CONCENTRATIONS OF MERCURY AND METHYLMERCURY

As part of the Ambient Monitoring program, the County monitors concentrations of total mercury in the lake's upper and lower waters several times each year using Method 1631, detection limit of approximately 0.1 ng/l. Prior to 1998, routine monitoring of mercury in lake waters used the cold vapor atomic absorption method 245.2, with a detection limit of 200 ng/l (0.2 µg/l). Sampling for mercury was conducted on three occasions in 1999: April 20, August 10, and October 15. These dates were selected to bracket the annual cycle of stratification and mixing and measure mercury levels during anoxic conditions in the lower waters.

Results are summarized in Figure 6-25 and Table 6-9. April sampling was completed during the period of lake mixing and concentrations of total mercury were consistent from top to bottom, north to south. Methyl mercury concentrations were virtually nondetectable (in the range of 0.1 – 0.2 ng/l) during this sampling event. Dissolved oxygen concentrations were close to saturation throughout the water column. The August sampling event was characterized by greater spatial variability in total mercury concentration between the north and south stations. Dissolved oxygen concentration was 0 mg/l at 18 m, and methyl mercury concentrations were consistent at 8 – 9 ng/l. By the October 15 sampling date, the lake had begun to mix and methyl mercury was detectable in the upper waters of both the north and south basins. Concentrations were higher in the anoxic lower waters.

6.10 TREND ANALYSIS

The seasonal Kendall test (Hirsch and Slack 1984) forms the technical basis of the trend analysis software developed by Dr. William W. Walker to analyze long-term trends in water quality. Table 6-10 summarizes the trend analysis results for the Onondaga Lake epilimnion and hypolimnion at the South and North Deep monitoring stations. Because the North Deep is sampled only four times each year, the results of the South Deep trend analysis are more robust indicators of changes in lakewide water quality.

The trend analysis considers the number of samples over the time period, median concentration of each parameter, percent change in the median value per year, serial correlation coefficient (trend and seasonal variations removed), and statistical significance of any change in value over time. Statistical evaluation calculates the probability that the trends are due to chance. Generally, a five to ten percent probability that calculated trends are due to chance is considered acceptable. Results of trend analysis over the 1990 to 1999 period reflect changes in the water quality characteristics over this 10-year "window."

With implementation of the AMP, data analysis will increasingly focus on statistical testing for changes in water quality. Dr. William Walker completed "A Statistical Framework for the Onondaga Lake Ambient Monitoring Program Phase I and Phase II" to evaluate the sampling frequency and number of replicates. The AMP is designed to enable a statistically valid evaluation of the effectiveness of the improvements to the County's wastewater treatment and collection system.

As summarized in Table 6-10, epilimnetic concentrations of sodium and chloride are increasing at the South Deep station. This finding, first noted in the 1998 trend analysis, is a distinct change from previous years. Prior to 1998, the closure of AlliedSignal in 1986 and the resulting precipitous decline in chloride loading dominated the trend analysis. The pattern of wet years early in the 10-year record and dry years late in the record, discussed in Chapter 3, may be a contributing factor to the observed trend. Fecal coliform bacteria levels at South Deep show a decreasing trend. The concentration of sulfate is increasing in the upper waters. There is an increasing trend in the concentration of total solids, which includes these dissolved salts. Finally, Secchi disk transparency is increasing at South Deep, indicating improved water clarity.

In the hypolimnion at South Deep, dissolved oxygen concentrations continue to demonstrate a statistically significant improvement. This trend is an indicator of improved water quality conditions. The increase in nitrite N may be an indicator of an improved oxygen status in the lake's lower waters or may reflect inhibition of the nitrification process that would fully oxidize ammonia to nitrate. In the lower waters, concentrations of calcium, total suspended solids, filtered and unfiltered total organic carbon, and total Kjeldahl nitrogen are decreasing. Overall, the decrease in these water quality parameters may reflect a decline in the level of algal production in the lake.

Trends at the North Deep station are based on fewer samples and are therefore less representative of lakewide water quality conditions. It is interesting that the North Deep results suggest a decrease in phosphorus concentrations of the upper and lower waters and an increasing trend in pH.

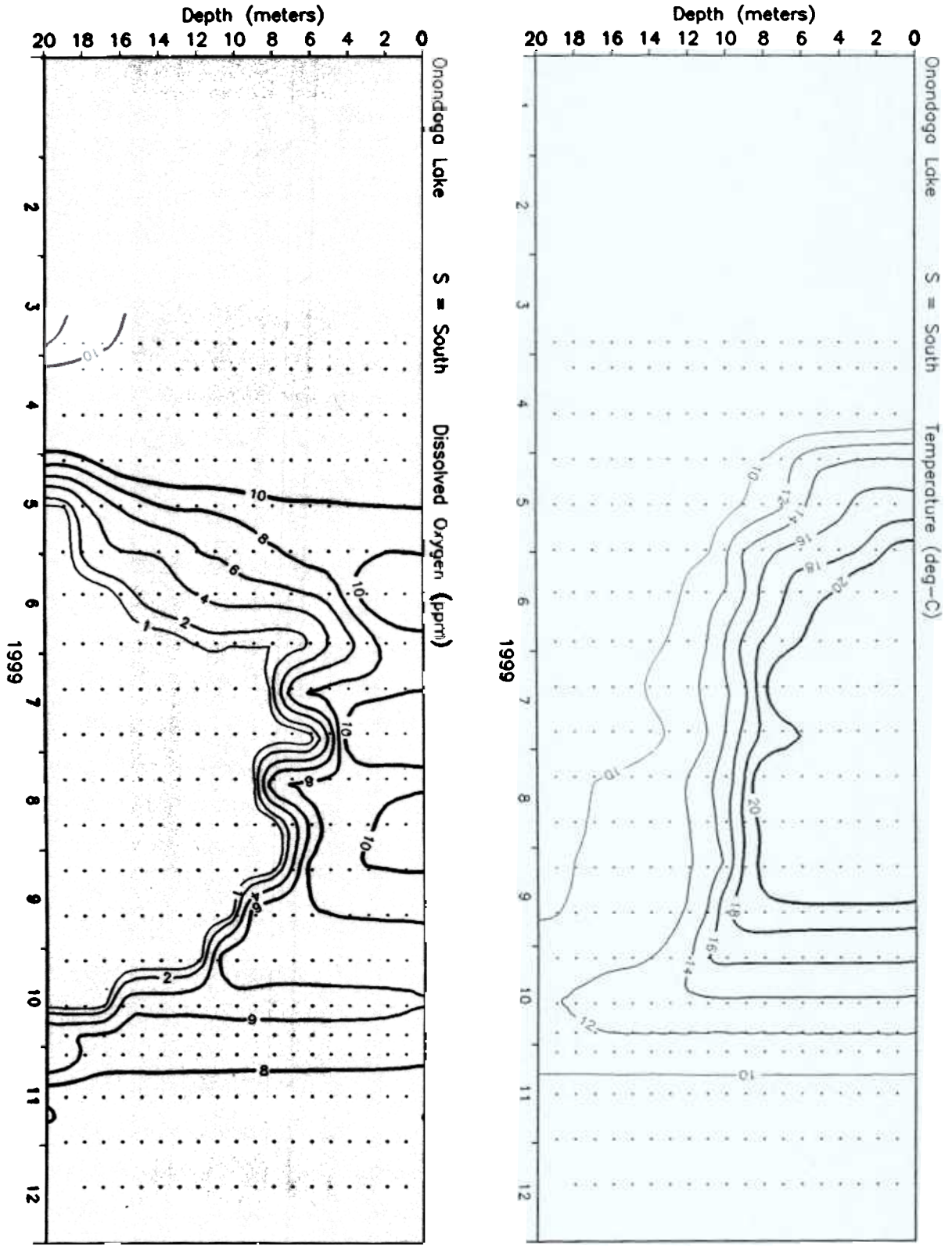


Figure 6.1 Isopleths of Water Temperature and Dissolved Oxygen Concentration, 1999

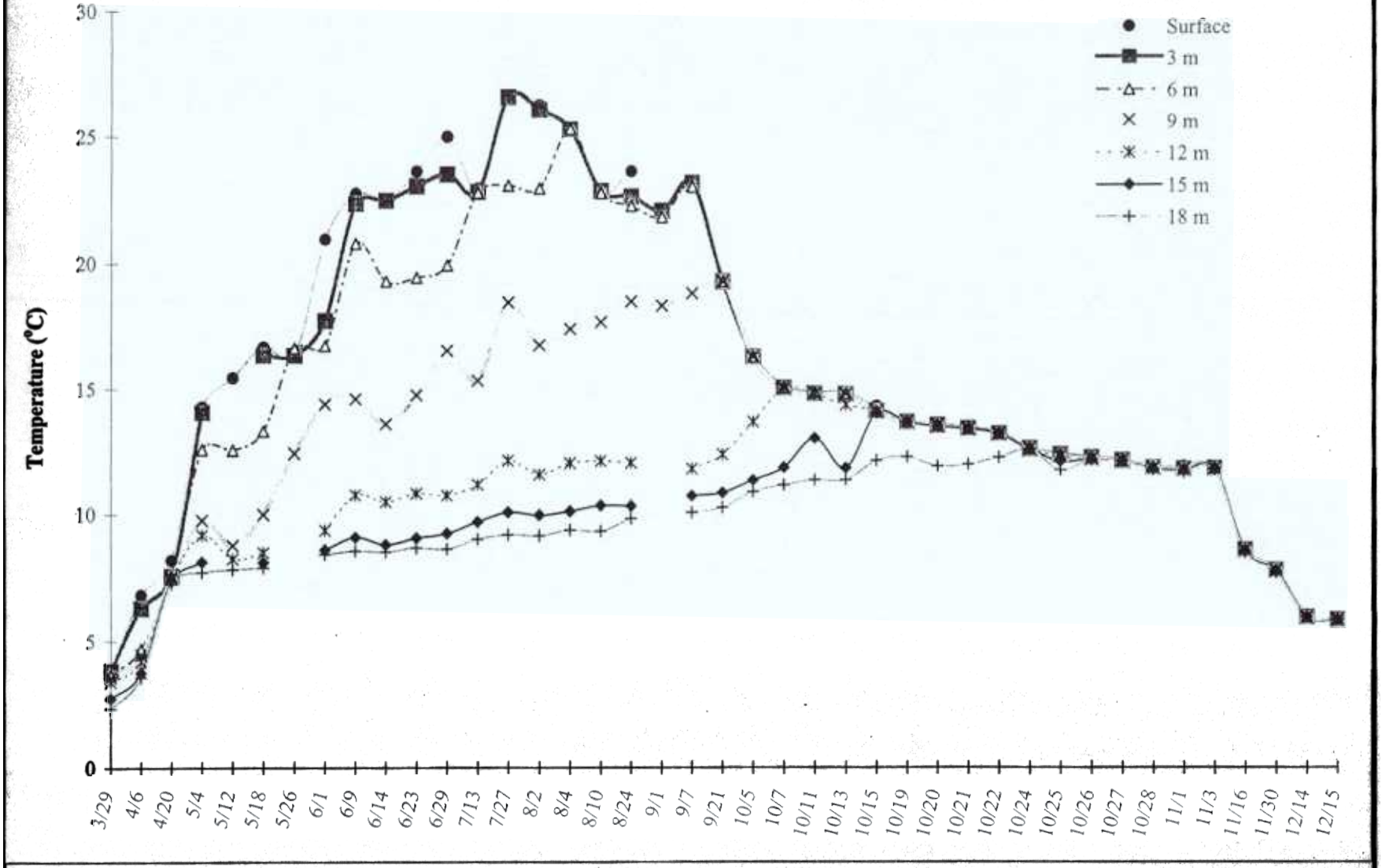
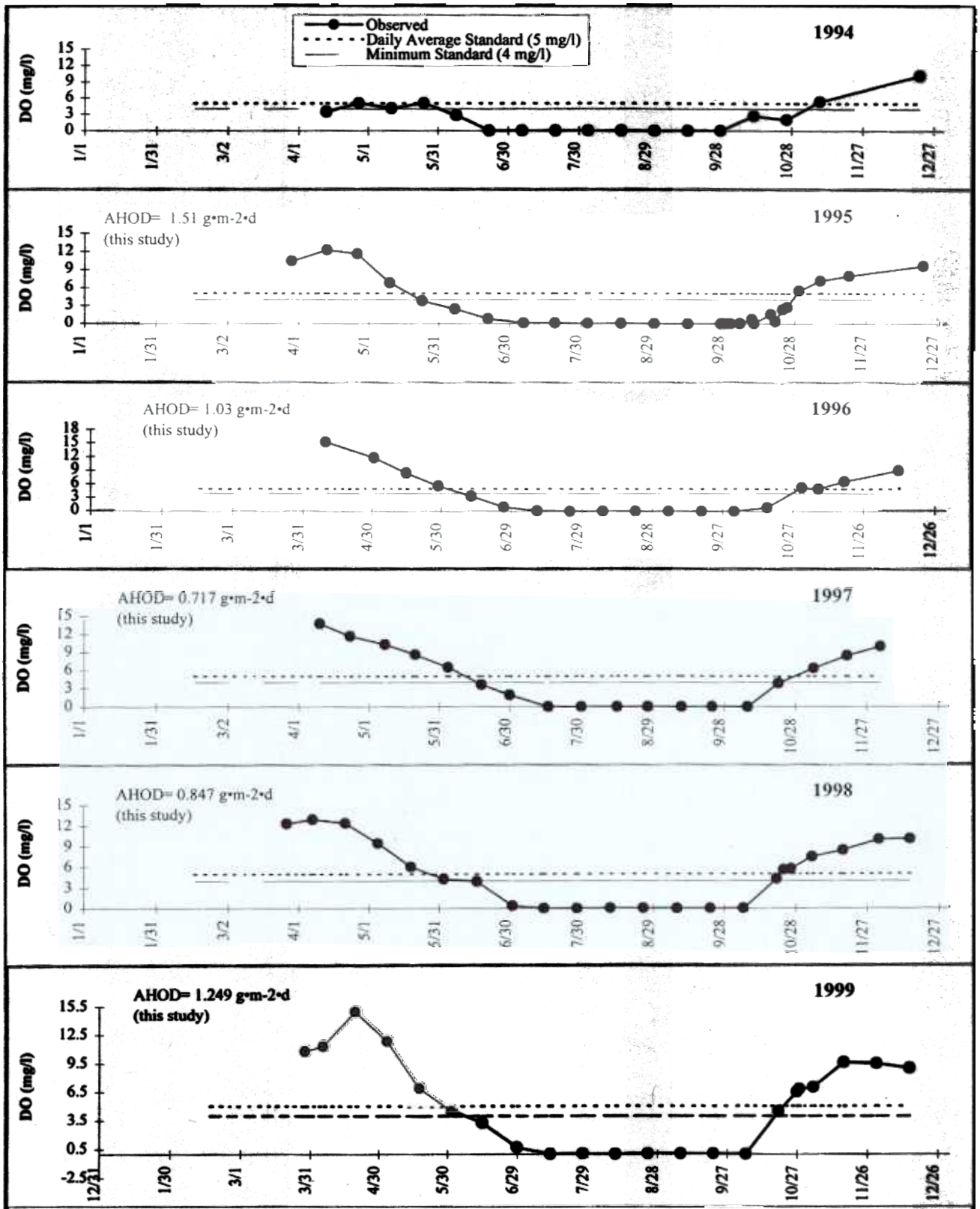


FIGURE 6-2 **TEMPERATURES AT 3 METER INTERVALS IN ONONDAGA LAKE, 1999**

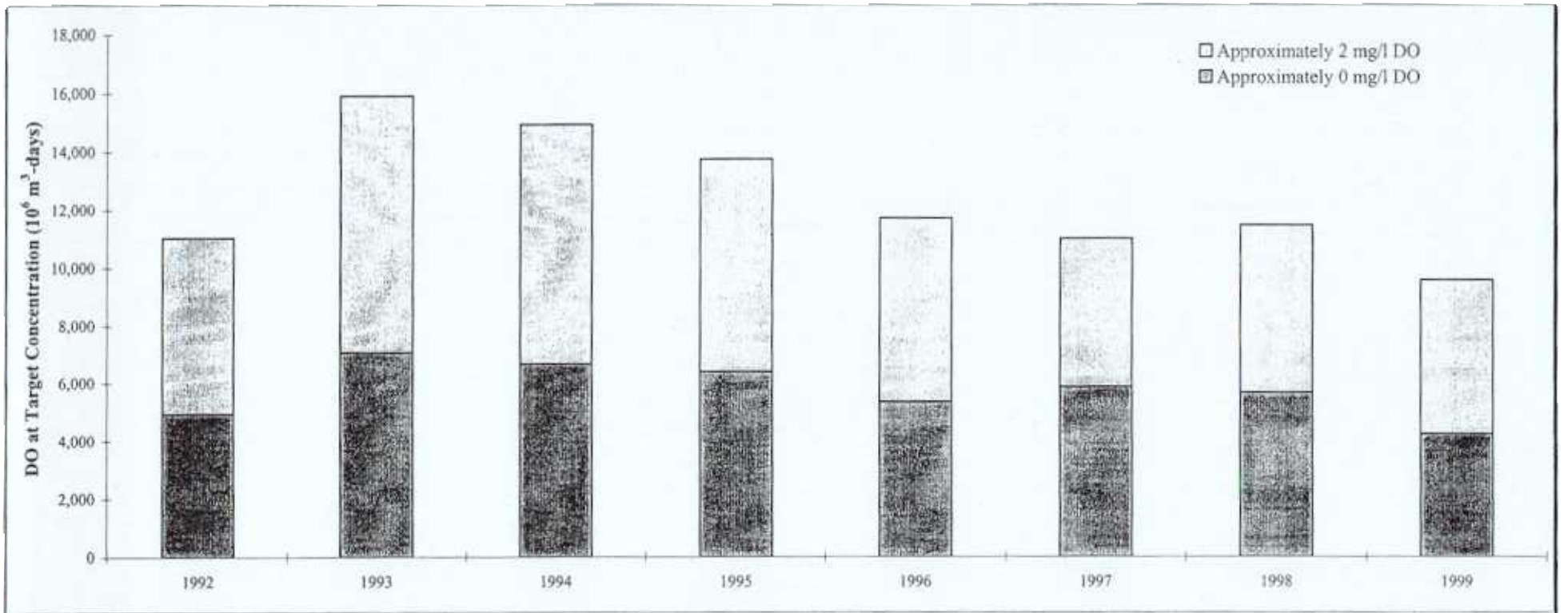
*Includes data collected during regularly scheduled events.



Standards are published in New York Ambient Water Quality Standards and Guidance Values for Class B, C waters (NYSDEC, 1993).

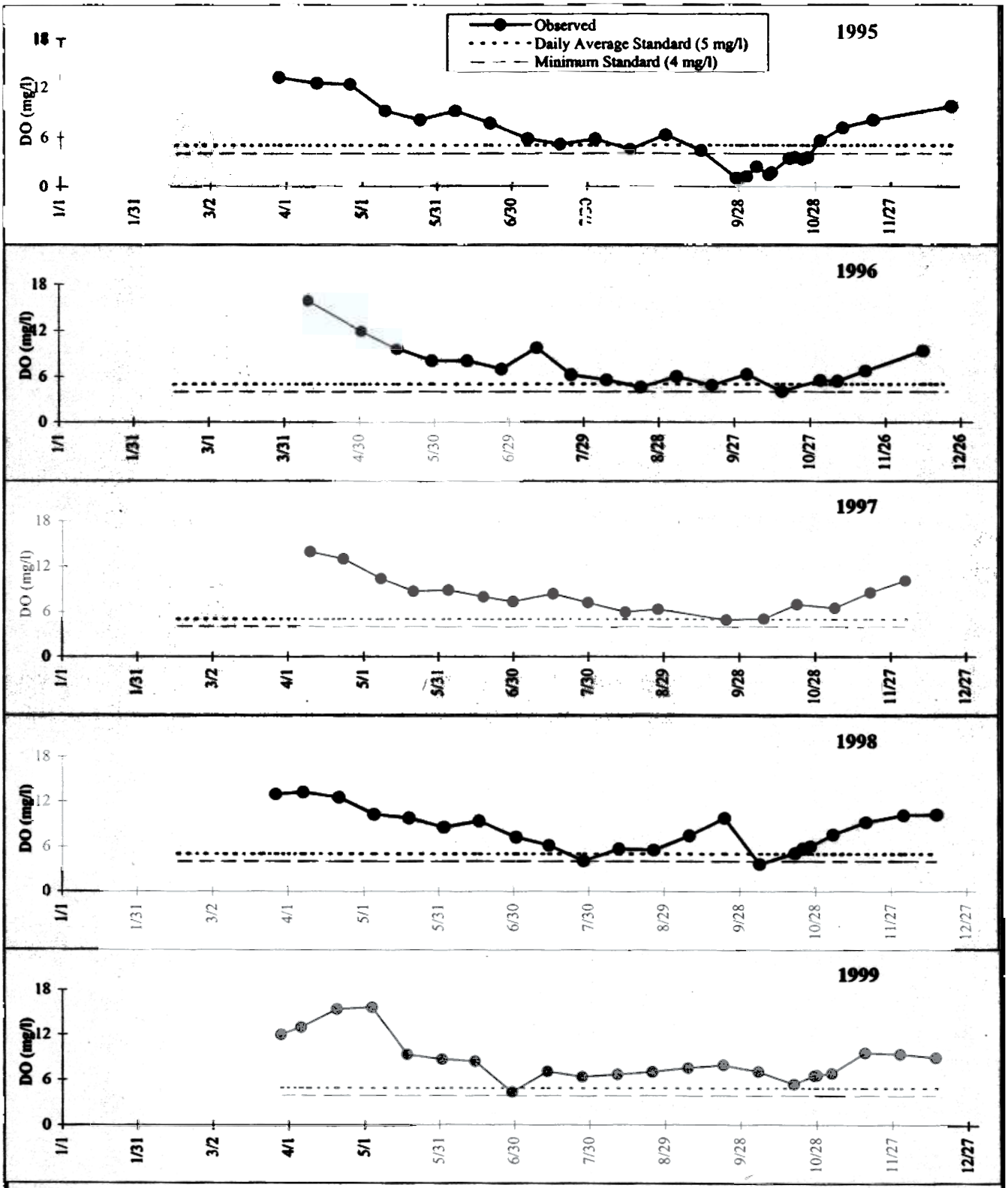
*** See text for discussion of AHOD calculation.**

FIGURE 6-3 VOLUME-WEIGHTED DISSOLVED OXYGEN IN THE LOWER WATERS (12-18M) OF ONONDAGA LAKE, 1994-1999



Note:
In 1993, DO at 15 m depth was approximately 2 mg/l at the start of the monitoring program. In 1993 and 1994, DO at 18 m depth was approximately 0 mg/l at the start of the monitoring program. In these cases, DO was assumed to be at the indicated level beginning with April 1 of that year (the approximate start of lake monitoring).
Calculations use sampling data collected approximately bi-weekly.

FIGURE 6-4 VOLUME-DAYS OF DISSOLVED OXYGEN AT TARGET CONCENTRATIONS IN ONONDAGA LAKE, 1992-1999



Standards are published in New York Ambient Water Quality Standards and Guidance Values for Class B, C waters (NYSDEC, 1993).

FIGURE 6-5 VOLUME-WEIGHTED DISSOLVED OXYGEN IN THE SOUTH BASIN UPPER WATERS (0-9M) OF ONONDAGA LAKE, 1995-1999

Fig 6-5 epi_DO.xls

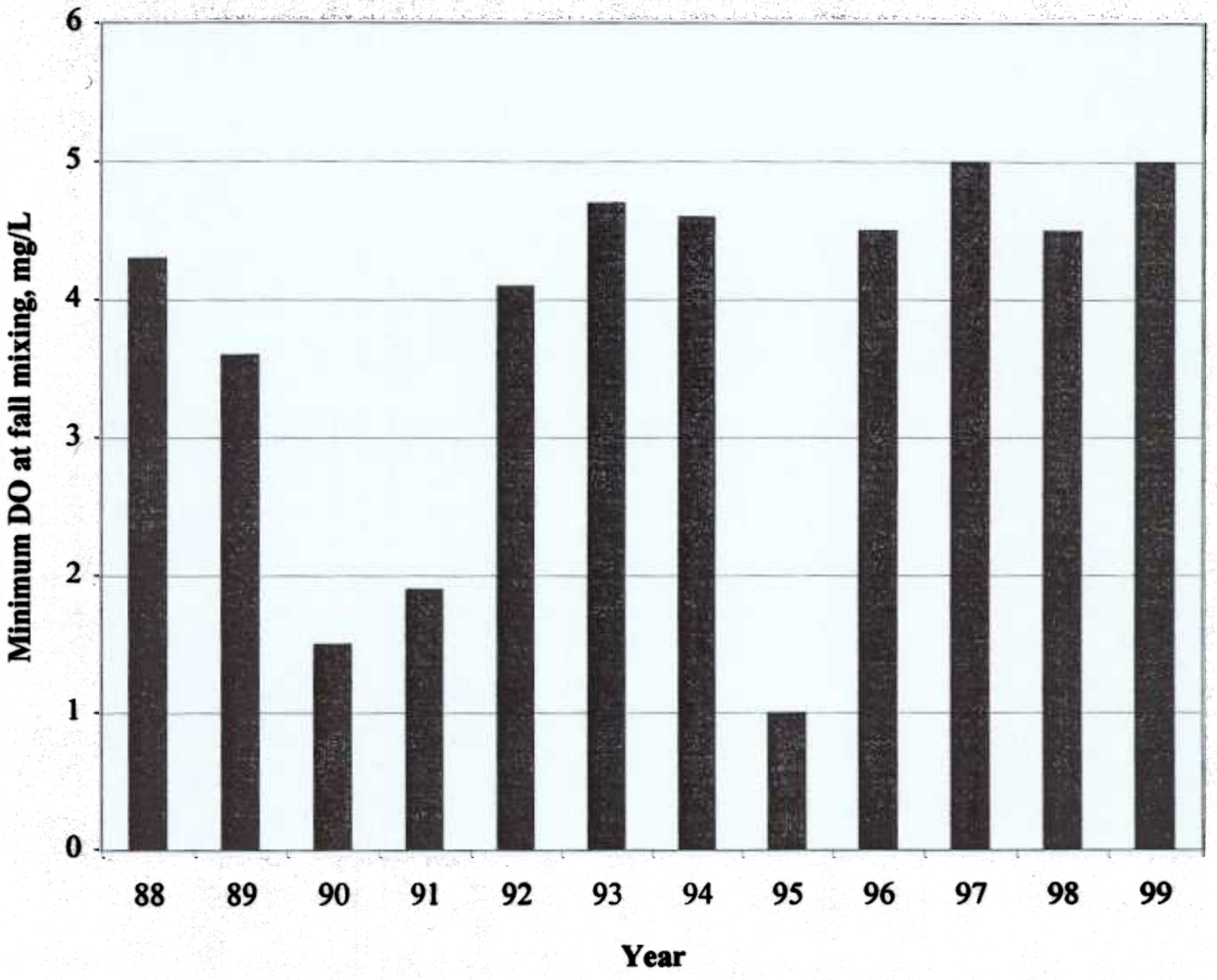
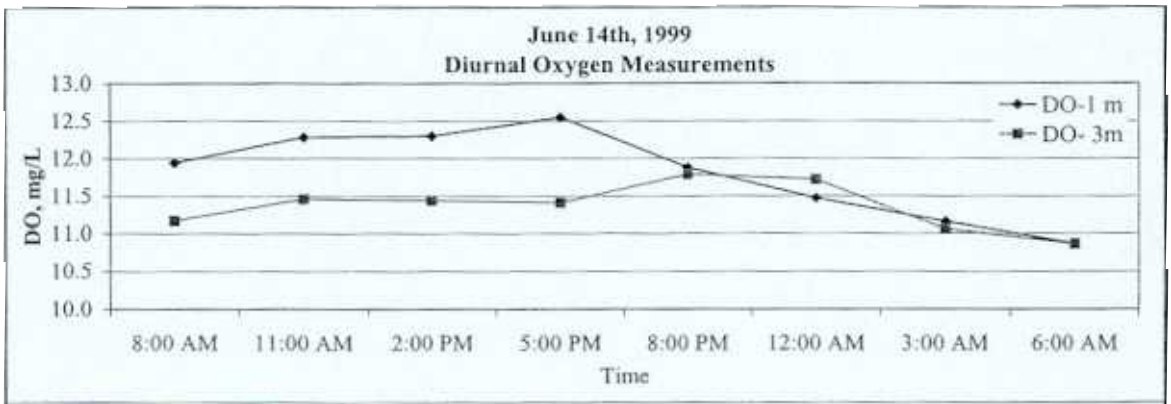
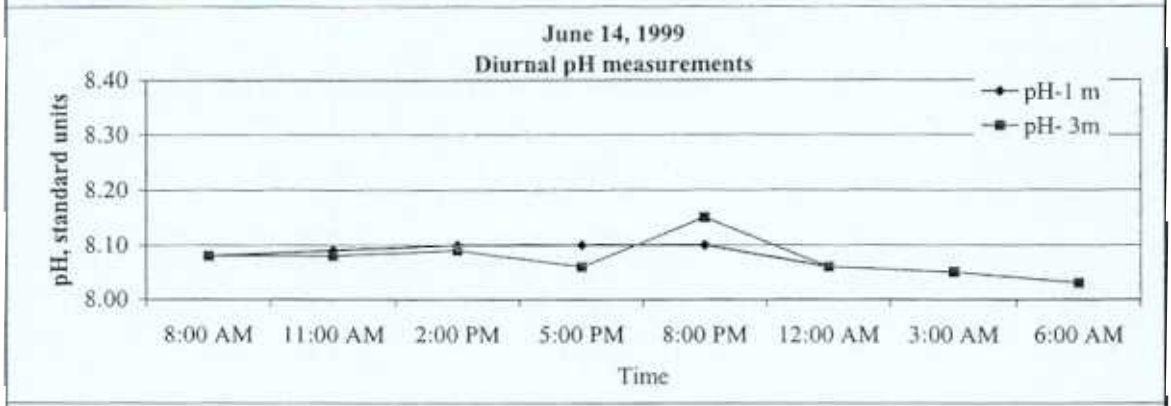
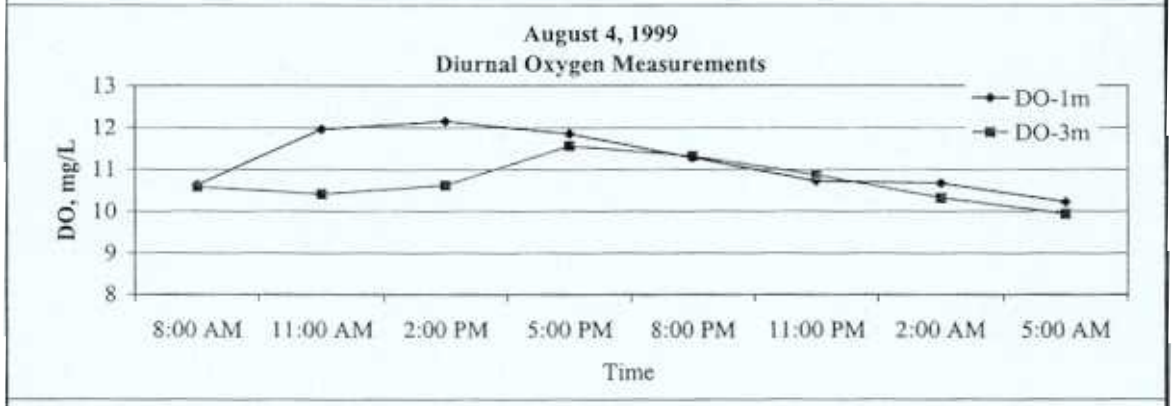


FIGURE 6-6 : Minimum Dissolved Oxygen Concentration Measured in Upper Waters of Onondaga Lake During Fall Mixing, 1988-1999







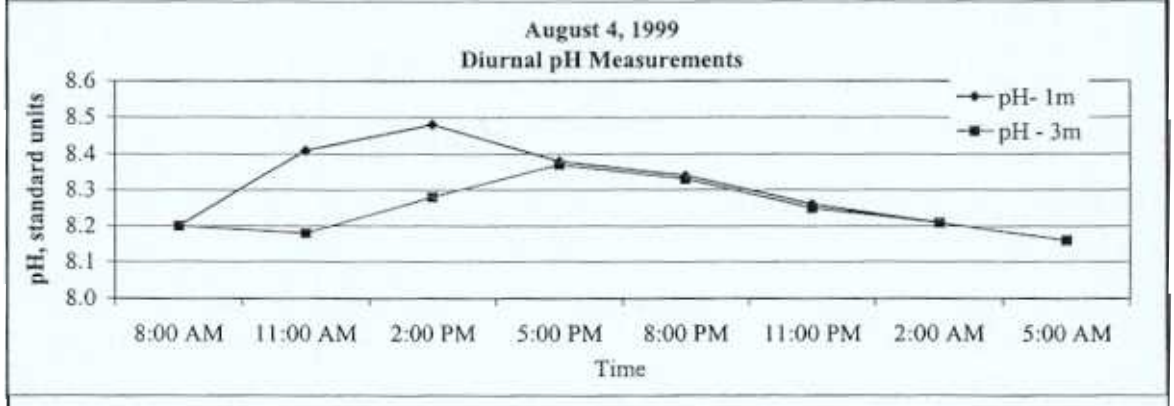
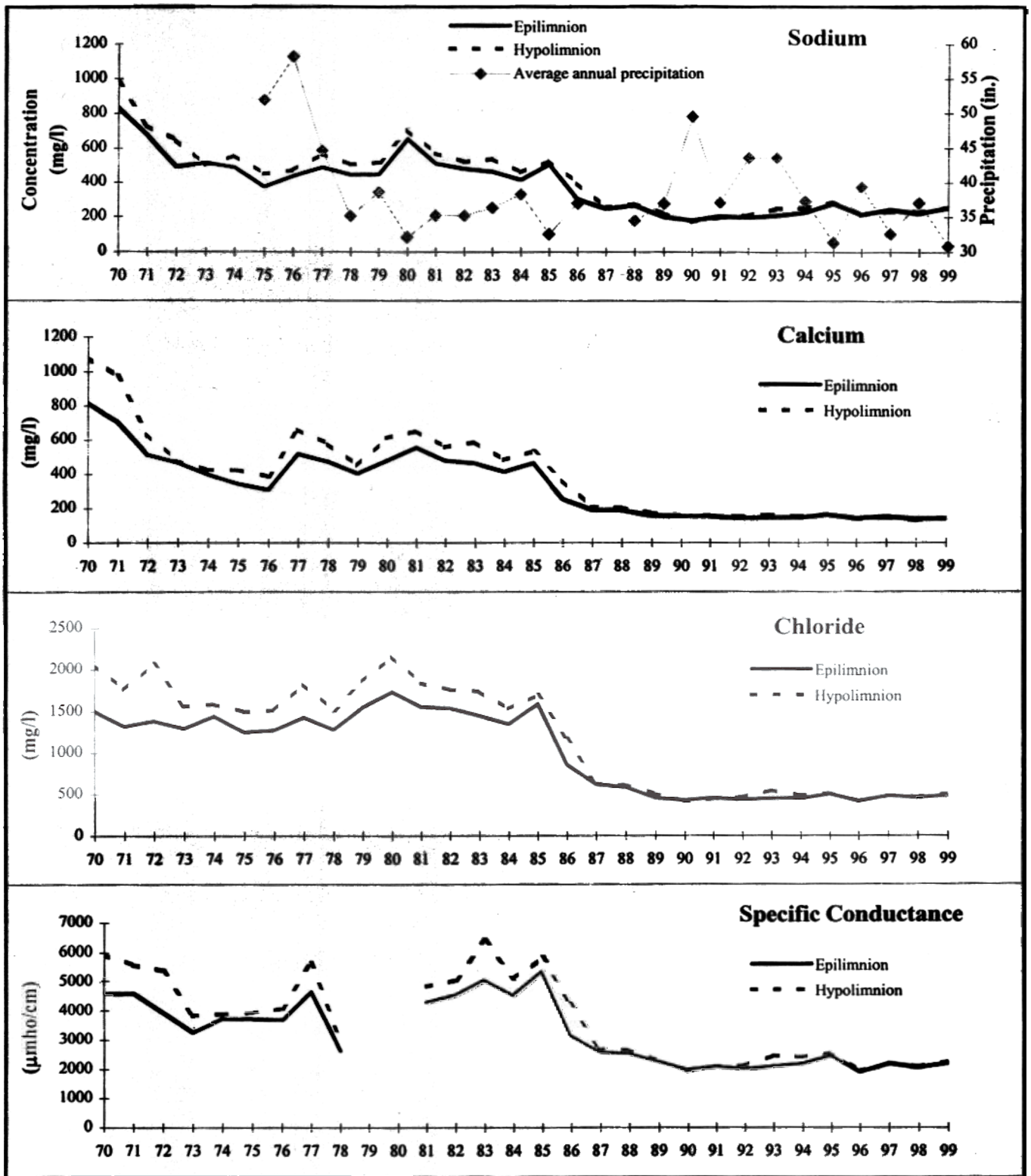


FIGURE 6-7: Diurnal fluctuations in dissolved oxygen and pH at 1 and 3 meter depths, Onondaga Lake



Notes: Allied-Signal ceased operations in April 1986.
Yearly points are means calculated from the ice-free season data (mid-March or April to mid-December). Specific conductance was not measured in 1979 or 1980.

FIGURE 6-8 CHANGES IN SODIUM, CALCIUM, CHLORIDE, AND SPECIFIC CONDUCTANCE IN ONONDAGA LAKE, 1970-1999

Fig 6-8 ions

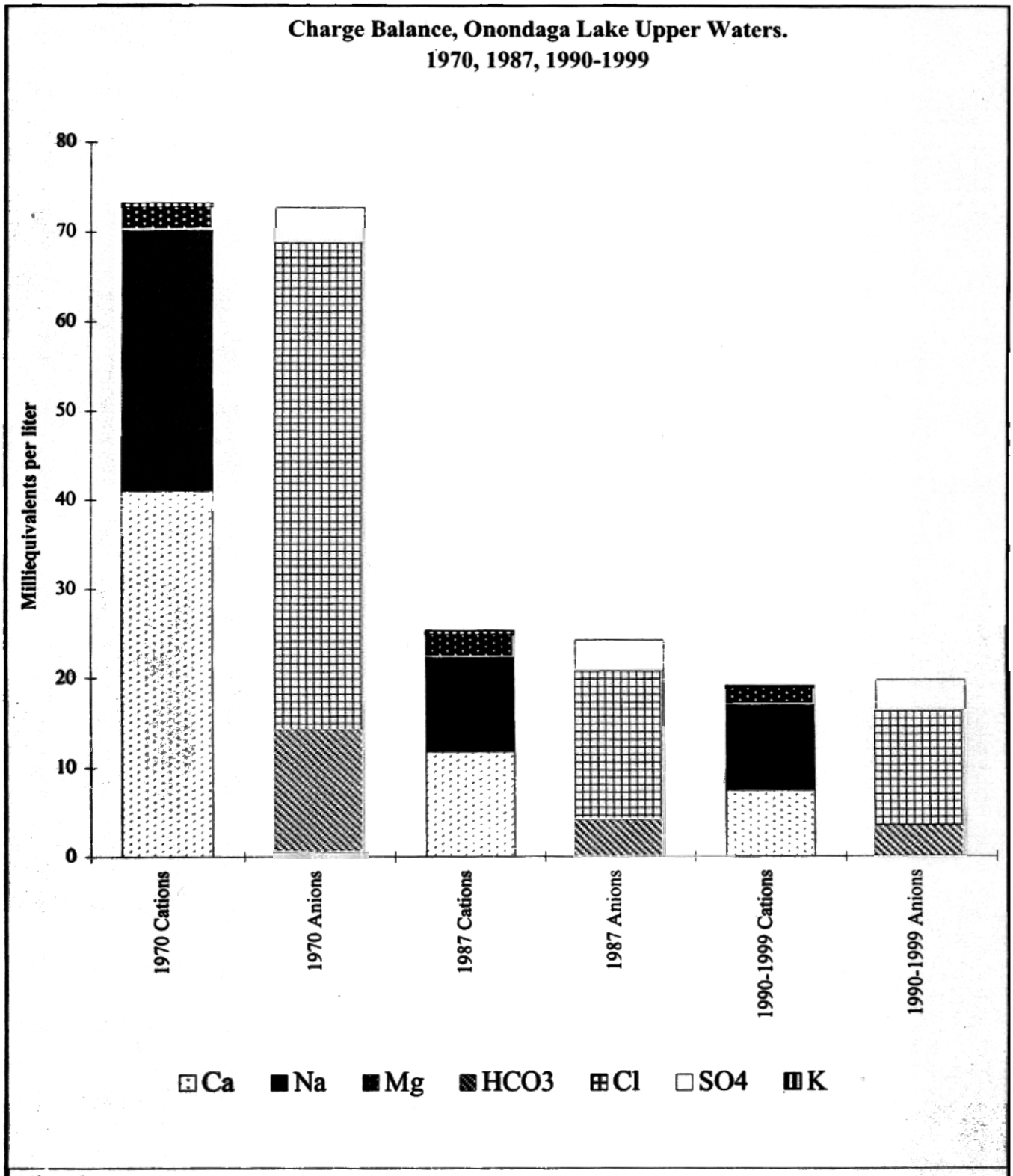


FIGURE 6-9 CHARGE BALANCE IN THE UPPER WATERS (0-9M) DURING 1970, 1987, 1990-1999, IN ONONDAGA LAKE, NY

Fig 6-9 charge bal

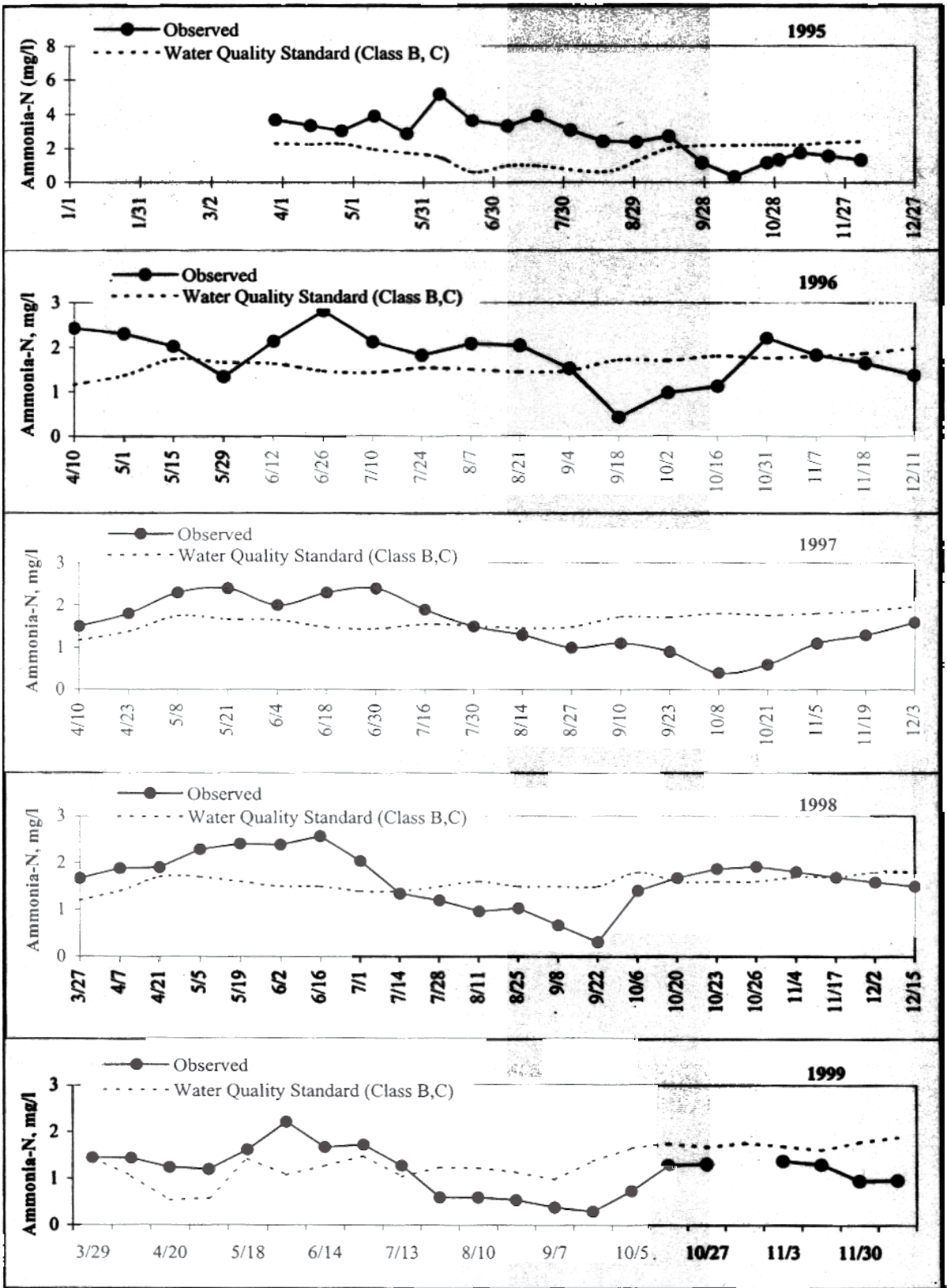
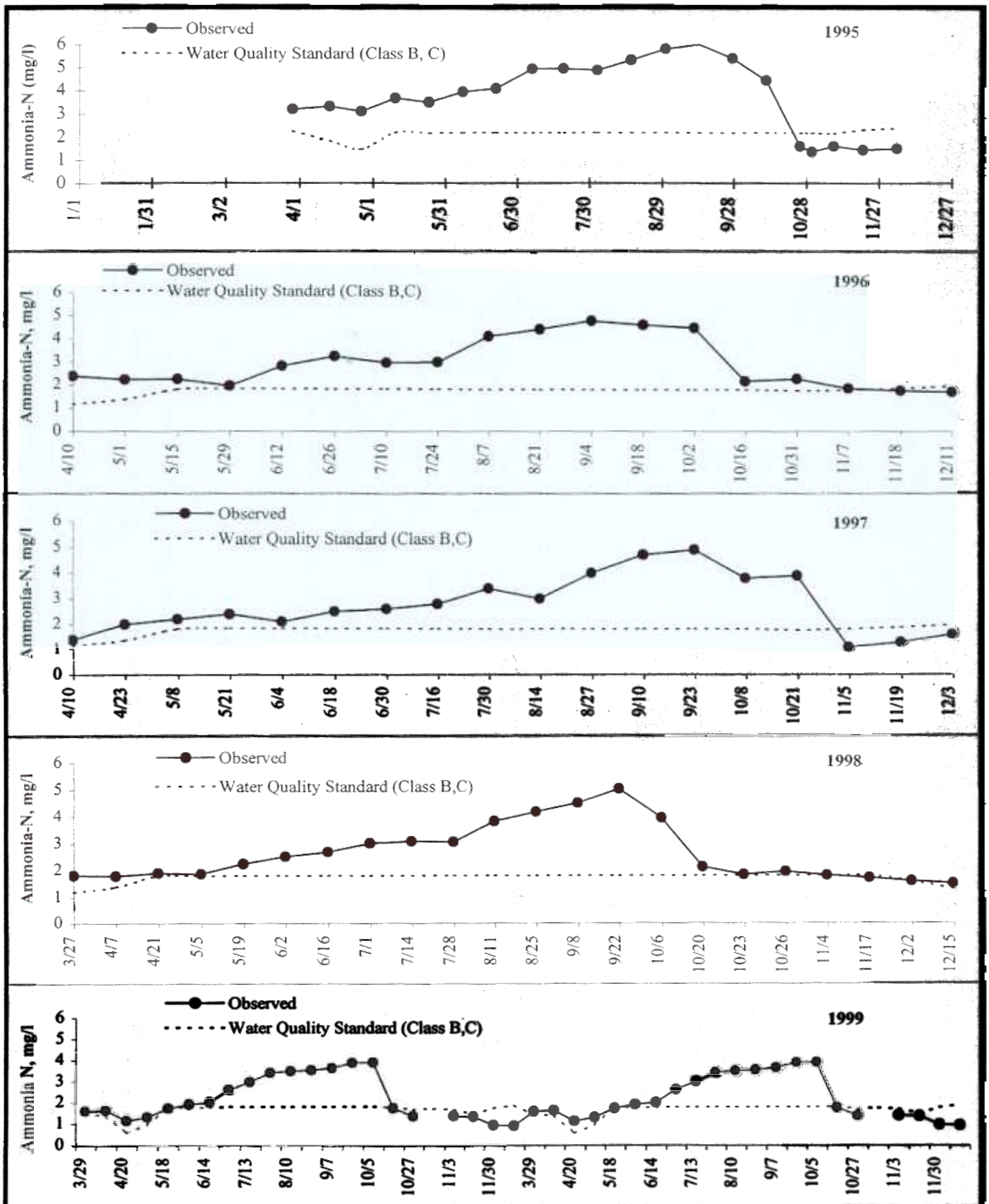


FIGURE 6-10 VOLUME-WEIGHTED AMMONIA-NITROGEN IN THE UPPER (0-9M) WATERS OF ONONDAGA LAKE, 1995-1999.
NOTE CHANGE IN SCALE AFTER 1995

Fig 6-10 ammonia up.xls



Standards are published in New York Ambient Water Quality Standards and Guidance Values (NYSDEC, 1993).

FIGURE 6-11 **VOLUME-WEIGHTED AMMONIA-NITROGEN IN THE LOWER (12-18M) WATERS OF ONONDAGA LAKE, 1995-1999**

fig 6-11 ammonia low

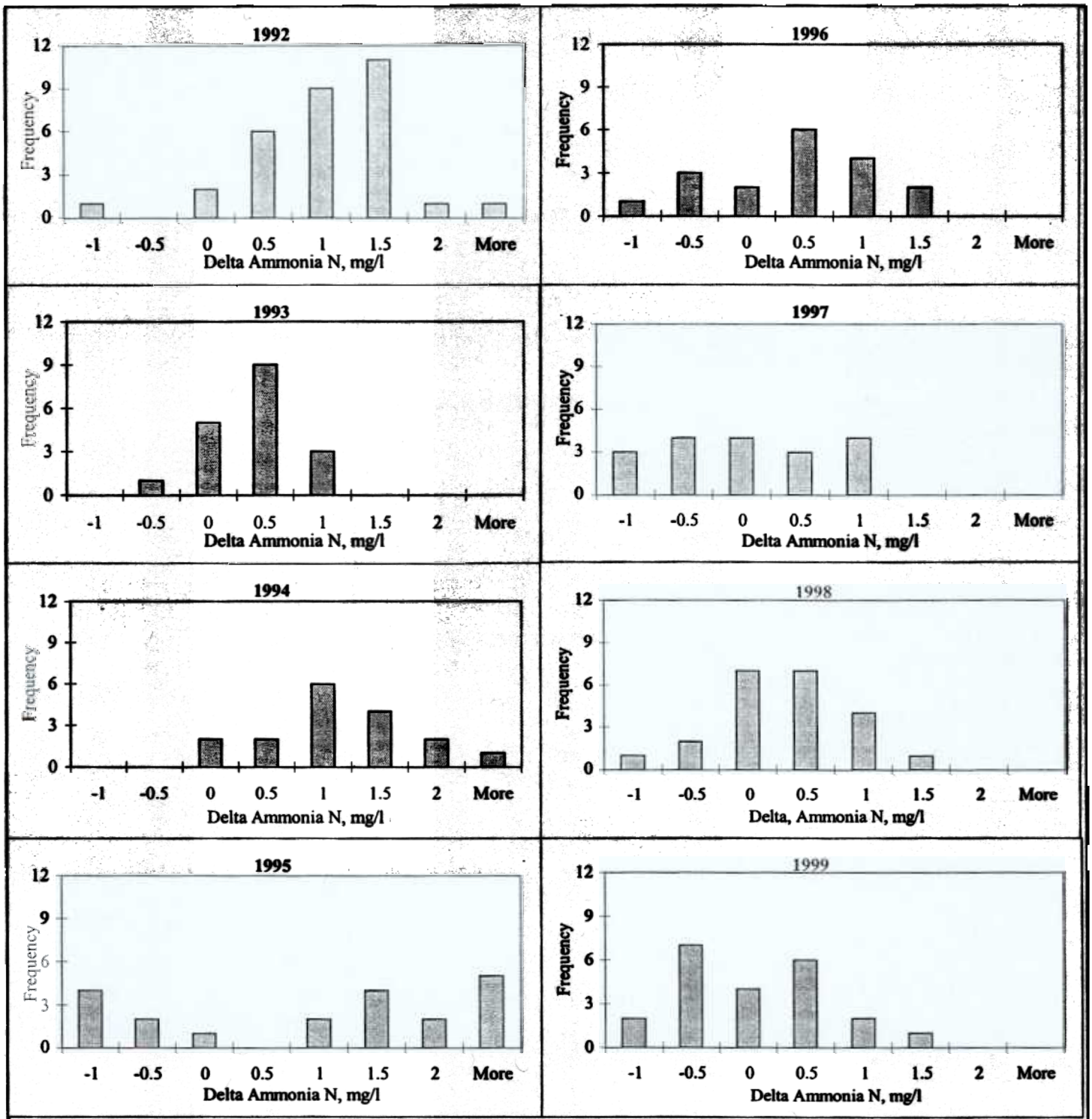


FIGURE 6-12: Delta ammonia N is the difference between the measured concentration of ammonia in the epilimnion of Onondaga Lake and the NYS ambient water quality standard for Class B,C waters at the conditions of pH and temperature. Positive values indicate a violation of the ambient water quality standard.

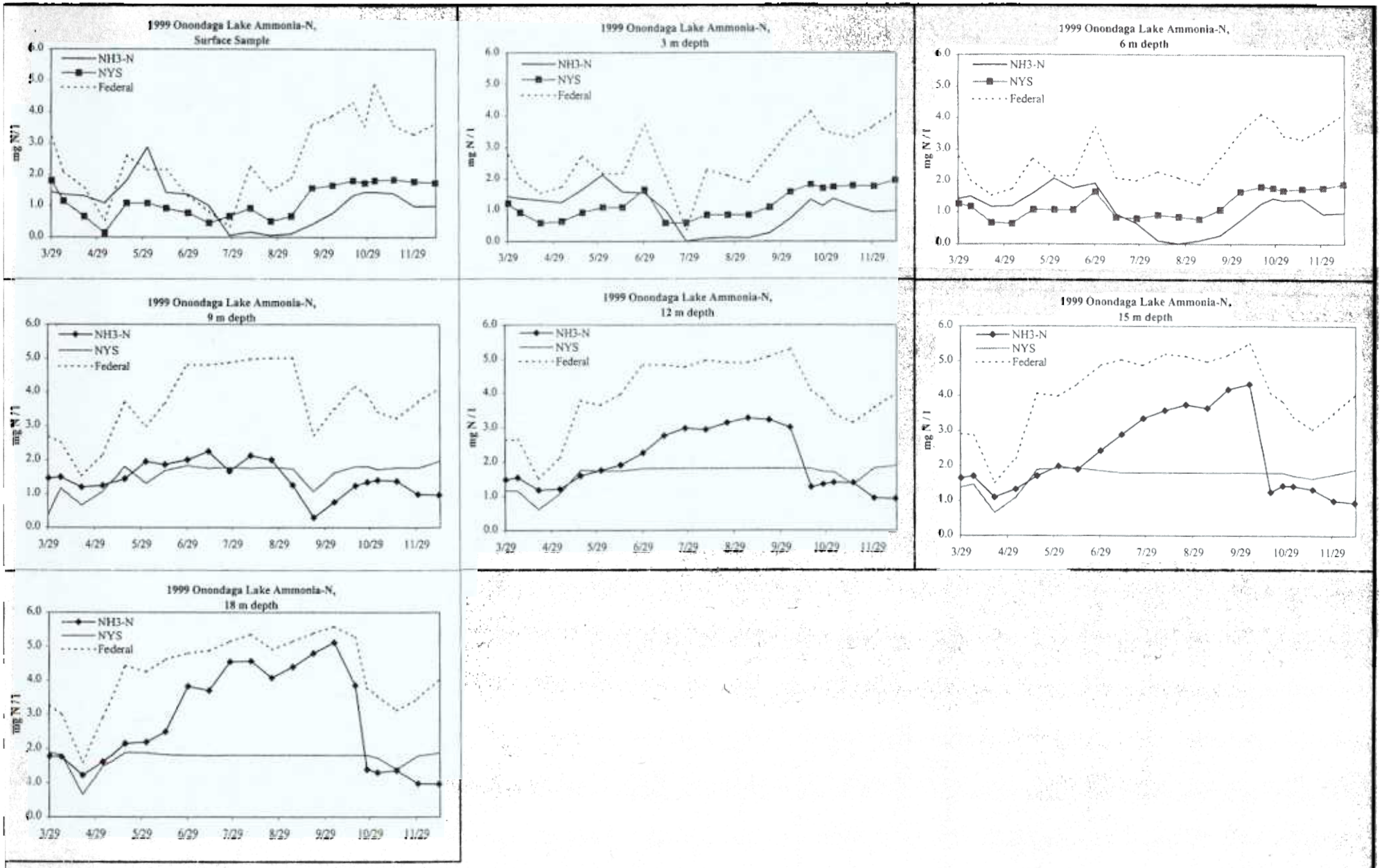


FIGURE 6-13: 1999 Ammonia N measured at specific depths, compared with NY standards and federal criteria

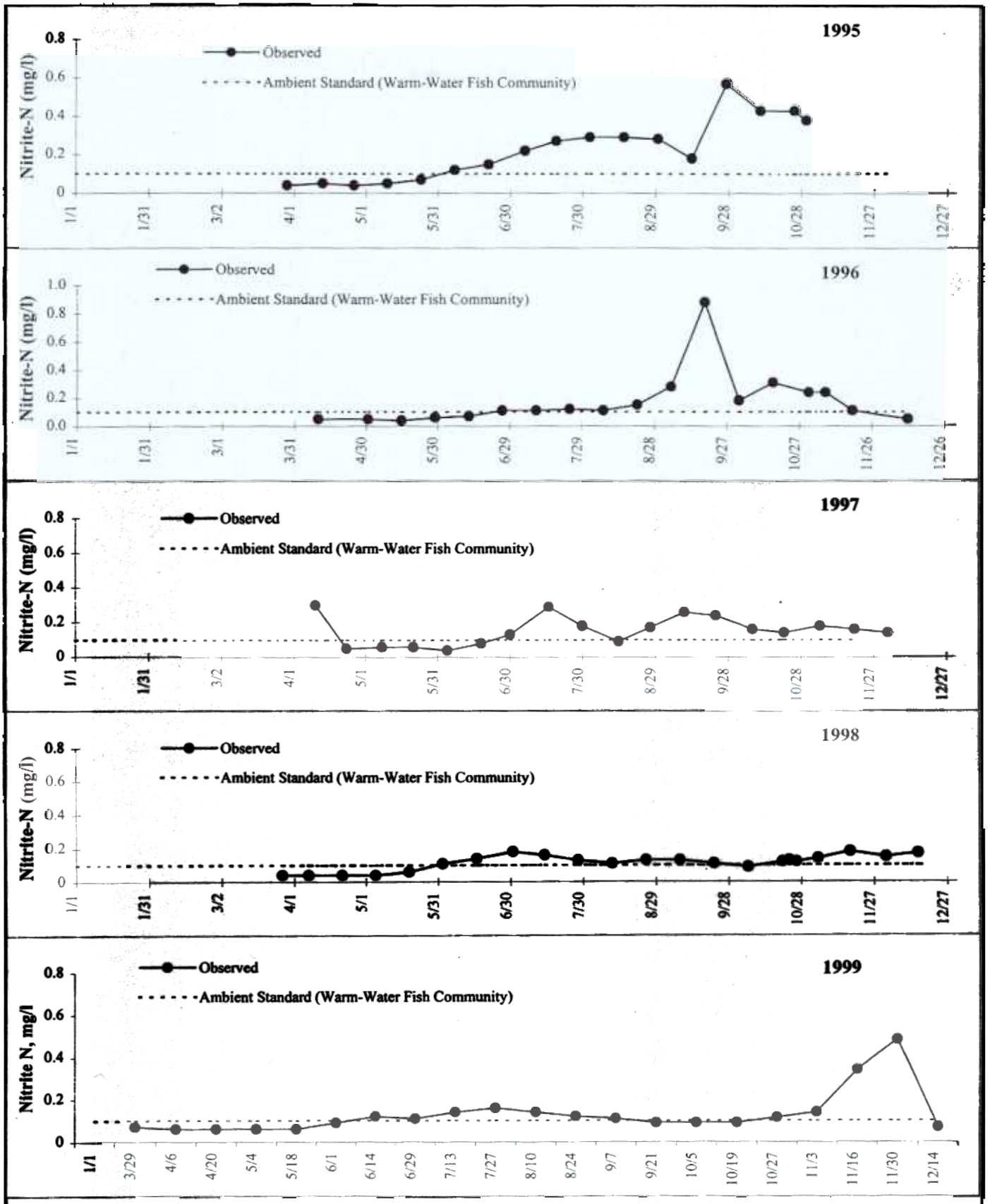


FIGURE 6-14 VOLUME-WEIGHTED NITRITE-NITROGEN IN THE UPPER (0-9 M) WATERS OF ONONDAGA LAKE, 1995-1999

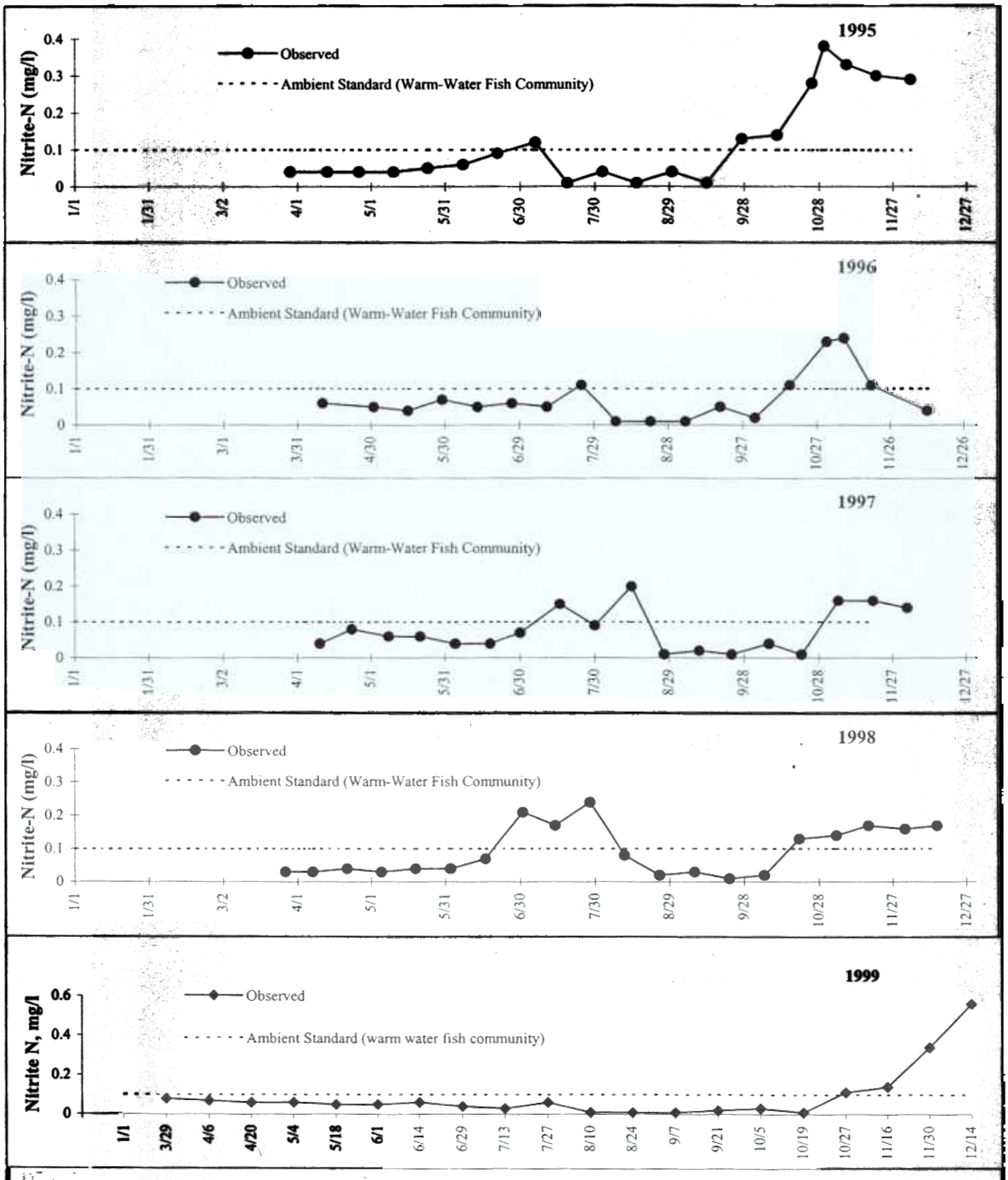


FIGURE 6-15 **VOLUME-WEIGHTED NITRITE-NITROGEN IN THE LOWER (12-18M) WATERS OF ONONDAGA LAKE, 1995-1999**

fig 6-15 hypo no2.xls

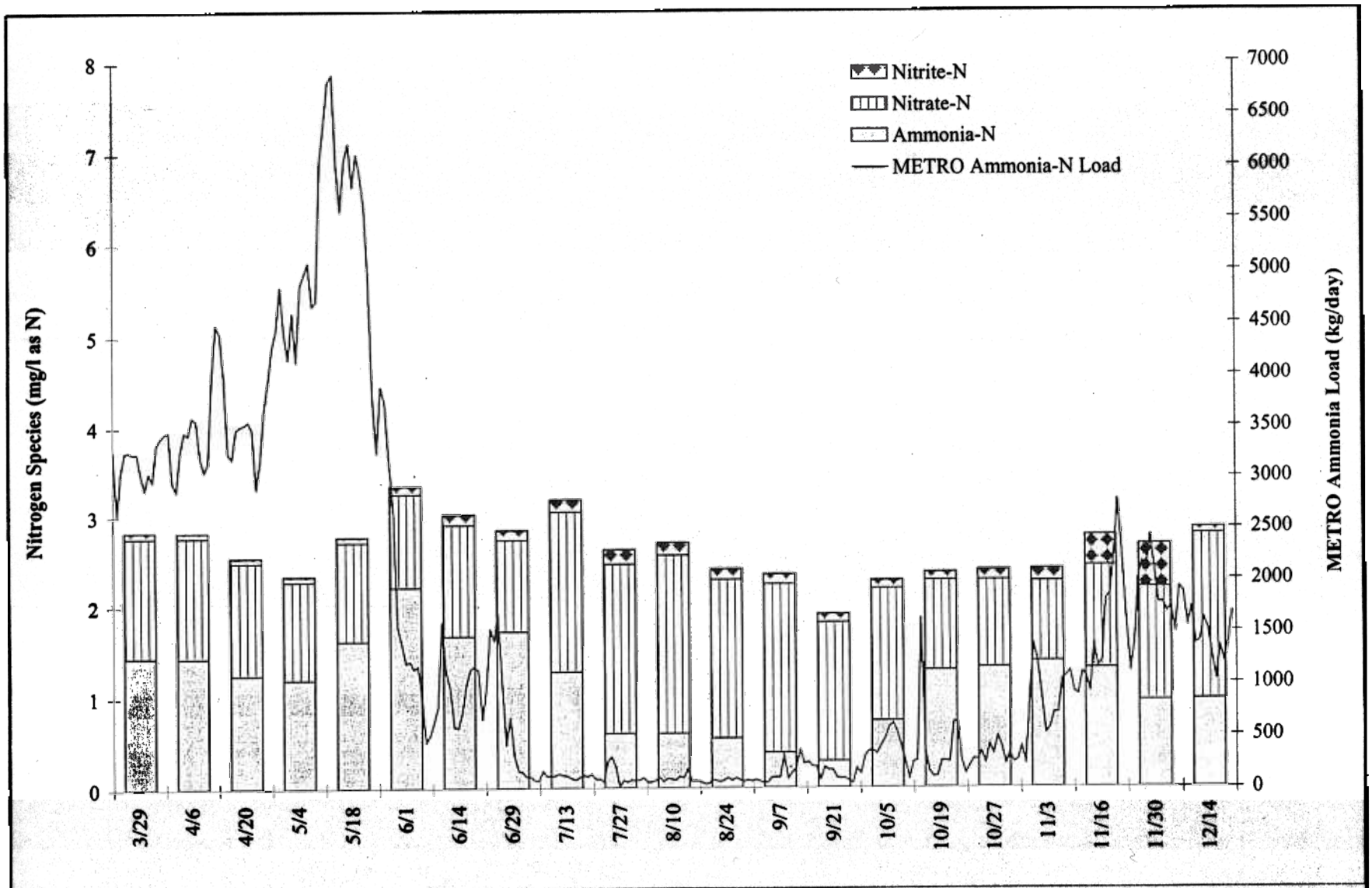


FIGURE 6-16 VOLUME-WEIGHTED NITROGEN SPECIES IN THE UPPER MIXED LAYER OF ONONDAGA LAKE VS. METRO AMMONIA-N DAILY LOADING, 1999

Fig 6-16 N species and Metro.xls

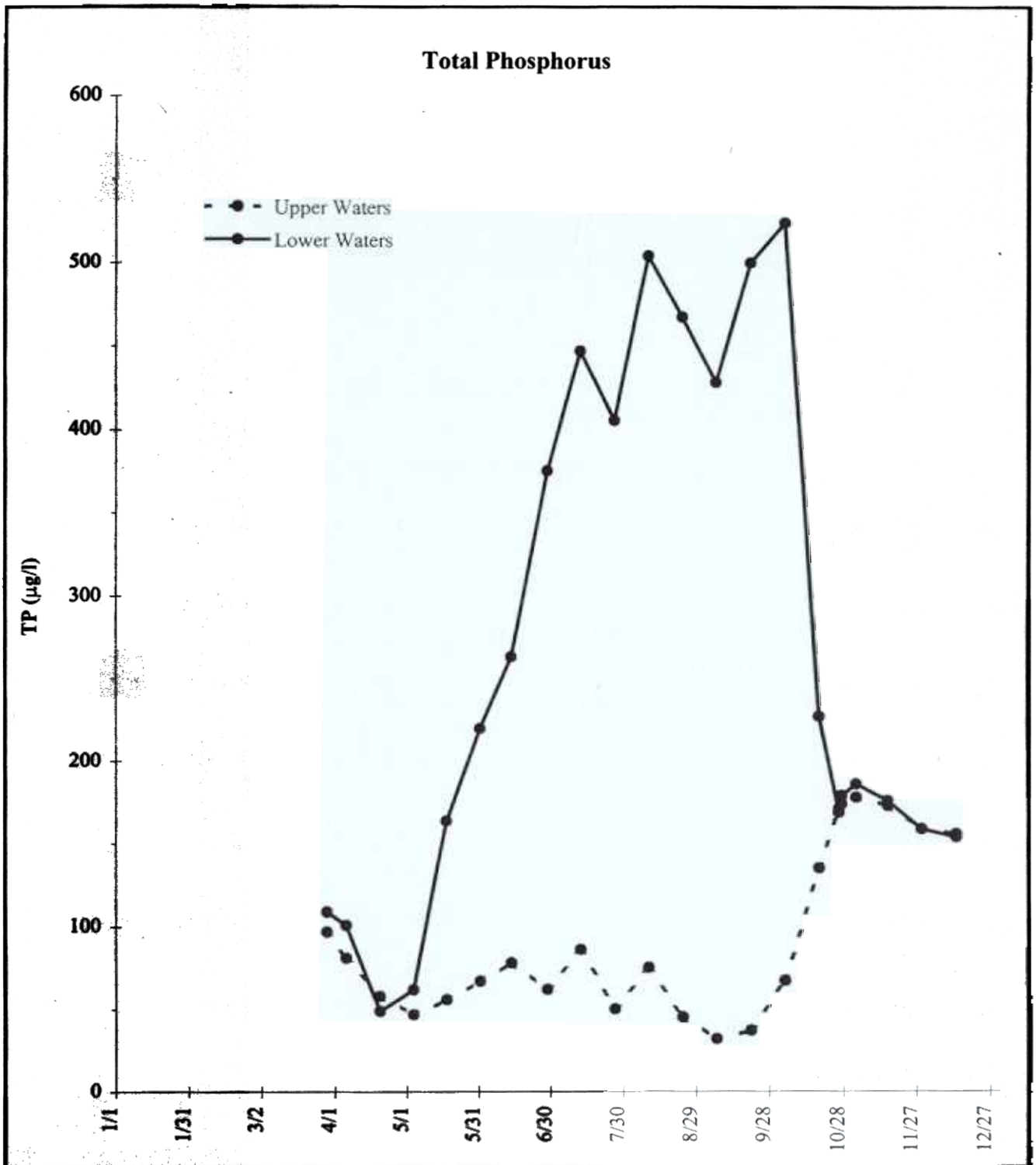
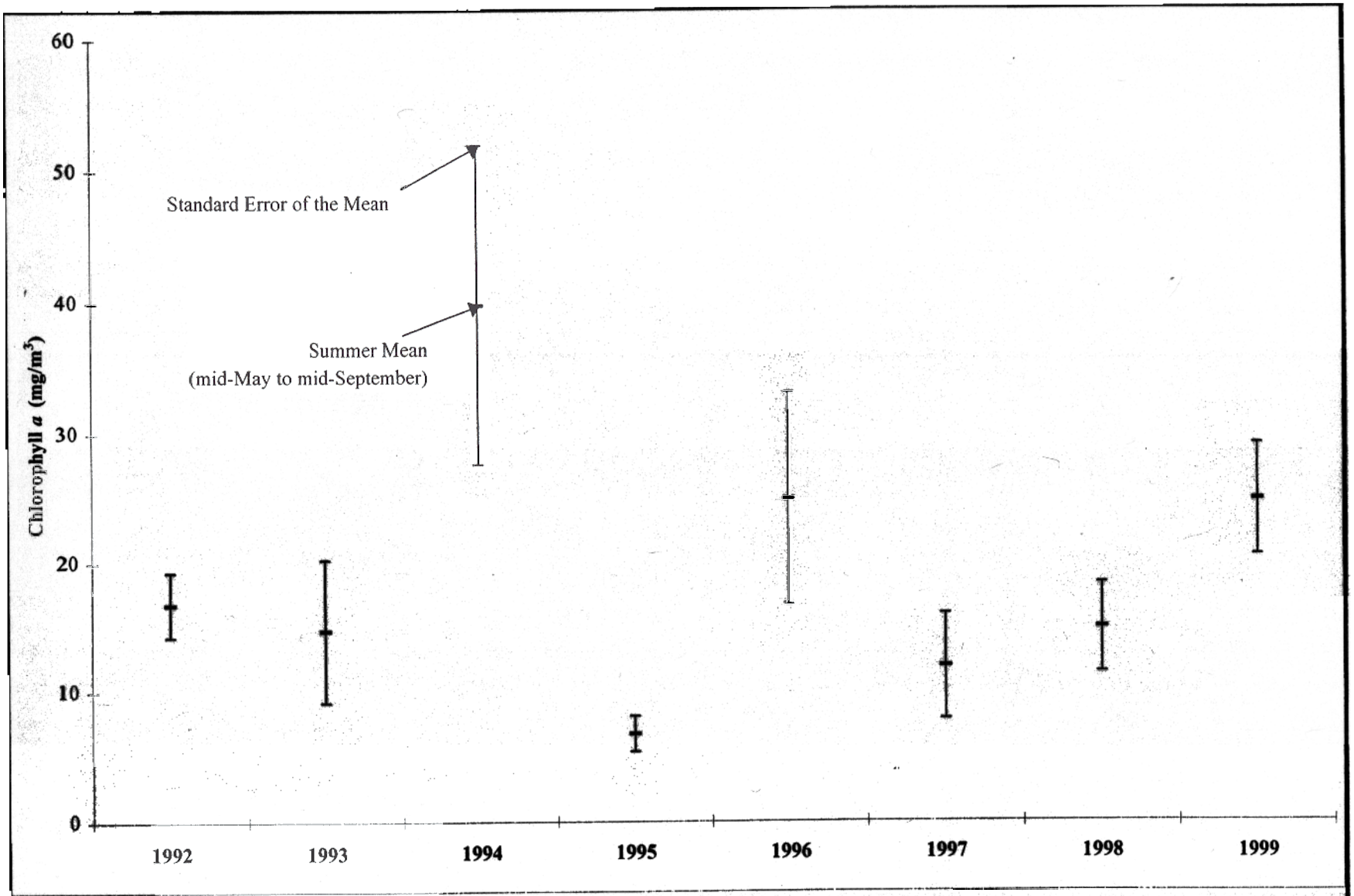


FIGURE 6-17 VOLUME-WEIGHTED TOTAL PHOSPHORUS IN THE UPPER AND LOWER WATERS OF ONONDAGA LAKE, 1999

Fig 6-17 TP99



Summer average is mid-May to mid-September.

FIGURE 6-18 SUMMER AVERAGE CHLOROPHYLL *a* IN THE SURFACE WATERS OF ONONDAGA LAKE, 1992-1999

Fig 6-18 chlora

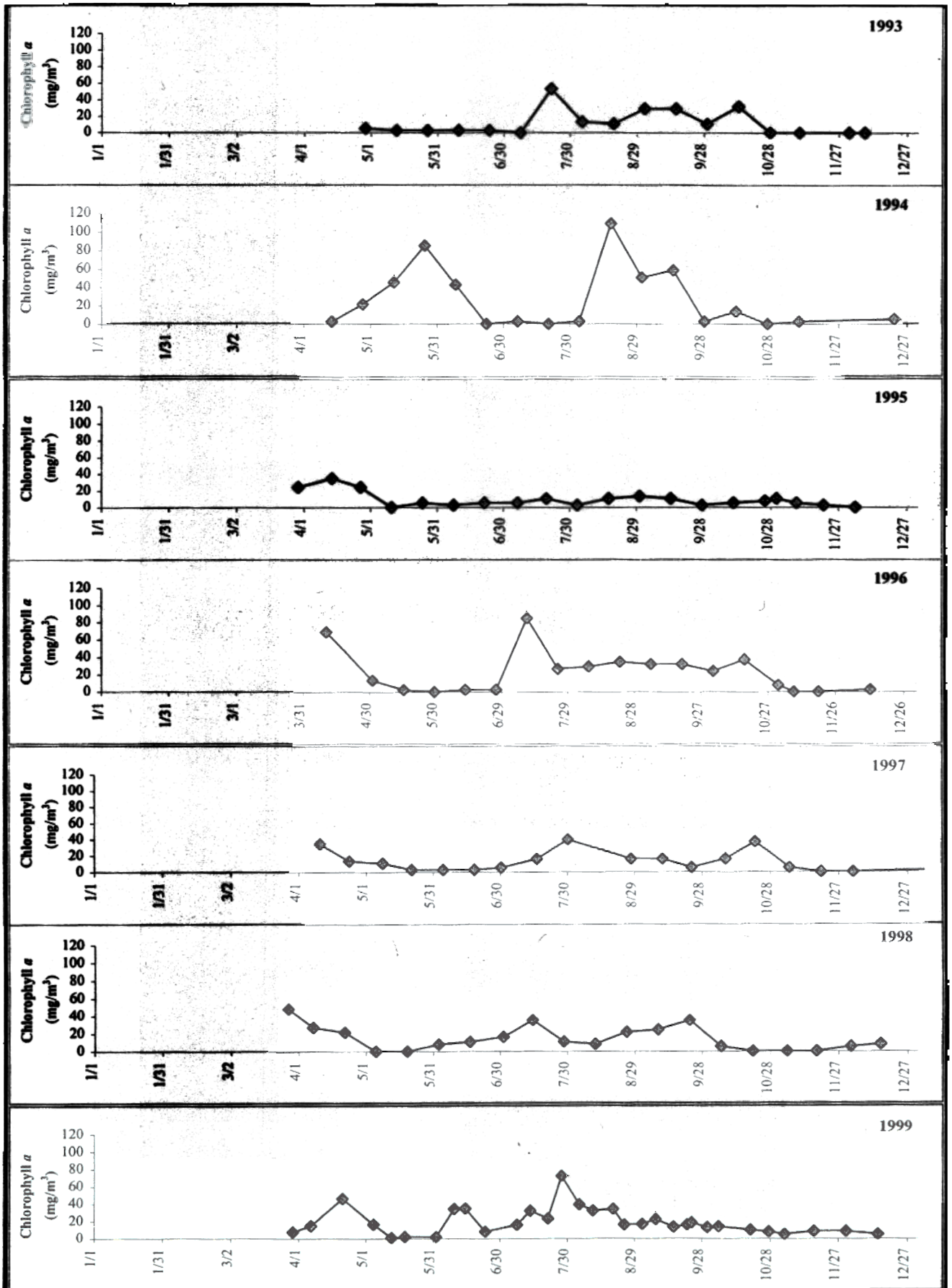


FIGURE 6-19 CHLOROPHYLL *a* IN THE SURFACE WATERS OF ONONDAGA LAKE, 1993-1999

Fig 6-19 time_chlor

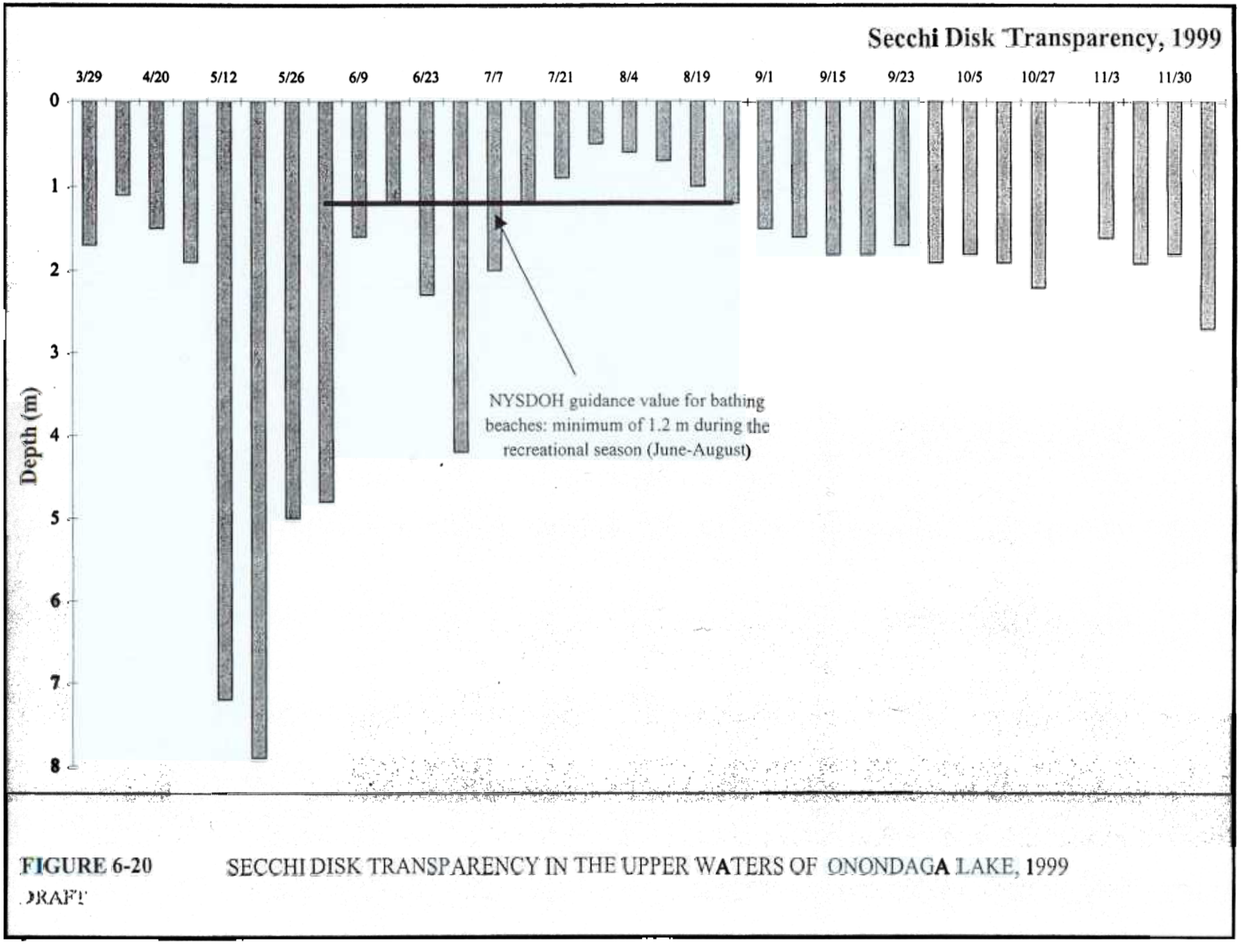
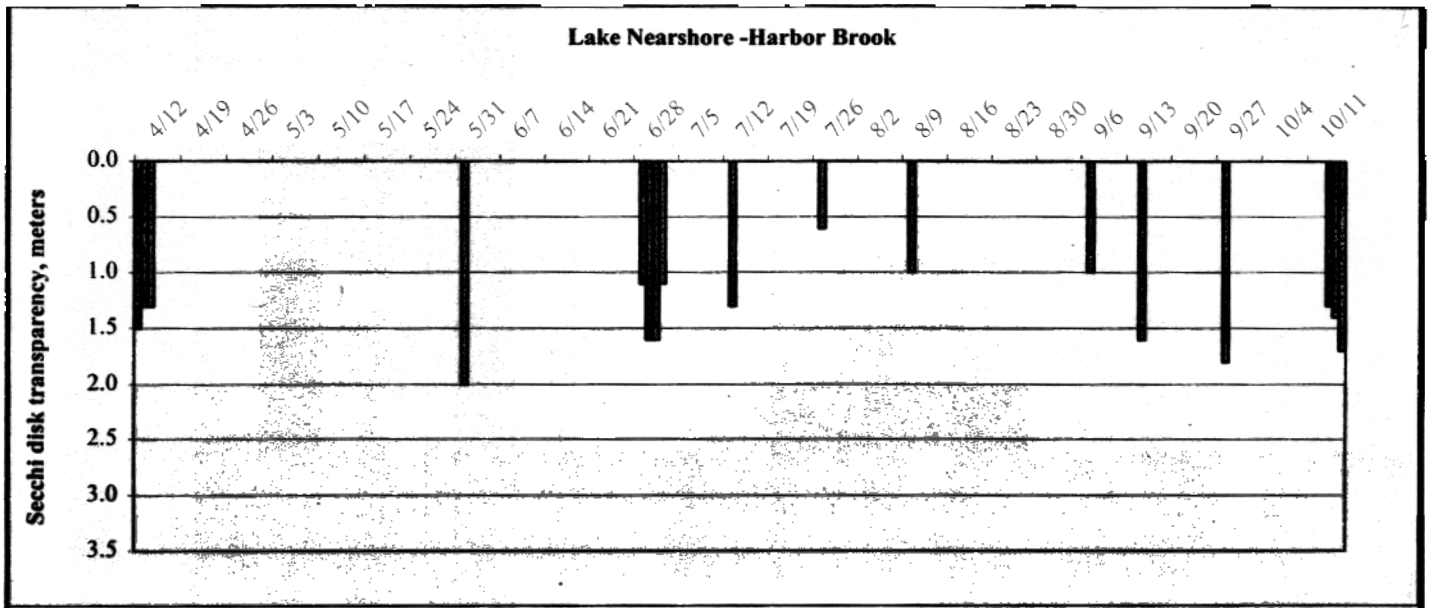
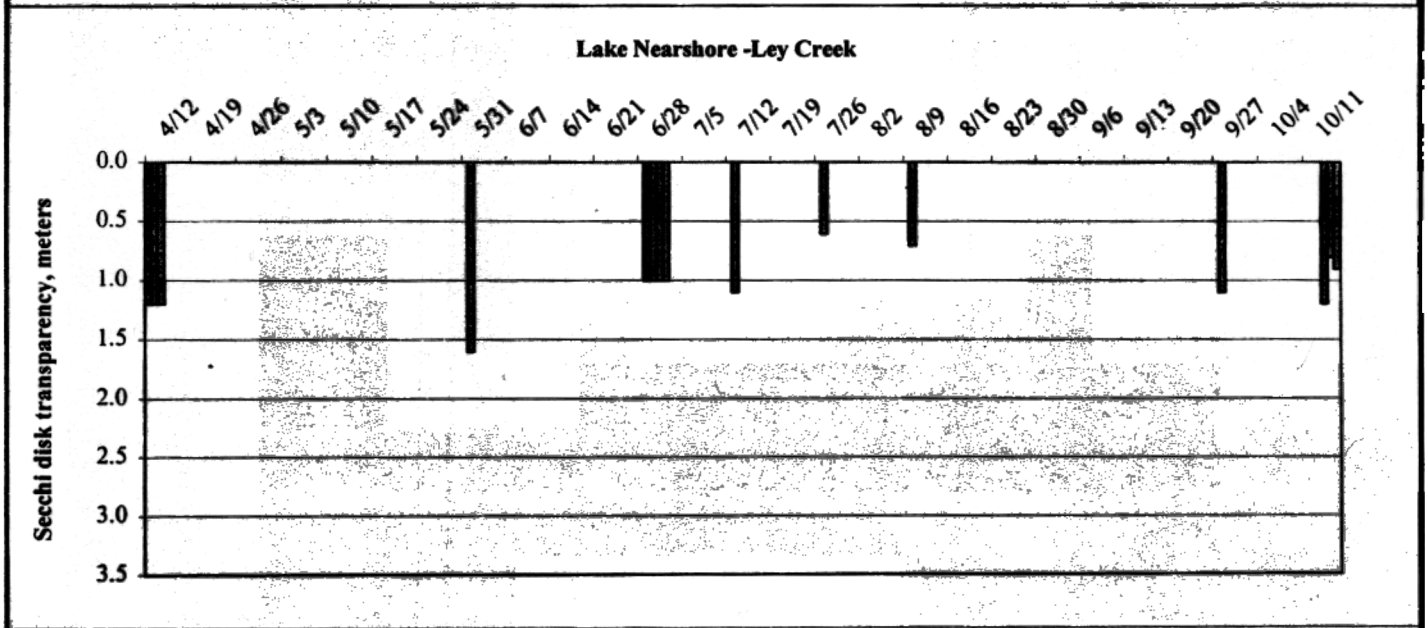


FIGURE 6-20 SECCHI DISK TRANSPARENCY IN THE UPPER WATERS OF ONONDAGA LAKE, 1999

DRAFT

ig 6-20 Secchi





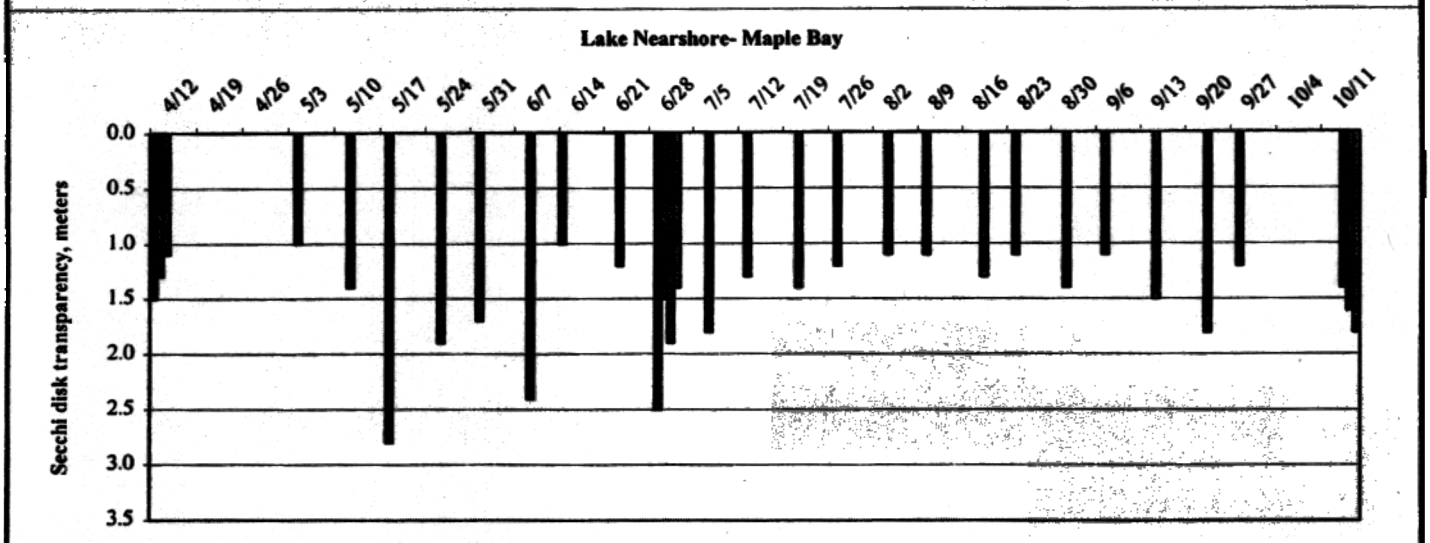


FIGURE 6-21: Near-Shore Station Secchi Disk Transparency Results

fig21 nearshorebactplot

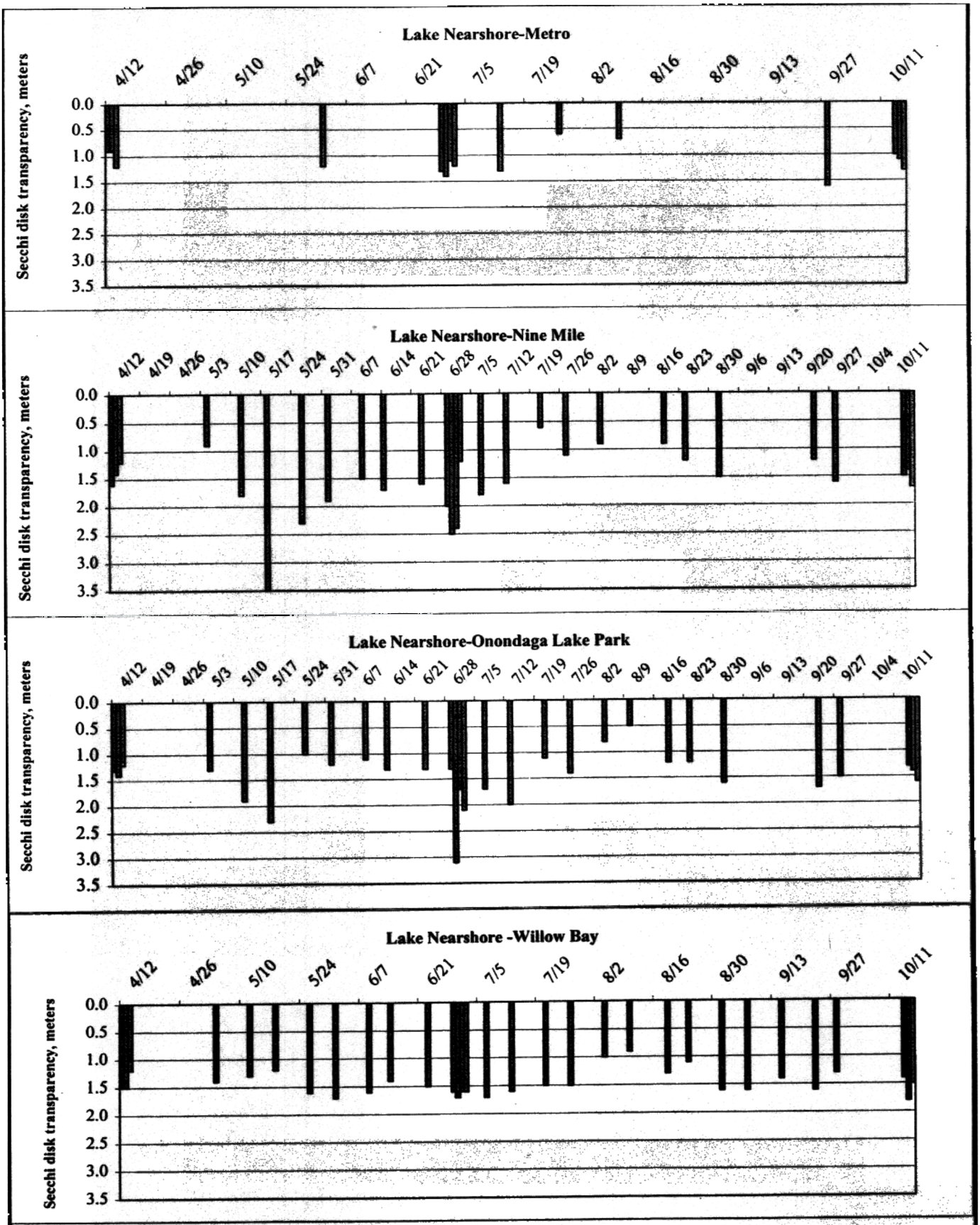
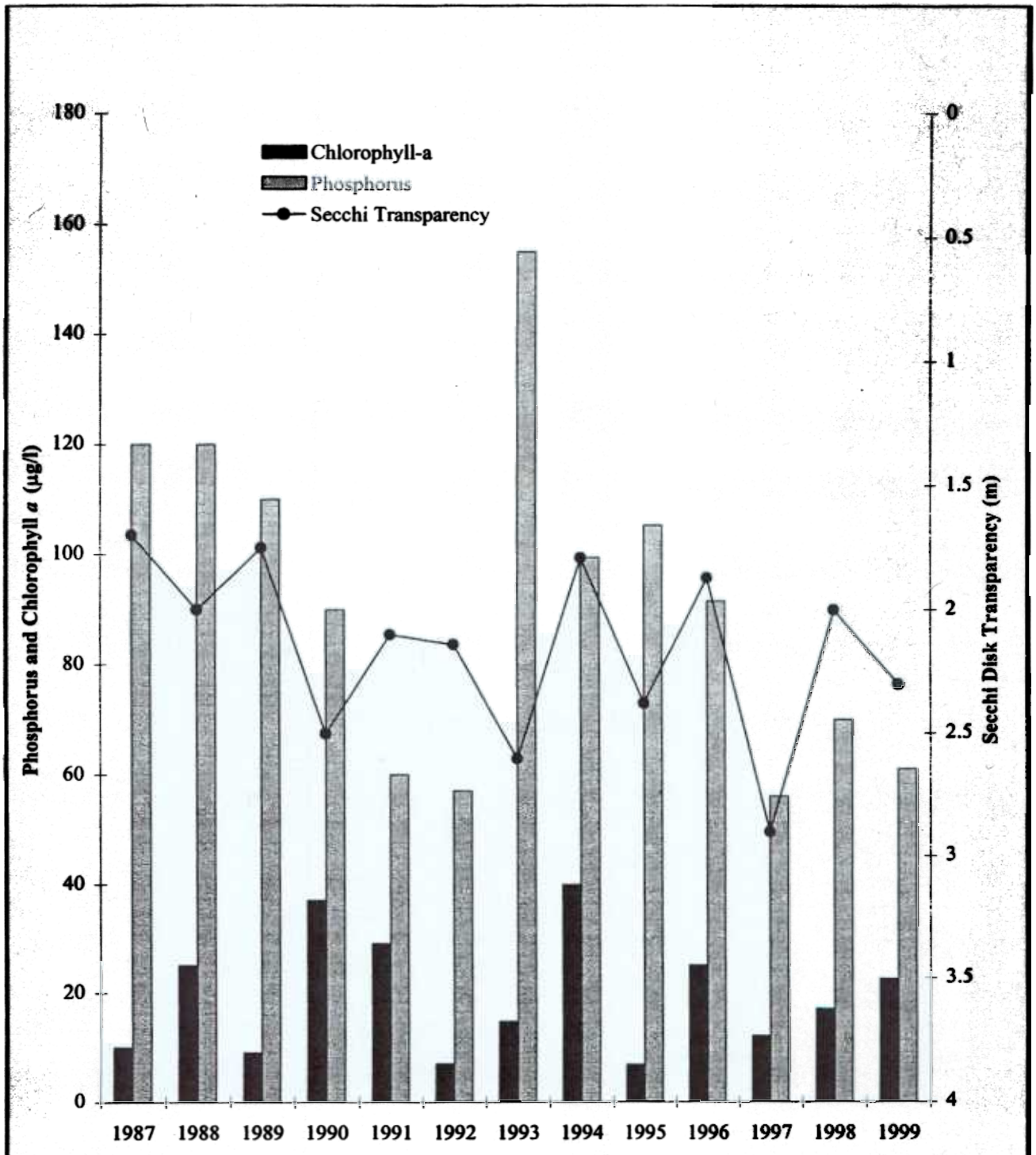


FIGURE 6-21continued: Near-Shore Station Secchi Disk Transparency Results

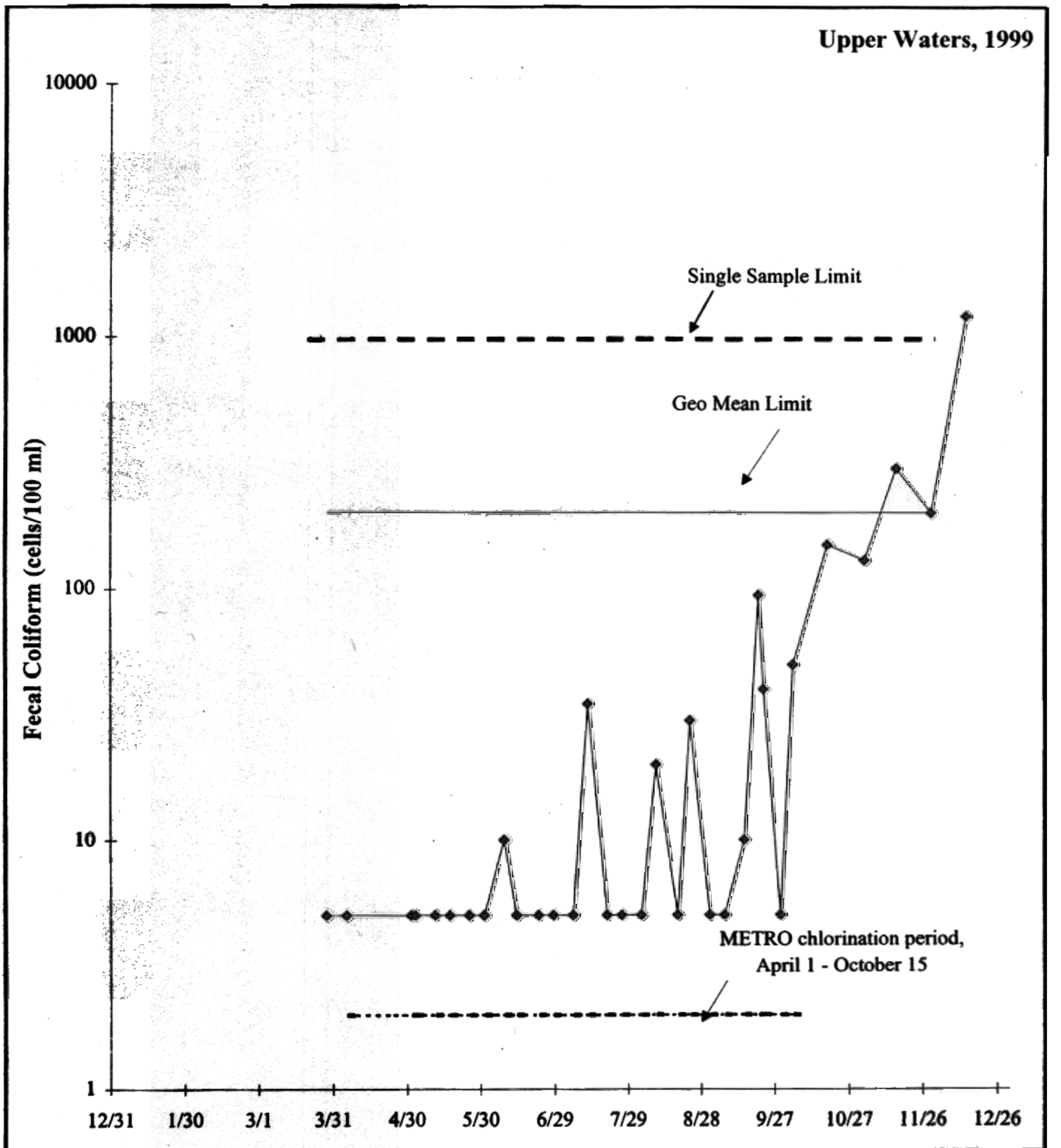
fig21 nearshorebactplot



Total phosphorus, chlorophyll *a* and Secchi disk transparency, 1987 - 1999. Values are averages of observations during the growing season (mid-May through mid-September) in the upper waters (0-9 m) of Onondaga Lake, NY.

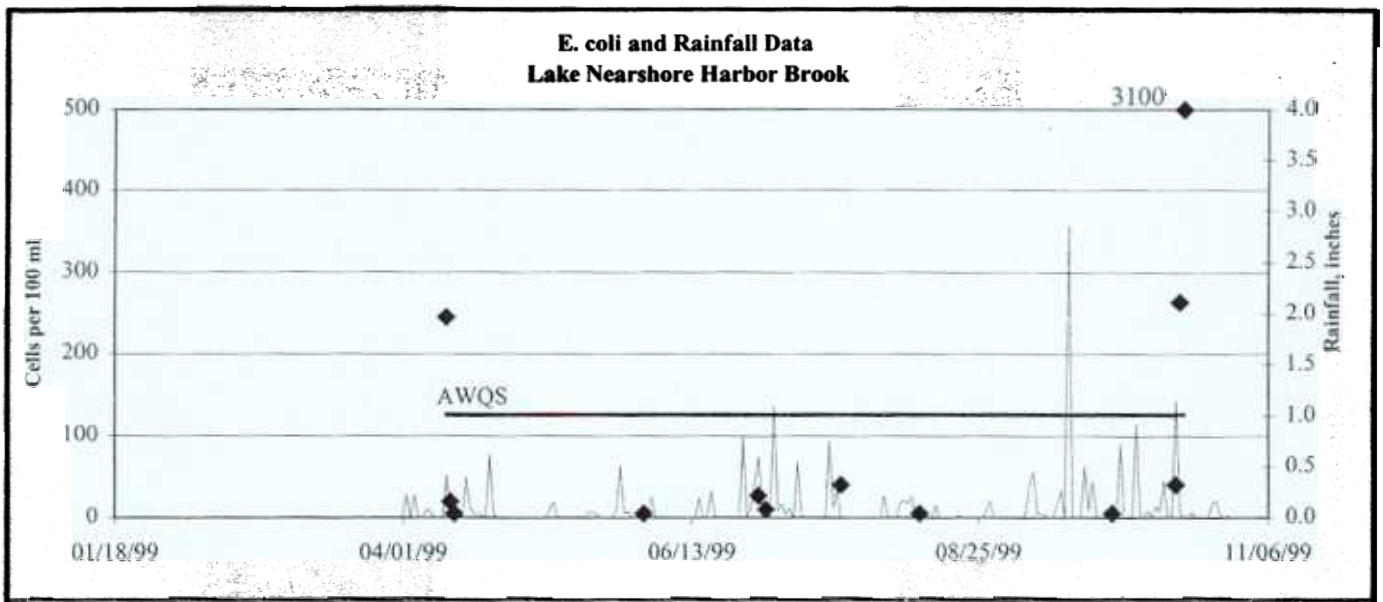
FIGURE 6-22 **TROPHIC INDICATORS IN THE UPPER WATERS DURING THE GROWING SEASON, 1987-1999**

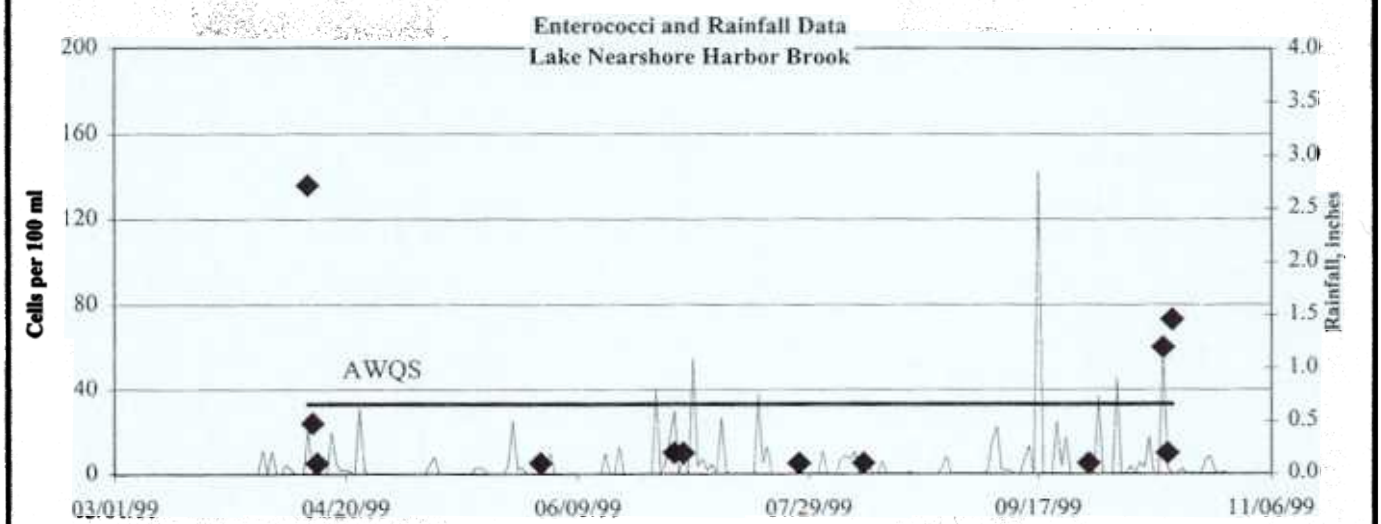
fig 6-22 trophic



METRO is required by its SPDES permit to chlorinate effluent from April 1 - October 15.
Note the limit of detection is 5 cells/100 ml.

FIGURE 6-23 FECAL COLIFORMS IN THE UPPER WATERS OF ONONDAGA LAKE, 1999





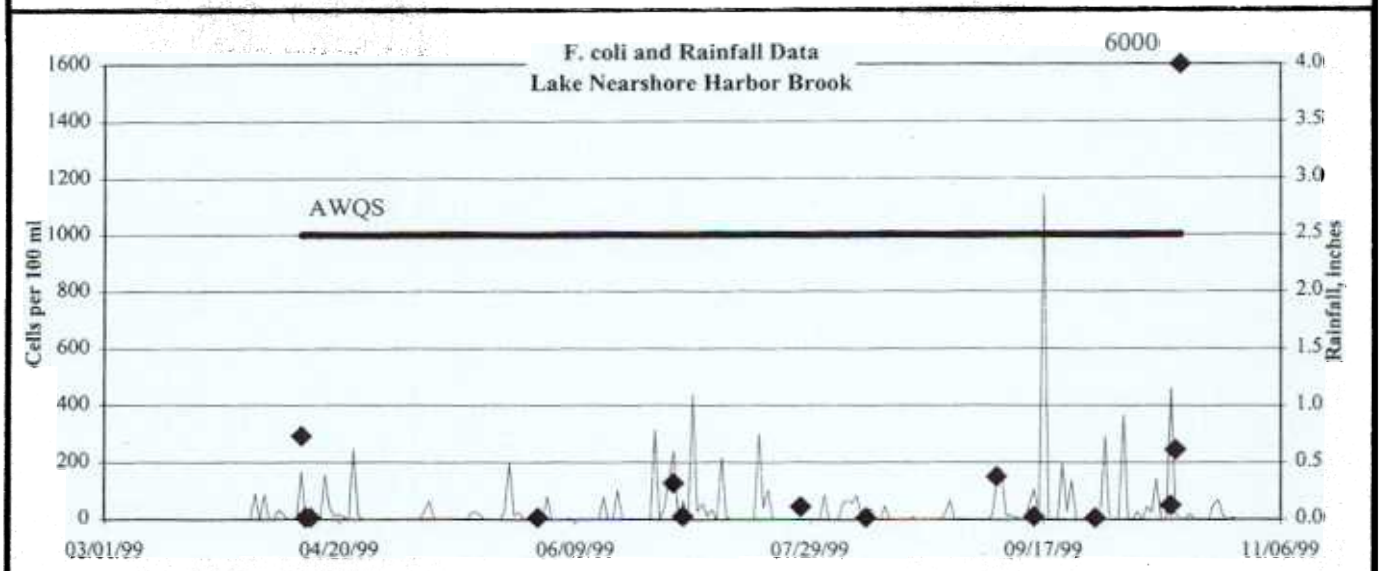
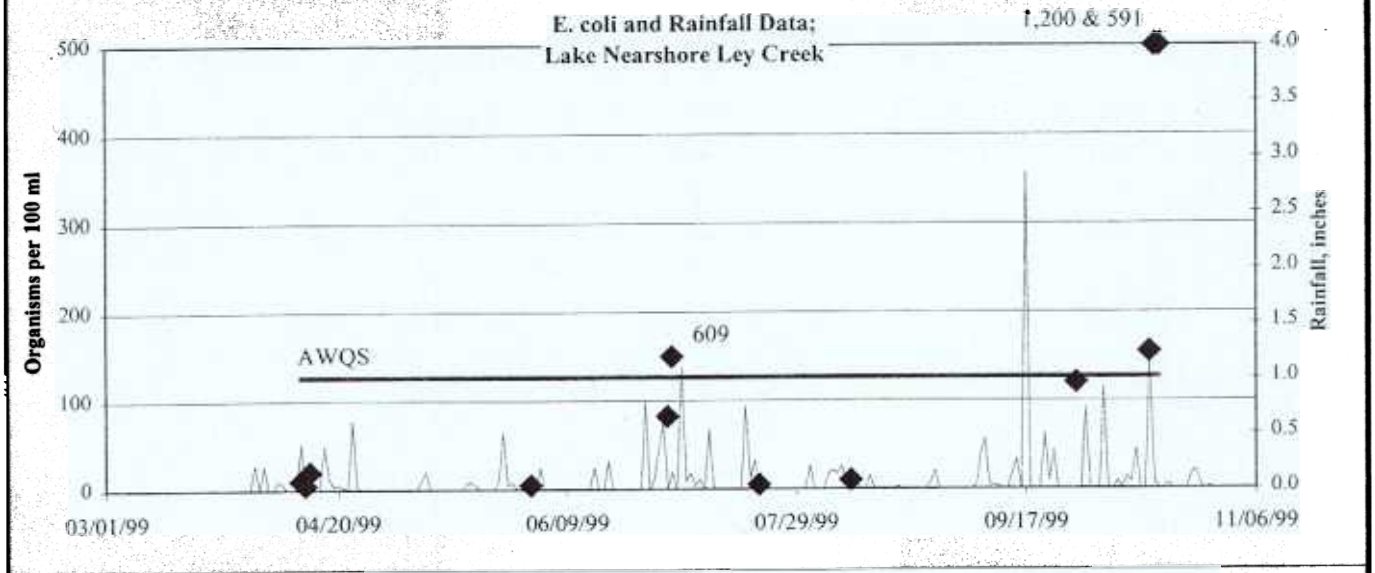
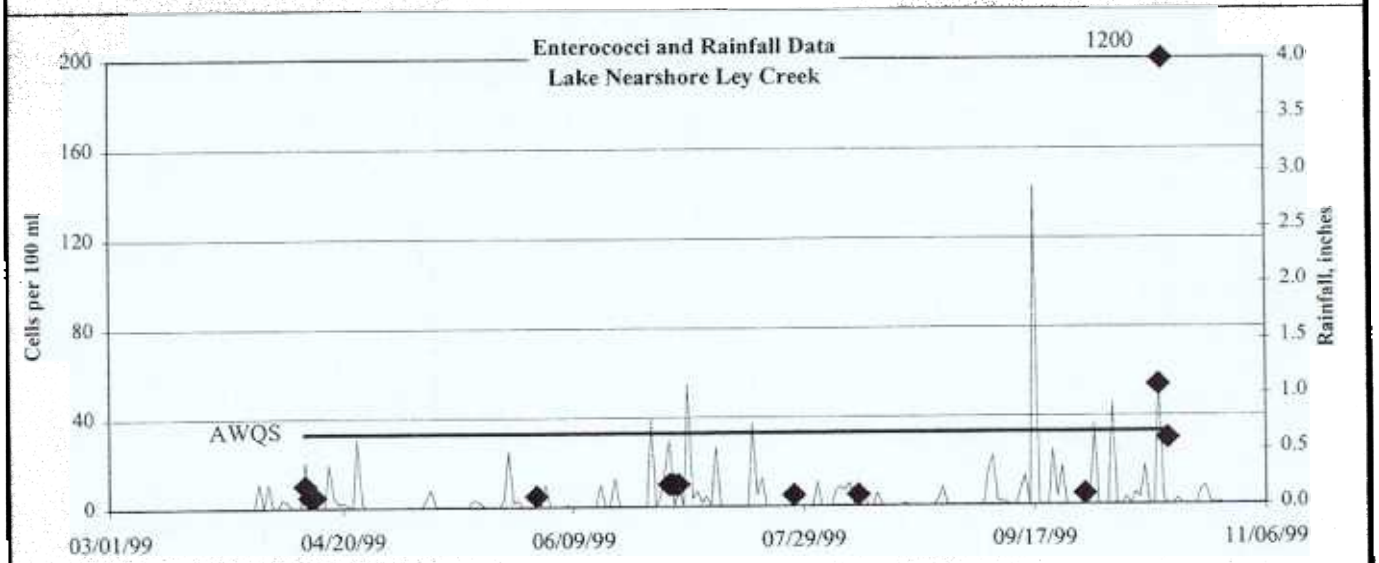


FIGURE 6-24: Results of monitoring at near-shore stations for indicator bacteria, 1999

fig 6-24 nearshore bacteria





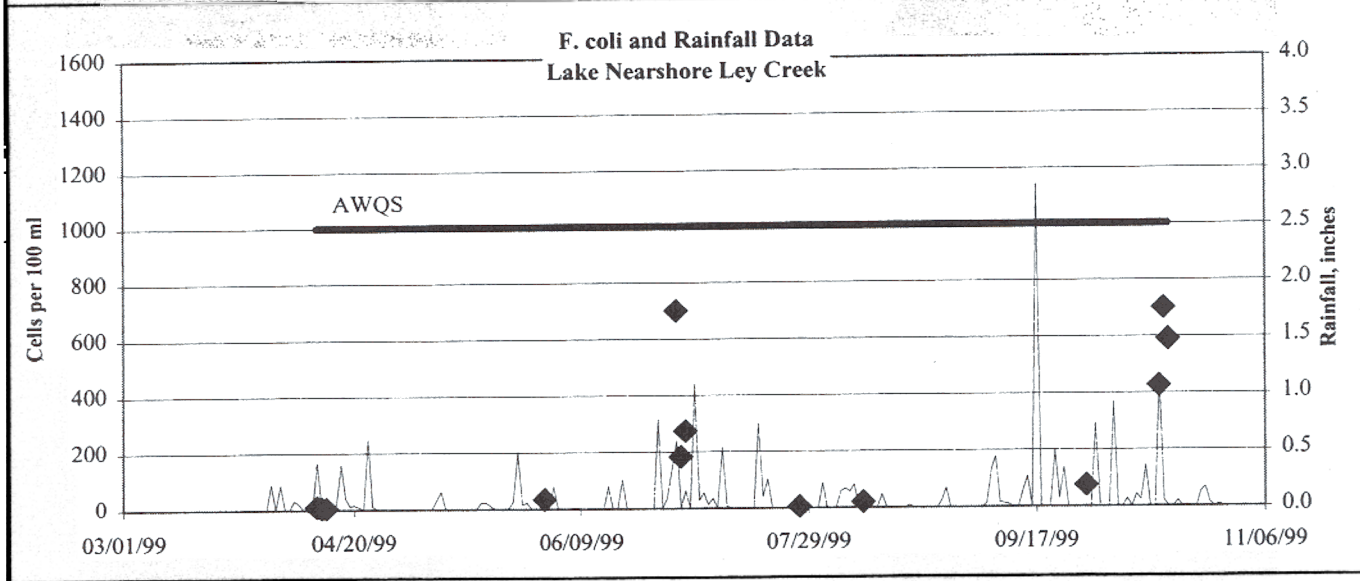


FIGURE 6-24 (cont): Results of monitoring at near-shore stations for indicator bacteria, 1999

fig 6-24 nearshore bacteria

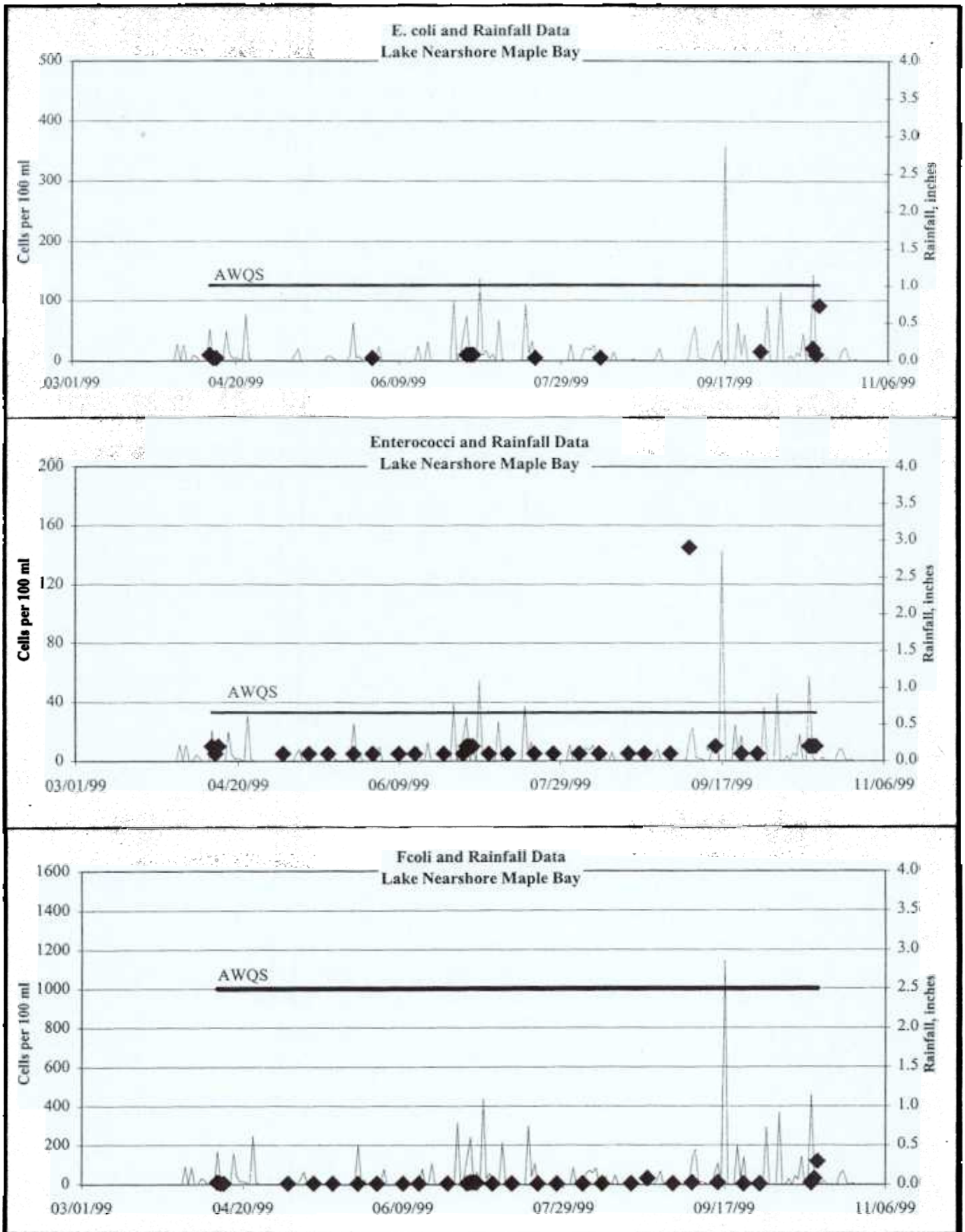
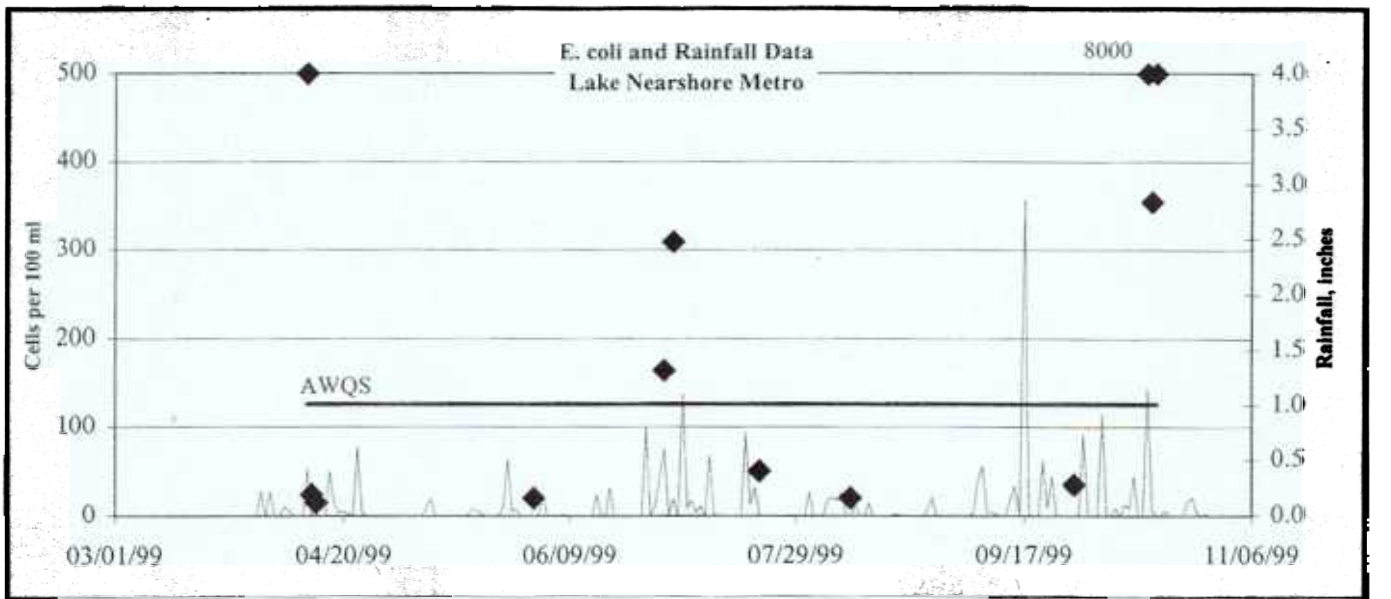
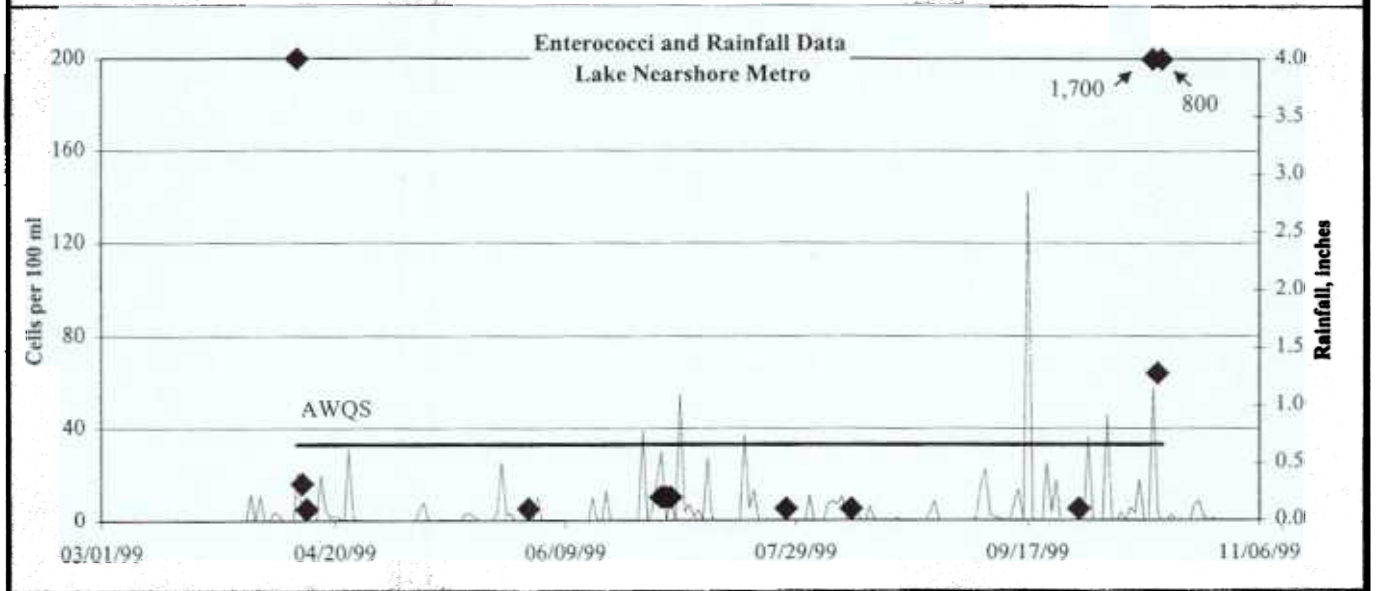


FIGURE 6-24 (cont): Results of monitoring at near-shore stations for indicator bacteria, 1999

fig 6-24 nearshore bacteria





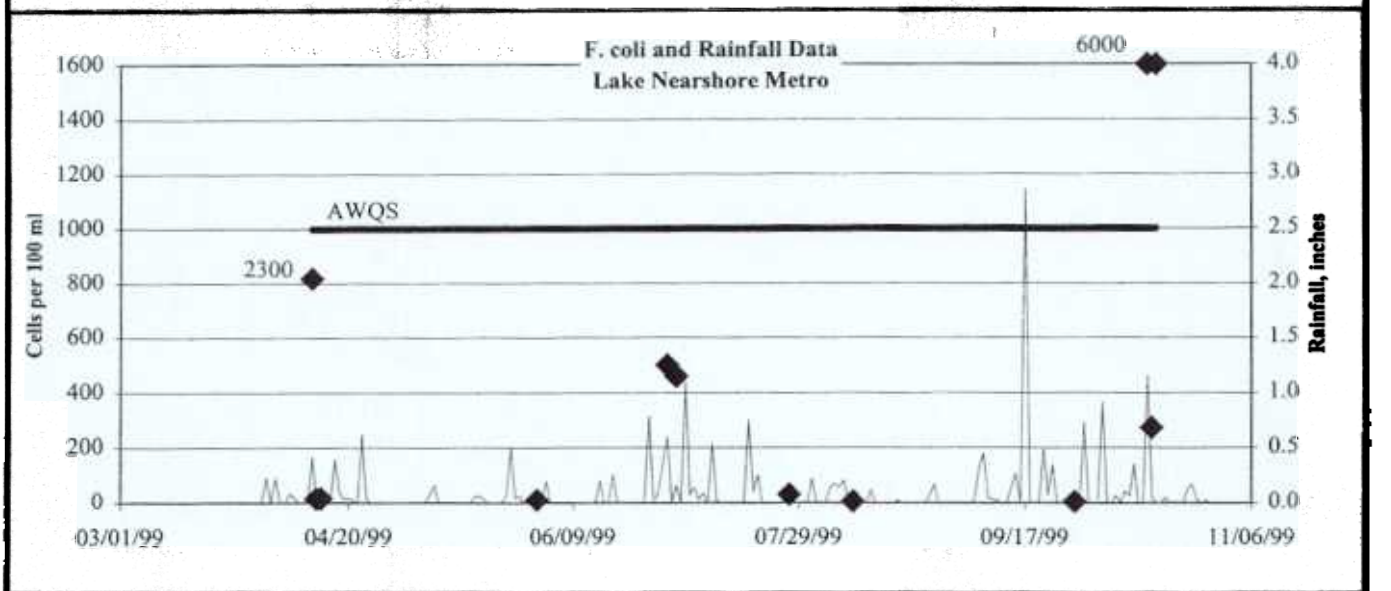


FIGURE 6-24(cont.) Results of monitoring at near-shore stations for indicator bacteria, 1999

fig 6-24 nearshore bacteria

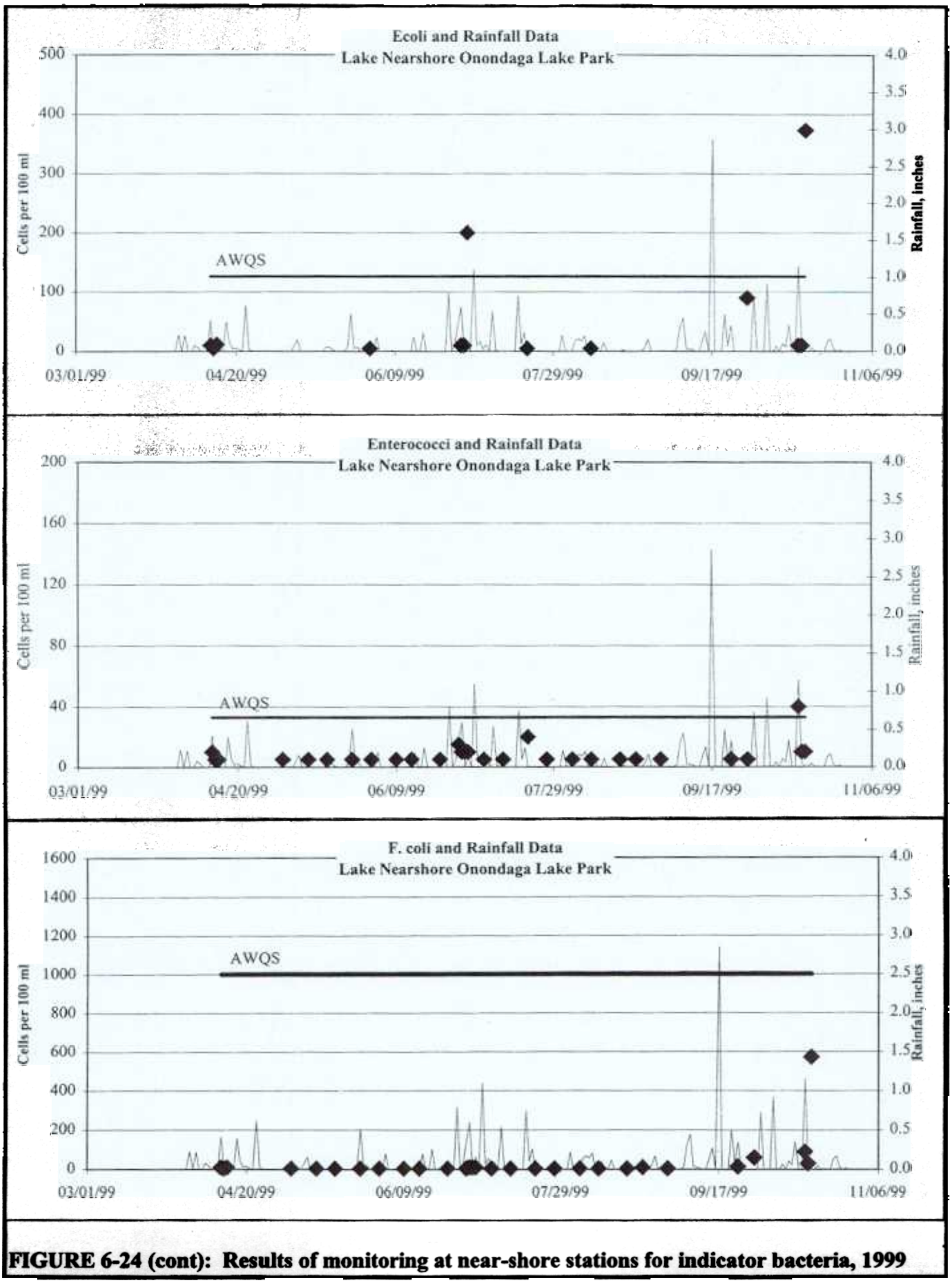
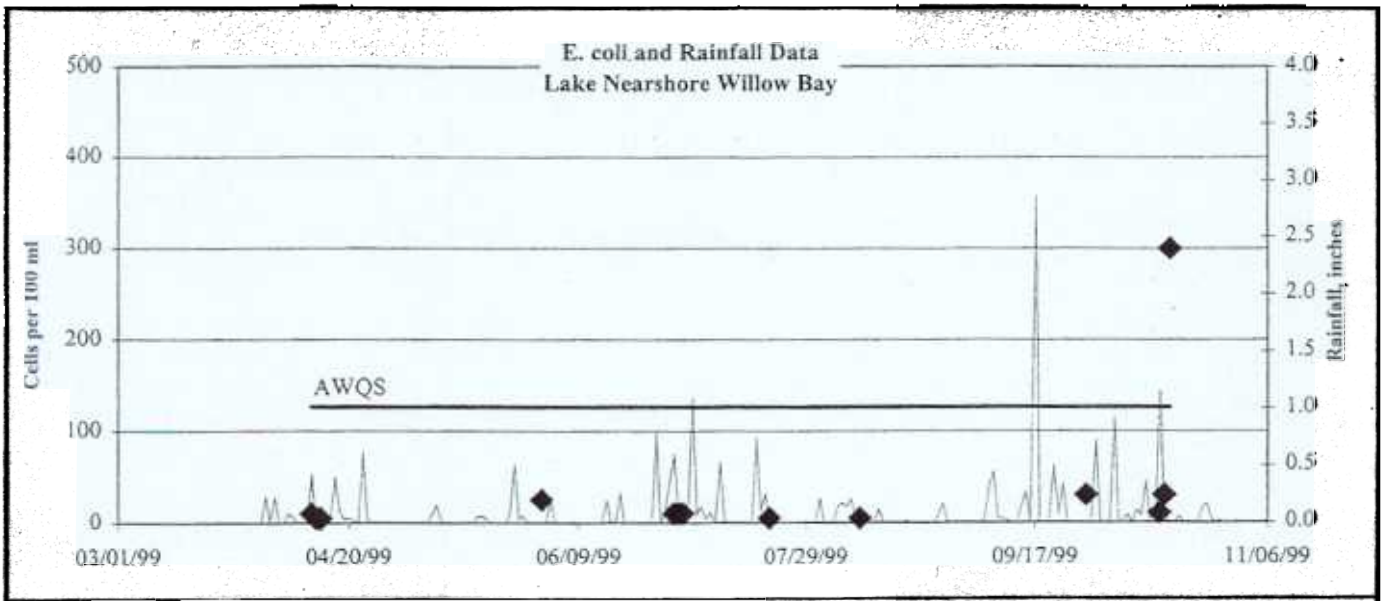
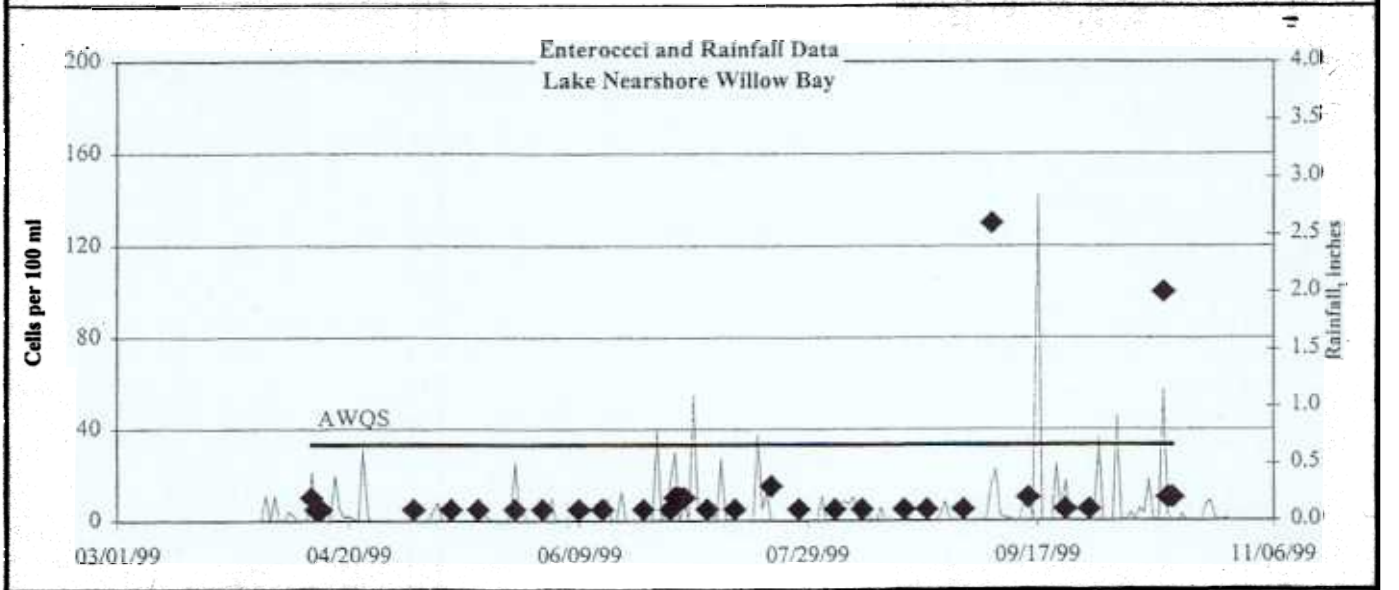


FIGURE 6-24 (cont): Results of monitoring at near-shore stations for indicator bacteria, 1999

fig 6-24 nearshore bacteria





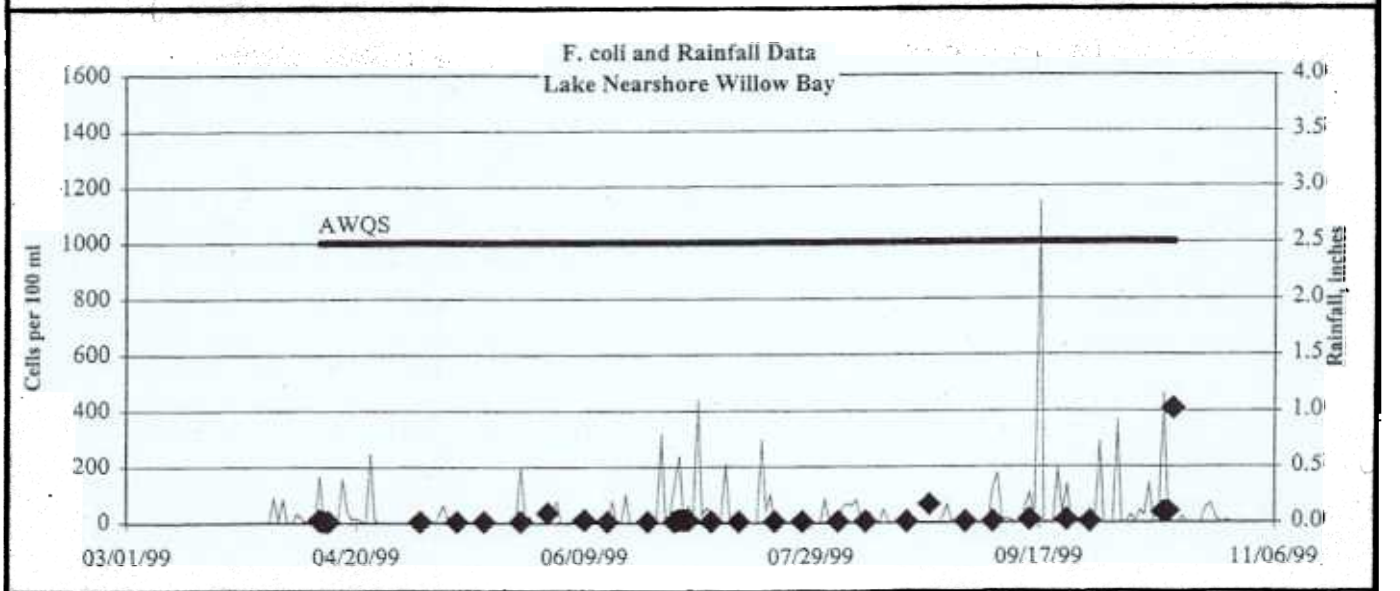
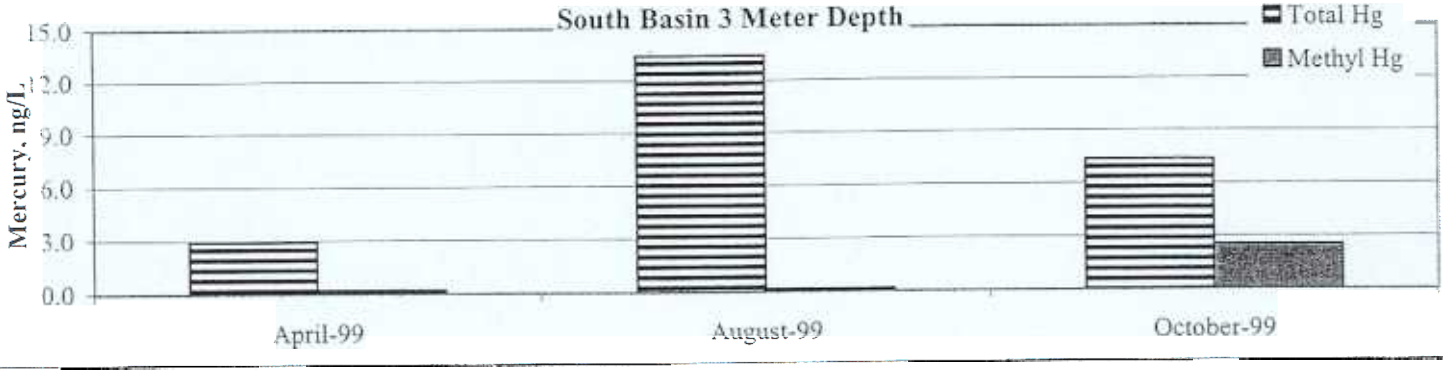
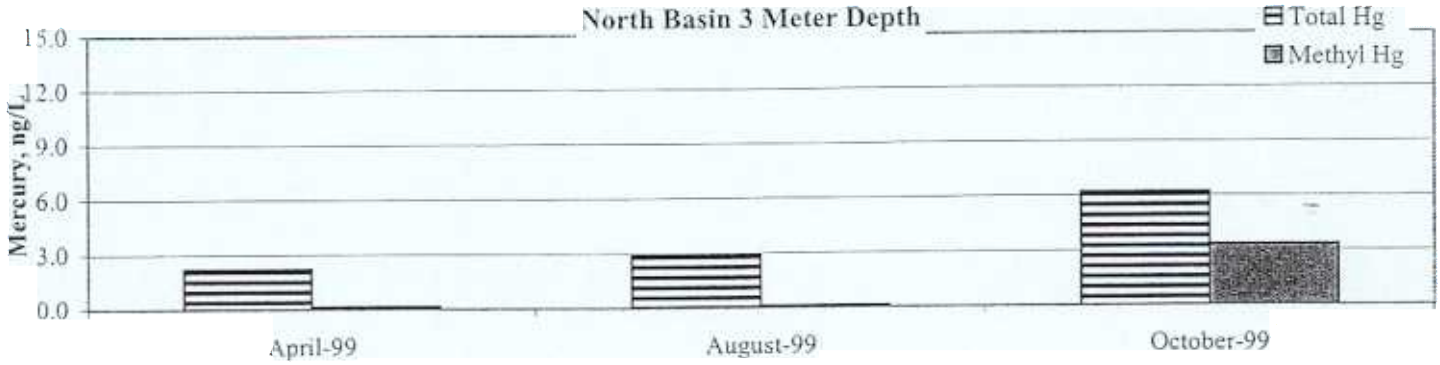
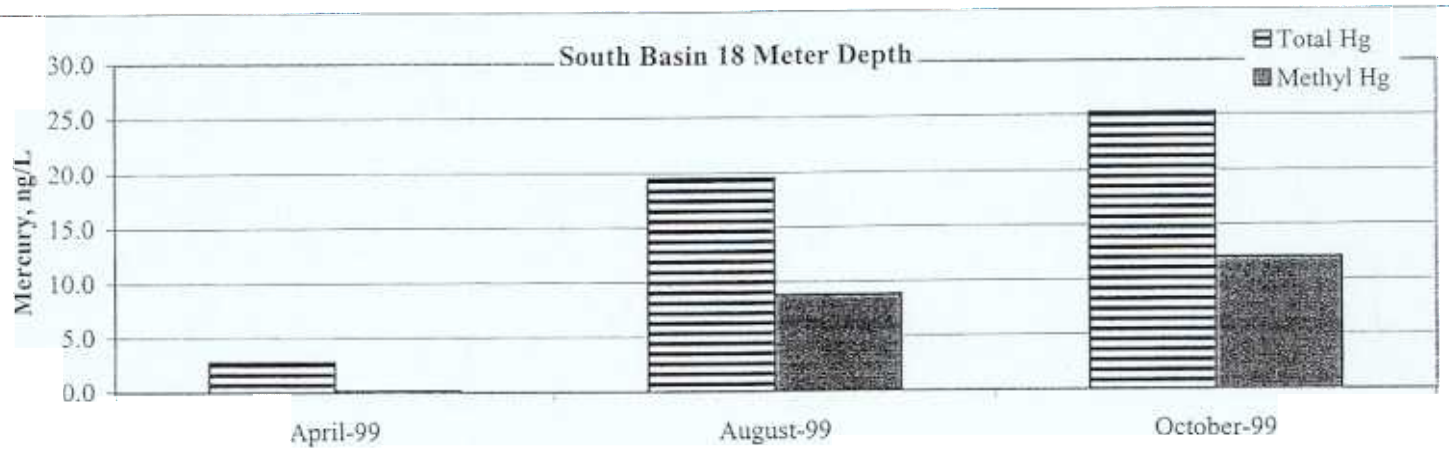


FIGURE 6-24 (cont): Results of monitoring at near-shore stations for indicator bacteria, 1999

fig 6-24 nearshore bacteria







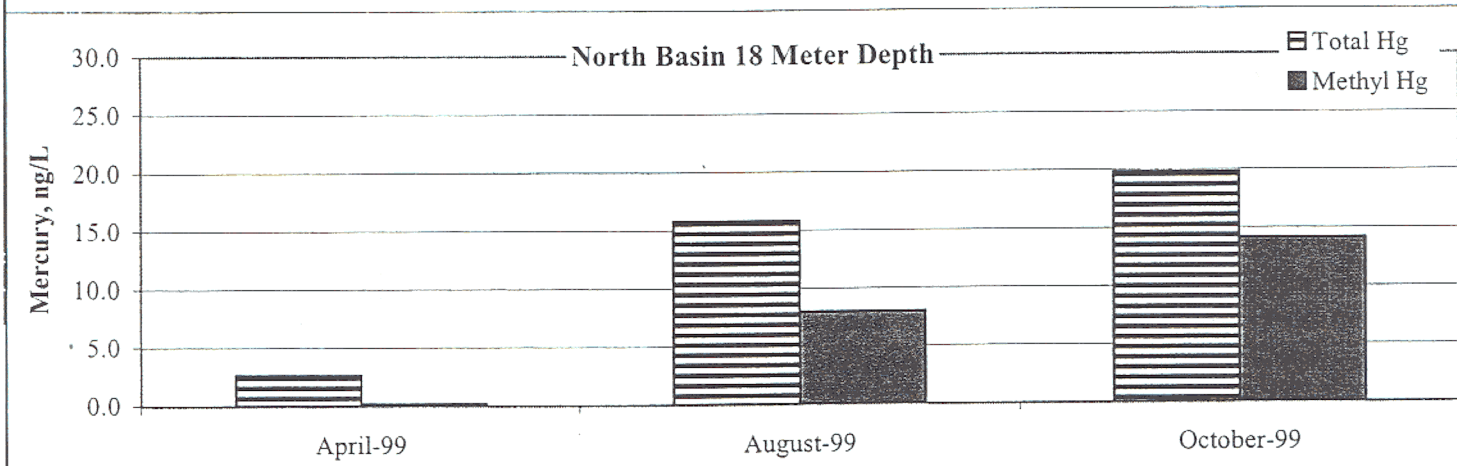


FIGURE 6-25: Total and Methyl Mercury Concentrations, Onondaga Lake 1999

TABLE 6-1

VOLUME-WEIGHTED MEANS OF THE UPPER (0-9 M) WATERS OF ONONDAGA LAKE, 1999, DURING THE ICE-FREE AND GROWING SEASONS

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Units	Ice-free Season Mean	Ice-free Season Median	Growing Season Mean	Growing Season Median
Secchi Disc Transparency	m	2.2	1.8	2.3	1.6
pH	standard units	7.87	7.88	7.92	7.94
Temperature	° C	14.52	13.86	20.28	21.53
Specific Conductance	µmhos/cm	2180	2279	2246	2270
Dissolved Oxygen	mg/l	9.30	7.74	7.23	6.96
5-day BOD	mg/l	3	3	3	2
Total Alkalinity	mg/l	146	148	133	146
Total Organic Carbon	mg/l	4.47	4.36	4.37	4.37
TOC-filtered	mg/l	4.13	4.01	3.99	3.96
Total Inorganic Carbon	mg/l	36.0	37.1	33.8	33.7
Total Kjeldahl Nitrogen	mg/l	1.84	1.87	1.93	1.87
Organic Nitrogen	mg/l	0.69	0.69	0.76	0.69
Ammonia-N	mg/l	1.15	1.27	1.18	1.27
Nitrate-N	mg/l	1.36	1.24	1.51	1.74
Nitrite-N	mg/l	0.13	0.11	0.12	0.12
Arsenic	µg/l	<2	<2	<2	<2
Cyanide	µg/l	<2	<2	<2	<2
Total Phosphorus	µg/l	95	76	61	62
Soluble Reactive P	µg/l	49	23	15	18
Silica	mg/l	1.72	1.34	1.12	1.20
Calcium	mg/l	143	139	144	143
Sodium	mg/l	255	256	249	250
Sulfate	mg/l	189	194	193	194
Chloride	mg/l	488	516	504	497
Total Solids	mg/l	1424	1430	1473	1487
Total Suspended Solids	mg/l	4	3	5	5
Volatile Suspended Solids	mg/l	3	2	5	4
Total Volatile Solids	mg/l	251	251	303	292
Total Dissolved Solids	mg/l	1333	1336	1365	1351

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TABLE 6-1 (continued)

VOLUME-WEIGHTED MEANS OF THE UPPER (0-9 M) WATERS OF ONONDAGA LAKE, 1999, DURING THE ICE-FREE AND GROWING SEASONS
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Units	Ice-free Season Mean	Ice-free Season Median	Growing Season Mean	Growing Season Median
Zinc	µg/l	8.9	8.3	11.9	11.9
Copper	µg/l	0.9	1.3	0.7	0.7
Chromium	µg/l	0.6	0.6	0.6	0.6
Cadmium	µg/l	0.4	0.4	0.4	0.4
Lead	µg/l	4.5	4.8	5.0	5.0
Iron	mg/l	0.087	0.064	0.085	0.076
Magnesium	mg/l	23.9	24.2	24.1	24.2
Manganese	mg/l	0.020	0.012	0.010	0.002
Potassium	mg/l	5.37	5.45	5.42	5.42
Nickel	µg/l	8.7	5.2	4.4	4.4
Phenol	µg/l	11	10	10	10
Chlorophyll *a*	mg/m^3	21.5	15.0	22.3	19.2
Fecal Coliforms	cells/100ml	8	5	9	5

Ice-free season calculations are based on measurements taken from March 29 to December 14. Growing season calculations include data from May 18 to September 15.
Calculations use the laboratory limit of detection when observations are below that limit *(see Table 6-5).*

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TABLE 6-2

VOLUME-WEIGHTED MEANS OF THE LOWER (12-18 M) WATERS OF ONONDAGA LAKE, 1999, DURING THE ICE-FREE AND GROWING SEASONS

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Units	Ice-free Season Mean	Ice-free Season Median	Growing Season Mean	Growing Season Median
pH	standard units				
Temperature	° C	9.50	10.21	10.24	10.73
Specific Conductance	µmhos/cm	2229	2236	2196	2209
Dissolved Oxygen	mg/l	5.29	4.60	1.58	0.07
5-day BOD	mg/l	4	3	4	3
Total Alkalinity	mg/l	182	185	195	195
Total Organic Carbon	mg/l	4.31	4.16	4.13	4.11
TOC-filtered	mg/l	4.05	3.99	3.85	3.77
Total Inorganic Carbon	mg/l	46.4	46.1	48.3	48.7
Total Kjeldahl Nitrogen	mg/l	2.72	2.36	3.34	3.31
Organic Nitrogen	mg/l	0.50	0.55	0.42	0.45
Ammonia-N	mg/l	2.22	1.77	2.92	3.20
Nitrate-N	mg/l	0.62	0.78	0.31	0.06
Nitrite-N	mg/l	0.09	0.06	0.03	0.04
Arsenic	µg/l	<2	<2	<2	<2
Cyanide	µg/l	<2	<2	<2	<2
Total Phosphorus	µg/l	267	203	377	417
Soluble Reactive P	µg/l	218	160	325	377
Silica	mg/l	3.29	2.94	3.88	4.18
Calcium	mg/l	143	144	144	146
Sodium	mg/l	257	250	251	249
Sulfate	mg/l	172	166	168	168
Chloride	mg/l	516	508	504	492
Total Solids	mg/l	1428	1416	1454	1448
Total Suspended Solids	mg/l	2	2	2	2
Volatile Suspended Solids	mg/l	2	2	2	2
Total Volatile Solids	mg/l	248	241	284	295
Total Dissolved Solids	mg/l	1336	1346	1351	1339

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TABLE 6-2 (continued)

VOLUME-WEIGHTED MEANS OF THE LOWER (12-18 M) WATERS OF ONONDAGA LAKE, 1999, DURING THE ICE-FREE AND GROWING SEASONS

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Units	Ice-free Season Mean	Ice-free Season Median	Growing Season Mean	Growing Season Median
Zinc	µg/l	6.7	7.4	6.4	7.4
Copper	µg/l	1.0	0.7	0.5	0.4
Chromium	µg/l	0.7	0.5	0.5	0.5
Cadmium	µg/l	0.4	0.4	0.4	0.4
Lead	µg/l	4.1	3.5	4.1	3.5
Iron	mg/l	0.096	0.099	0.103	0.096
Magnesium	mg/l	23.3	23.1	23.1	23.0
Manganese	mg/l	0.220	0.156	0.272	0.324
Potassium	mg/l	4.91	4.78	4.69	4.74
Nickel	µg/l	7.5	4.2	3.8	4.2
Phenol	µg/l	10	10	10	10

Ice-free season calculations are based on measurements taken from March 29 to December 14. Growing season calculations include data from May 18 to September 15.
Calculations use the laboratory limit of detection when observations are below that limit *(see Table 6-5).*

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TABLE 6-3

VOLUME-WEIGHTED ANNUAL MEANS OF CONSTITUENTS IN THE UPPER (0-9 M) WATERS OF ONONDAGA LAKE, 1988-1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Units	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Secchi disk depth	m												
Temperature	°C												
Specific Conductance	µmhos/cm												
Dissolved Oxygen	mg/l												
5-day BOD	mg/l												
Total Alkalinity	mg/l												
Total Organic Carbon	mg/l		5.2					6.0	4.3				
TOC-filtered	mg/l		4.8					5.2	3.9				
Total Inorganic Carbon	mg/l		39.9					42.3	43.7				
Total Kjeldahl N	mg/l		2.9			3.4		3.1	3.4				
Organic N	mg/l		1.2			1.3		0.81	0.82				
Ammonia-N	mg/l		1.9			2.1		2.3	2.6				
Nitrate-N	mg/l		1.5			0.95		0.89	1.3				
Nitrite-N	mg/l		0.18			0.10		0.11	0.24				
Arsenic	µg/l		*			2.0		2.0	2.0				
Total Cyanide	µg/l		*			3.0		2.3	2.3				
Total Phosphorus	µg/l	NA	NA	110	99.0	100		128	141			112	95
Total Inorganic P	µg/l	152	104	74.0	44.0	60.0		91.9	98.3			ND	ND
Soluble Reactive P	µg/l	82.0	74.0	41.0	30.0	40.0		73.0	85.7			63.0	49.0
Silica	mg/l	1.4	1.5	1.9	1.4	1.8		2.6	2.4			1.7	1.7
Calcium	mg/l	189	159	155	154	144		146	164			139	143
Sodium	mg/l	265	200	180	204	198		227	280			221	255
Sulfate	mg/l	171	152	156	166	168		152	166			176	189
Chloride	mg/l	590	458	432	460	437		453	508			462	488
Total Suspended Solids	mg/l	7.7	6.8	5.9	6.0	4.2		6.5	2.9		4.0	3.0	4.0
Zinc	µg/l	9.0	24.0	11.7	9.5	9.0		37.5	16.6		7.0	11.2	8.9
Copper	µg/l	11.0	20.0	10.1	8.0	6.8		7.2	8.0		6.0	11.7	0.9
Chromium	µg/l	7.0	3.0	2.0	1.3	1.7		2.6	0.93		2.00	1.58	0.60
Cadmium	µg/l	3.0	3.0	1.3	0.50	0.60		1.0	0.63		0.70	2.15	0.40
Lead	µg/l	21.0	7.0	1.8	0.80	0.90		2.4	1.4		0.60	2.75	4.50
Iron	mg/l	*	*	*	*	0.087		0.14	0.084		0.087	0.093	0.087
Magnesium	mg/l	*	*	*	*	23.0		23.4	24.3		24.5	22.6	23.9
Manganese	mg/l	*	*	*	*	0.035		0.042	0.042		0.031	0.033	0.020
Nickel	mg/l	*	*	*	*	0.031		0.022	0.024		0.026	0.032	0.009
Phenol	mg/l	*	*	*	*	0.006		0.006	0.011		0.020	0.010	0.011
Chlorophyll *a*	mg/m^3	23.0	14.0	31.0	36.0	16.0	11.5	26.3	9.3	22.5	12.8	14.2	21.5
Fecal Coliform	cells/100mls	49	45	102	73.4	176	136	35.9	140	135	138	85	8
Precipitation	inches	34.4	36.9	49.5	37.1	43.6	43.6	37.3	31.3	39.4	32.6	37.1	30.9

NA = not analyzed that year. * = data not available.
Means were calculated using data collected during the bi-weekly sampling program in the ice-free season.

TABLE 6-4

VOLUME-WEIGHTED ANNUAL MEANS OF CONSTITUENTS IN THE LOWER (12-18 M) WATERS OF ONONDAGA LAKE, 1988-1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	Unit	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
				1927						1906			
				10.7						9.3			
				4.3						4.2			
				4.5						3.4			
				206						191			
				5.8						4.6			
				5.3						4.3			
				52.9						50.8			
				2.9						3.7			
				0.6						0.72			
				2.2						3.0			
				0.82						0.66			
				0.07						0.07			
				*						2.0			
				*						2.0			
		NA	NA	319	251					351			
		459	339	281	301					310			
		363	296	243	199					290			
		2.1	1.5	2.5	NA					2.6			
		204	172	155	158					140			
		274	218	172	200					214			
		167	152	144	145					146			
		616	509	414	450					418			
		6.0	5.1	4.8	3.5					4.1			
		55.0	33.0	8.9	15.6					16.4			
		12.0	25.0	10.4	7.8					6.9			
		5.0	3.0	1.9	1.3					0.88			
		3.0	3.0	1.4	0.50					0.90			
		24.0	7.0	1.5	0.70					0.7			
		*	*	*	*					0.14			
		*	*	*	*					22.5			
		*	*	*	*					0.22			
		*	*	*	*					0.02			
		*	*	*	*					0.01			
		12.0	14.0	10.0	14.0					NA			
		32	35	99	56					240			

NA = not analyzed that year or data not available.
Means were calculated using data collected during the bi-weekly sampling program in the ice-free season.
Calculations use the laboratory limit of detection when observations are below that limit (see Table 6-5).

Table 6-5

FREQUENCY OF LAKE OBSERVATIONS (SOUTH DEEP STATION)
BELOW THE LABORATORY LIMIT OF DETECTION, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

	Limit of Detection (mg/l)	Epilimnion <LOD : Total #	Hypolimnion <LOD : Total #
Nitrite-N	0.01	0 : 21	1 : 20
Nitrate-N	0.01	0 : 21	2 : 20
Arsenic	0.002	5 : 5	5 : 5
Cyanide	0.002	5 : 5	5 : 5
Soluble Reactive P	0.001	2 : 22	0 : 22
Total Suspended Solids	1.0	0 : 20	0 : 20
Volatile Suspended Solids	1.0	2 : 20	2 : 20
Chromium	0.0005	1:5	3:5
Cadmium	0.0004	5:5	4:5
Sulfides	0.2	NA	0 : 26
Lead	0.0005	0:5	0:4
Chlorophyll *a* (1)	0.2	0 : 64	NA
Phaeophytin (1)	0.2	10 : 64	NA
Phenol	0.01	4 : 5	5 : 5
Fecal Coliform	2.0 / 100ml	18 : 32	0 : 7

Notes:
(1) Units for Chlorophyll *a* and Phaeophytin are mg/m^3.
NA: not analyzed or monitored in 1999.

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TABLE 6-6

CONCENTRATIONS OF MAJOR IONS IN EPILIMNETIC WATERS OF
ONONDAGA LAKE - 1981 AND 1999
COMPARED TO CONCENTRATIONS IN OTISCO LAKE

IONS	ONONDAGA LAKE 1981		ONONDAGA LAKE 1999		OTISCO LAKE 1978	
	MEQ/L	%	MEQ/L	%	MEQ/L	%
Ca2+	32.1	55.2	7.1	35.1%	2.4	69.6
Na2+	24	41.2	11.1	55.0%	0.15	4.3
Mg2+	2	3.4	2	9.9%	0.9	26.1
SUM OF CATIONS	58.1		20.2		3.45	
HCO3-	1.9	3.4	2.9	14.1%	2.65	77.9
Cl-	48.7	89.1	13.8	67.0%	0.4	11.8
SO42-	4.1	7.5	3.9	18.9%	0.35	10.3
SUM OF ANIONS	54.7		20.6		3.4	

6ions99.xls

TABLE 6-7

Summary of compliance of nearshore samples with ambient water quality standards and criteria for indicator bacteria. 1999 data set.
Onondaga Lake 1999 Annual report

	Nearshore Station Locations						
	1 Harbor Brook (southwest)	2 Ley Creek (southeast)	3 Maple Bay (northwest)	4 Metro (south)	5 Nine Mile Creek (west, central)	6 Onondaga Lake Park (east, central)	7 Willow Bay (northeast)
Indicator: E. coli							
Number of samples	12	13	13	13	12	13	13
Number > 126	3	5	0	7	1	2	1
Percent Compliance (Class B)	75	62	100	46	92	85	92
Indicator: Enterococcus							
Number of samples	12	13	31	13	28	29	31
Number > 33	3	2	1	4	1	1	2
Percent Compliance (Class B)	75	85	97	69	96	97	94
Indicator: Fecal coliform							
Number of samples	14	13	31	13	28	29	31
Number > 1000	1	0	0	3	0	0	0
Percent Compliance (Class B)	93	100	100	77	100	100	100
Number of samples	14	13	31	13	28	29	31
Number > 200	3	5	0	7	0	1	1
Percent Compliance (Class B)	79	62	100	46	100	97	97

TABLE 6-8

REGULATORY COMPLIANCE IN ONONDAGA LAKE WATERS, 1999

Onondaga Lake 1999 Annual Report

Onondaga County, New York

Parameter (units)	NYSDEC Standard (Class B,C)[2]	Averages		Observations in Compliance
pH (standard units)	Shall not be less than 6.5 nor more than 8.5	UW :	7.9	100%
		LW :	7.6	100%
Dissolved Oxygen (mg/l)	Minimum daily average 5.0 mg/l, at no time shall DO be < 4.0 mg/l	UW :	9.3	100% >4.0; 100% >5.0
		LW :	5.2	52% >4.0; 42% >5.0
Dissolved Solids (mg/l)	Shall be kept as low as practicable to maintain the best usage of waters but in no case shall it exceed 500 mg/l.	UW :	1333	0%
		LW :	1336	0%
Fecal Coliform[3] (cells/100 ml)	Percent individual observations > 200 cells. *See footnote*	UW :	8	90%
Ammonia-N (mg/l)	Varies with pH and temperature.	0m	1.08	62%
		3m	1.01	52%
		6m	1.10	48%
		9m	1.44	52%
		12m	1.98	33%
		15m	2.23	33%
		18m	2.76	24%
Arsenic * [1] (µg/l)	190 µg/l	UW :	2.0	100%
		LW :	2.0	100%
Cyanide * (µg/l)	5.2 µg/l (Free CN)	UW :	2.0	100%
		LW :	2.0	100%
Nitrite-N (µg/l)	100 µg/l (Warm water fishery)	UW :	129	50%
		LW :	90	84%

5-COMPLY_99.xls/TAB6-7

TABLE 6-8 (continued)

REGULATORY COMPLIANCE IN ONONDAGA LAKE WATERS, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter (units)	NYSDEC Standard (Class B,C)	Averages	Observations in Compliance
Copper [1] (µg/l)	0.96 exp (0.8545 [ln (ppm hardness)]-1.702) Standard(µg/l): 26.1	UW : 1.0 LW : 9.6	100% 100%
Lead (µg/l)	(1.46203 - [ln (hardness) 0.145712]) exp (1.273 [ln (hardness)]-4.297) Standard(µg/l): 14.34	UW : 4.50 LW : 4.10	100% 100%
Cadmium (µg/l)	0.85 exp (0.7852 [ln (ppm hardness)]-2.715) Standard(µg/l): 5.60	UW : 0.42 LW : 0.42	100% 100%
Zinc [1] (µg/l)	exp (0.85 [ln (ppm hardness)] + 0.50) Standard(µg/l): 240	UW : 8.9 LW : 6.7	100% 100%
Chromium (µg/l)	0.86 exp (0.819 [ln (ppm hardness)]+1.561) Standard(µg/l): 497	UW : 0.58 LW : 0.70	100% 100%
Iron (µg/l)	300 µg/l	UW : 87 LW : 96	100% 100%
Nickel (µg/l)	0.997 exp (0.846 [ln (ppm hardness)]+0.0584) Standard(µg/l): 248	UW : 8.7 LW : 7.5	100% 100%

TABLE 6-8 (continued)
REGULATORY COMPLIANCE IN ONONDAGA LAKE WATERS, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter (units)	NYSDEC Standard (Class B,C)	Averages	Observations in Compliance
Total Phosphorus (µg/l)	None in amounts that will result in growths of algae, weeds, and slimes that will impair the waters for their best usages. Guidance value of 20 µg/l, *upper waters summer average.*	UW 66	0%
Secchi Disk Transparency (m)	NYSDOH guidance for bathing beaches: 1.2 m during recreational season (June, July, August)	UW 2.0	71%

UW = upper waters, LW = lower waters.

(1) : Standard value applies to dissolved fraction, though currently only acid soluble, total recoverable fraction is measured within the monitoring program. Standard values for all other metals apply to acid soluble, total recoverable fraction.

(2) :Standard values are derived from NYSDEC Ambient Water Quality Standards and Guidance Values, 1993, and 6NYCRR Part 703, with Jan. 1994 updates for bacteria and zinc; and 1998 updates for metals.

(3) :Bacteria compliance reported by comparing individual measurements to the standard of 200 cells/100mL. Since the standard is a geometric mean of at least 5 samples, compliance will always be equal or greater than the percent listed.

Compliance calculations were made using a hardness value of 350 ppm, which is the maximum value allowed by NYSDEC for these calculations. Average hardness of Onondaga Lake waters was 488 ppm in 1999.

* Averages derived from observations made during quarterly sampling. All other averages derived from observations made during the bi-weekly sampling program from March 27 to December 15. Calculations use the laboratory limit of detection when observations are below that limit (see Table 6-5).

TABLE 6-9

LOW-LEVEL MERCURY SAMPLING

Onondaga Lake 1999 Annual report
Onondaga County, New York

April 20, 1999 Sampling Event
DO at Saturation

Location and Depth	Total Hg (ng/l)	Methyl Hg (ng/l)	Ratio Total/Methyl
South Deep 3 m	2.92	0.192	15.2
South Deep 18 m	2.75	0.114	24.1
North Deep 3 m	2.2	0.137	16.1
North Deep 18 m	2.62	0.152	17.2

August 10, 1999 Sampling Event
DO 0 mg/l at 18m

Location and Depth	Total Hg (ng/l)	Methyl Hg (ng/l)	Ratio Total/Methyl
South Deep 3 m	13.4	0.152	88.2
South Deep 18 m	19.5	8.83	2.21
North Deep 3 m	2.92	0.112	26.1
North Deep 18 m	15.8	8.01	1.97

October 15, 1999 Sampling Event
DO 0 mg/l at 18 m

Location and Depth	Total Hg (ng/l)	Methyl Hg (ng/l)	Ratio Total/Methyl
South Deep 3 m	7.37	2.52	2.92
South Deep 18 m	25.2	12	2.10
North Deep 3 m	6.19	3.33	1.86
North Deep 18 m	19.8	14.1	1.40

TABLE 6-7 Hg results.doc

TABLE 6-10

SUMMARY OF TEN YEAR TRENDS IN CONCENTRATION, 1990 - 1999
ONONDAGA LAKE NORTH AND SOUTH DEEP STATIONS

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Parameter	South Deep Station		North Deep Station	
	Epilimnion (0 – 9 m)	Hypolimnion (12 – 18 m)	Epilimnion (0 – 9 m)	Hypolimnion (12 – 18 m)
Dissolved Oxygen		I		I
Temperature				
pH			I	I
Secchi Disk	I			
Total Suspended Solids		D		
Total Solids	I			
Total P			D	D
Soluble Reactive P			D	D
Organic N				
Nitrite N		I		I
Nitrate N				
Ammonia N				
Total Kjeldahl N		D		
Fecal coliform bacteria	D			
Sodium	I	I		I
Calcium		D		
Chloride	I			
Sulfate	I			
Total alkalinity			D	
BOD				
Total organic C		D		
Filtered total organic C		D		
Total inorganic C				
Silicate				
Chlorophyll a				

D Decreasing trend based on ten years of data. Probability P2 that trend is due to chance is less than 0.10

I Increasing trend based on ten years of data. Probability P2 that trend is due to chance is less than 0.10

CHAPTER 7

TROPHIC STATE

7.1 Objectives and Scope

Each year the Annual Report includes an expanded discussion of one issue related to the lake and its watershed. The 1999 topic is trophic state. Trophic state is defined as the level of productivity of a waterbody and is assessed by measuring various attributes of the system. These attributes may be causal factors (nutrients) that support primary production or response variables (e.g. algal abundance, water clarity, fish production, dissolved oxygen depletion rate) that reflect the level of productivity. Limnologists and lake managers classify lakes on a continuum of trophic state from oligotrophic (low level of nutrients and productivity) to eutrophic (high levels of nutrients and productivity). Mesotrophic conditions are intermediate. Wetzel (1966) added the term hypereutrophic to describe conditions of extreme eutrophy.

The Annual Reports summarize nutrient data, algal abundance, water clarity, and dissolved oxygen concentrations measured in the lake each year, and compare recent data with historical trends. In this chapter the approach is more integrative, with a focus on the structure and function of the lake as an ecosystem. Several trophic state indicators are presented to describe current conditions and changes in Onondaga Lake over the past decade or so. Findings of a paleolimnological investigation are summarized to provide a historical perspective of the lake's trophic status over the past two centuries.

7.2 Historical Conditions: Paleolimnology

Paleolimnology is a field of investigation that infers past water quality and watershed conditions from the historical record preserved in lake sediments. The silicon-rich frustules of diatoms are often well preserved in sediment cores and limnologists have identified assemblages of diatoms associated with levels of productivity and tolerance to other water quality conditions such as salinity.

Dr. H. Chandler Rowell obtained Onondaga Lake sediment cores and investigated paleolimnology of the system as part of his doctoral dissertation work at State University of New York, College of Environmental Sciences and Forestry (Rowell 1992). He concluded that prior to 1800 Onondaga Lake was a moderately productive alkaline lake with sediment characteristics typical of a north temperate setting. The lake became more productive following European settlement during the early to mid 1800s and was highly polluted by the mid 1900s. The lake's salt content also increased following European settlement of the watershed. A further increase occurred around 1900 in conjunction with increased industrial activity in the watershed and an increase in calcium carbonate content of the sediment.

Pollution was most intense from the late 1940's to around 1970, as evident from a sediment interval with high concentrations of total organic carbon (TOC), total phosphorus and trace metals. This sediment interval extends to a depth of approximately 40 cm. A slight improvement in lake water quality is suggested by the levels of these chemicals detected in the uppermost sediments that have been most recently deposited.

A long-term sediment accumulation rate in Onondaga Lake of 0.08 cm/yr. (determined from ^{14}C dates) is similar to rates reported from a number of nearby lakes. Sediment accumulation rates since 1964 are estimated at 0.88 cm/yr. for the southern basin and 0.82 cm/yr. for the northern basin. According to Dr. Rowell, this rate of deposition is comparable to other productive lakes with very high sedimentation rates.

Abundance and species composition of diatoms preserved in the lake sediments were examined. A total of 216 taxa were identified. Of these, 140 have been reported as preferentially occurring under different trophic and salinity regimes and are therefore useful in an assessment of historical trophic state conditions in the lake. All diatoms found in the sediment cores are present in alkaline conditions.

7.5 Dissolved Oxygen and the Fish Community

The rate of at which the concentration of dissolved oxygen in the hypolimnion declines once thermal stratification develops is one measure of the level of a lake's productivity. This metric has been calculated over the years of the monitoring program. Chapter 4 (Lake Results) and Chapter 12 (Mass Balance Modeling) present additional discussion of the data sets and calculation procedures used for this metric. Overall, the HOD rate in Onondaga Lake is high and characteristic of eutrophic lakes.

Ogelsby (1987) examined the relationships between trophic status and fish communities and indexed hypolimnetic oxygen resources to the TSI scale. From this anaysis, he drew conclusions regarding the fish communities associated with summer TP concentrations and the Carlson TSI scale. General categories were defined as outlined in Table 7-6. Using this integrated scale, Onondaga Lake is eutrophic based on TP in the 50 – 60 µg/l range and TSI of 60 – 80.

The lake's fish community is dominated by centrarchids (bass and sunfish) with percids (yellow perch and walleye) present as well. The AMP includes extensive monitoring of the fish community beginning in 2000 and continuing through 2012. Trends in community structure and reproductive success of individual species will be tracked over time.

7.6 Conclusions and recommendations

Paleolimnological evidence suggests that Onondaga Lake was a moderately productive alkaline lake with sediment characteristics typical of its north temperate setting. The lake became more productive following European settlement during the early to mid 1800s and was highly polluted by the mid 1900s. Ecological associations found in the lake sediments suggested that mesotrophic to meso-eutrophic lake conditions prevailed prior to the early 1800s. The most prevalent diatom taxa in sediments below 80 cm (deposited prior to 1822) were classified as oligotrophic and mesotrophic. However, eutrophic taxa were well represented.

Trophic state indices calculated using both causal factors and response variables are consistent with a classification of Onondaga Lake as eutrophic (highly productive). Total phosphorus, chlorophyll a and Secchi disk transparency remain in the eutrophic range. There is no trend in TSI from 1987 – 1999. The lake's fish community is largely dominated by centrarchids (bass and sunfish); percids are well represented.

Since 1970, the annual monitoring program has included collection, identification, and enumeration of phytoplankton and zooplankton. Recent data (1996 and later) are reported in terms of biomass and abundance. These data can be used to calculate various biological criteria and provide important insights into changes in community structure over time.

FIGURE 7-1TSI for secchi disk, chlorophyll, and total phosphorus in Onondaga Lake from 1987 to 1999.

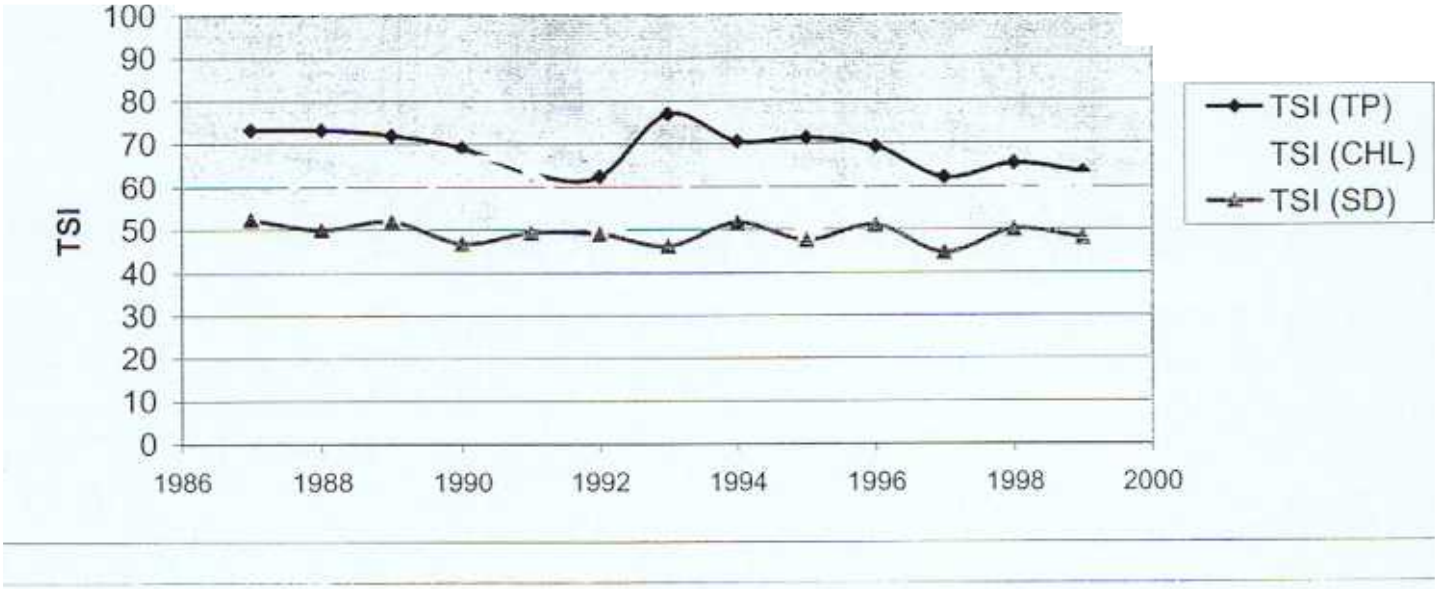
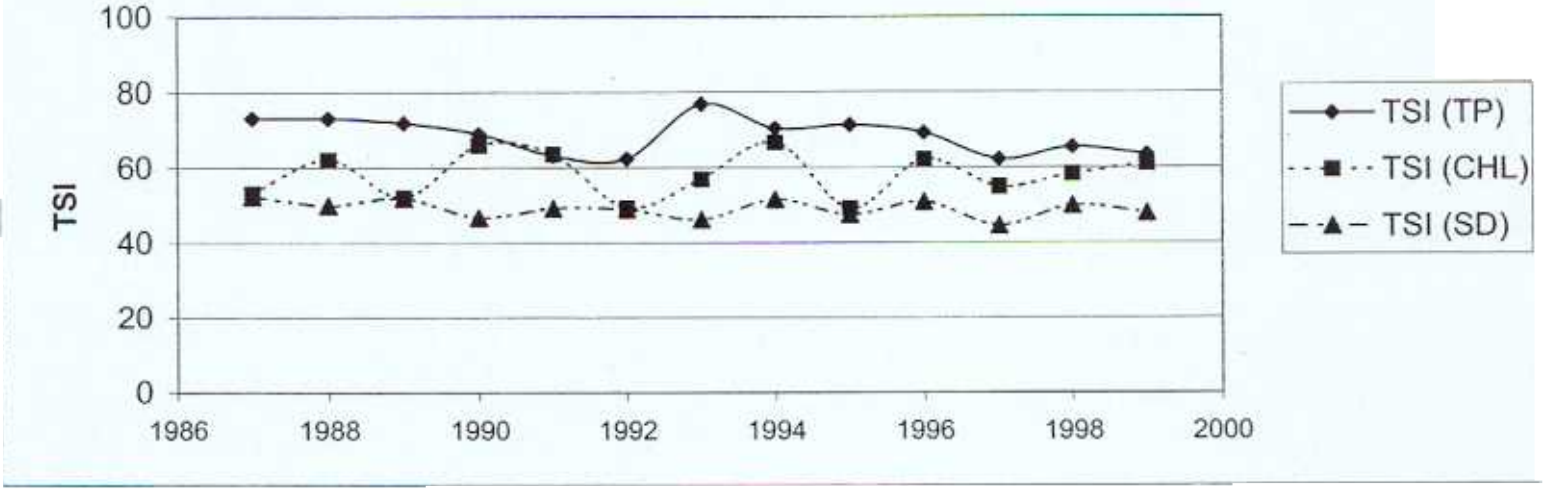


Figure 7-1. TSI for secchi disk, chlorophyll, and total phosphorus in Onondaga Lake from 1987 to 1999.



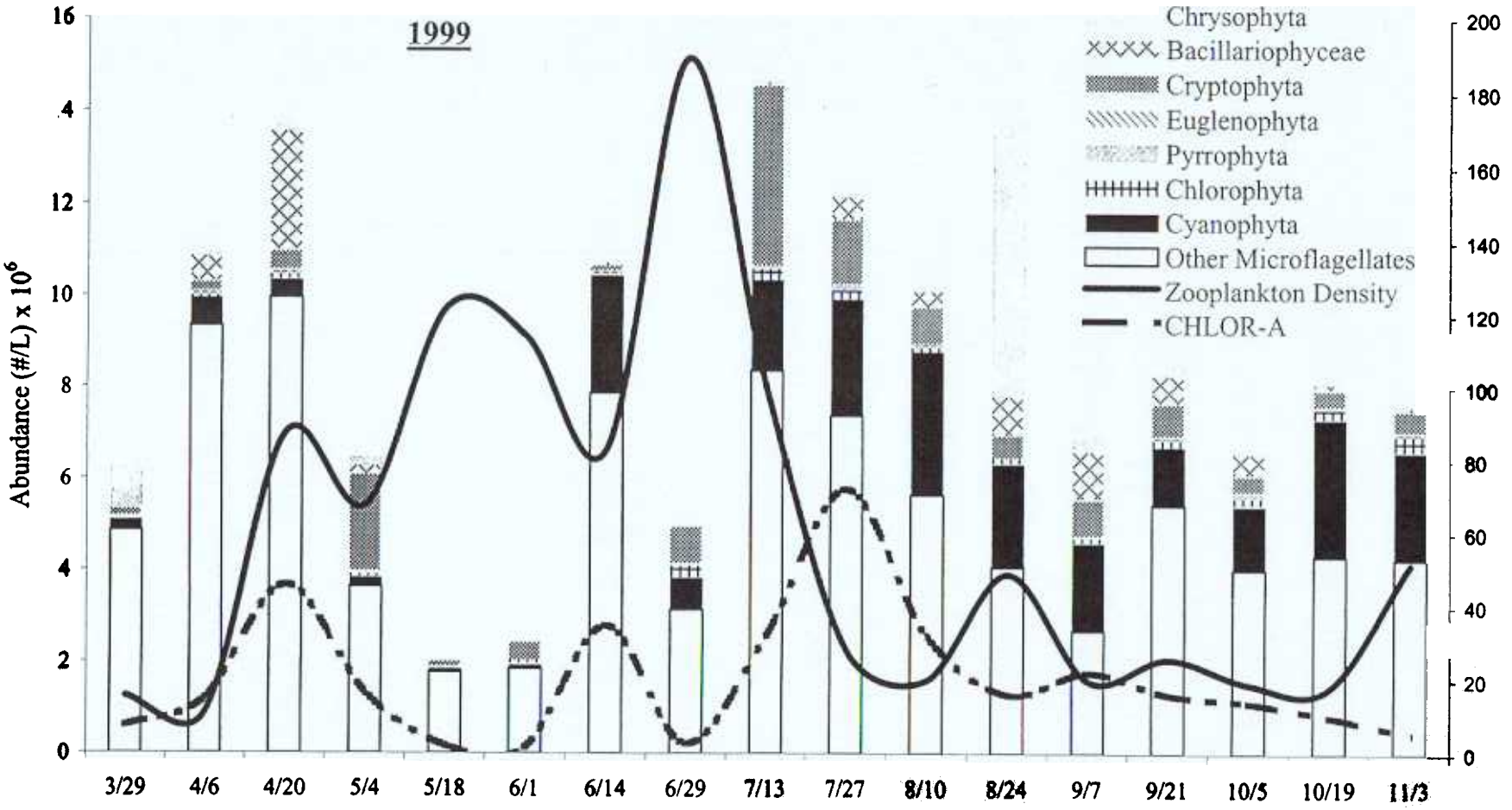


Figure 7-2. Abundance (#/L) x 10^6 of eight major groups of phytoplankton collected from Onondaga Lake, 3/29/99 - 11/3/99. Data averages of 0m, 3m, and integrated epilimnetic samples (3/29, 4/6*, 4/20, 5/4, 5/18, 6/1, 6/14, 6/29, 7/13*, 7/27, 8/10, 8/24, 9/7, 9/2 10/5, 10/19, 11/3). An asterix indicates "North" station samples were taken in addition to "South" station samples.

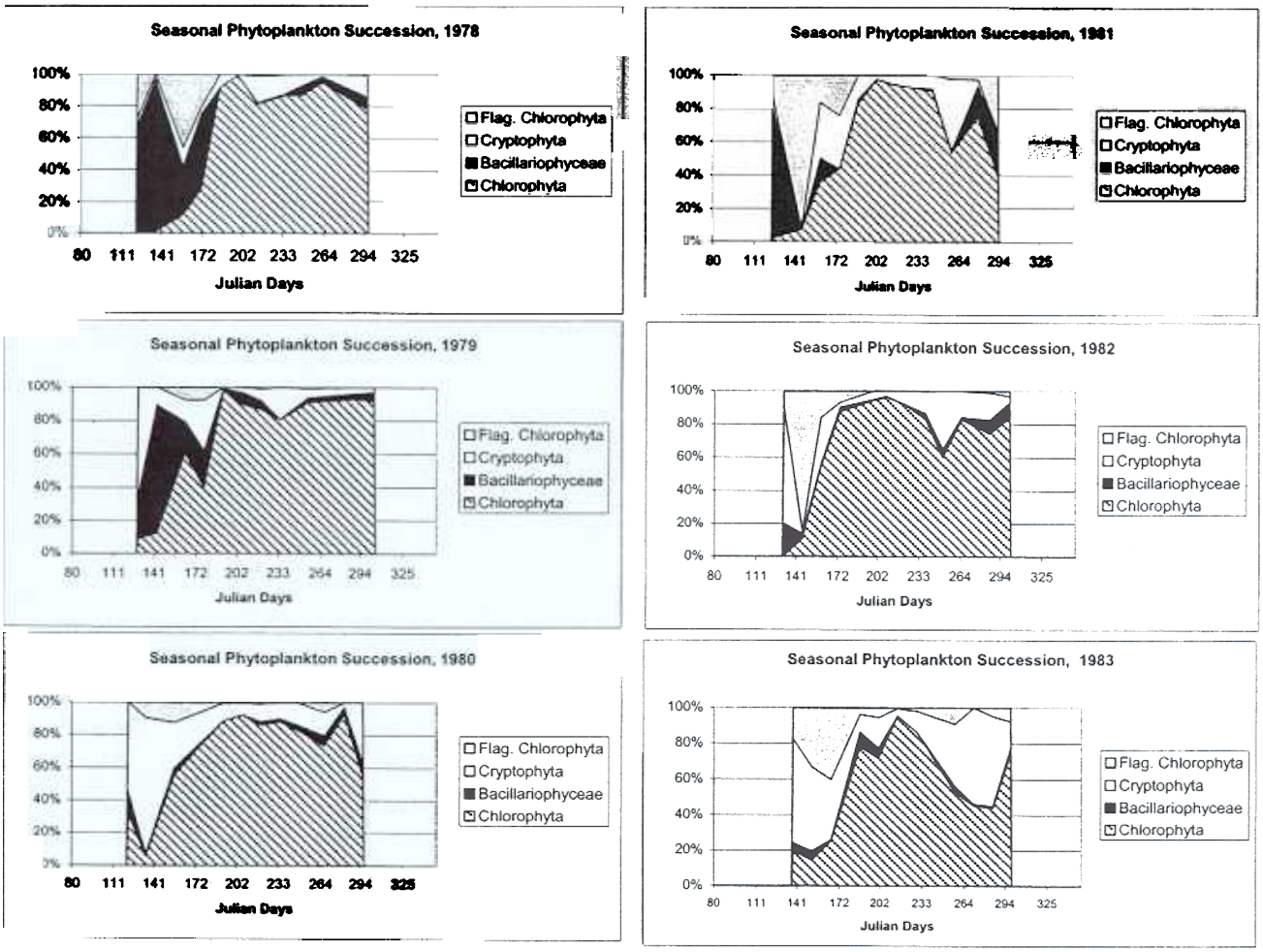


FIGURE 7-3a Seasonal biomass succession (abundance) 1978 - 1983

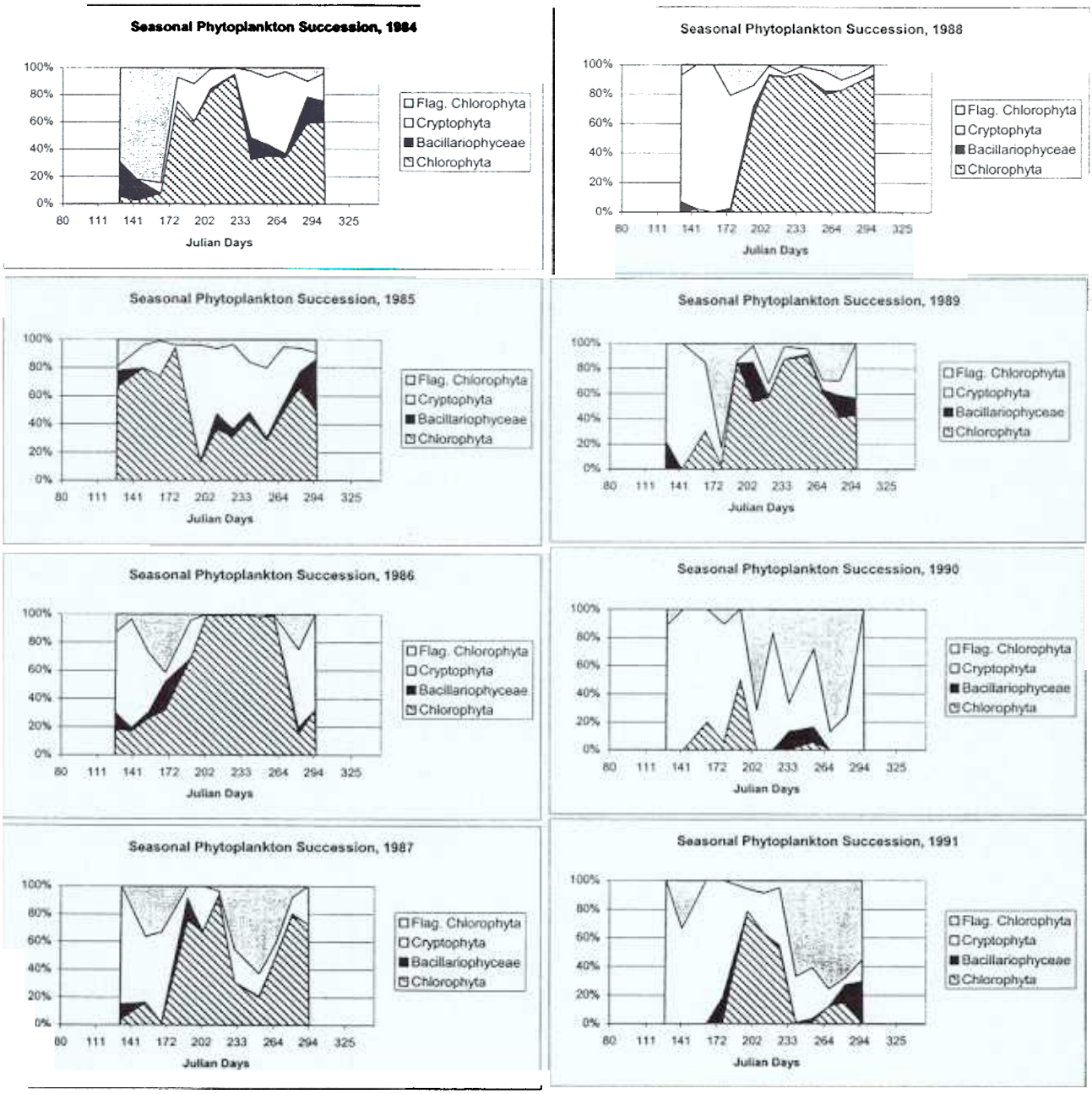


FIGURE 7-3b.(cont) Seasonal phytoplankton succession, abundance, 1984 - 1991

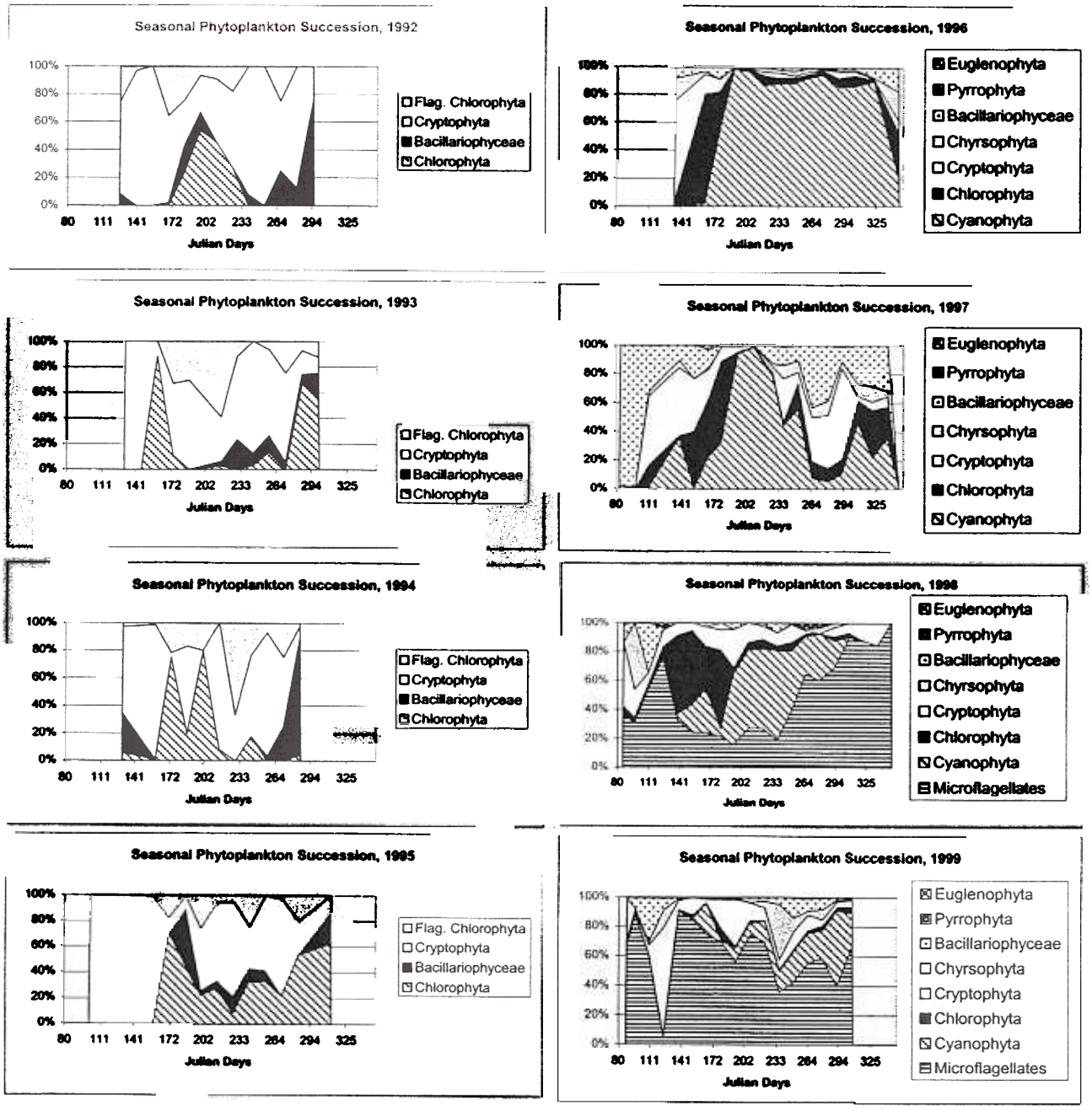
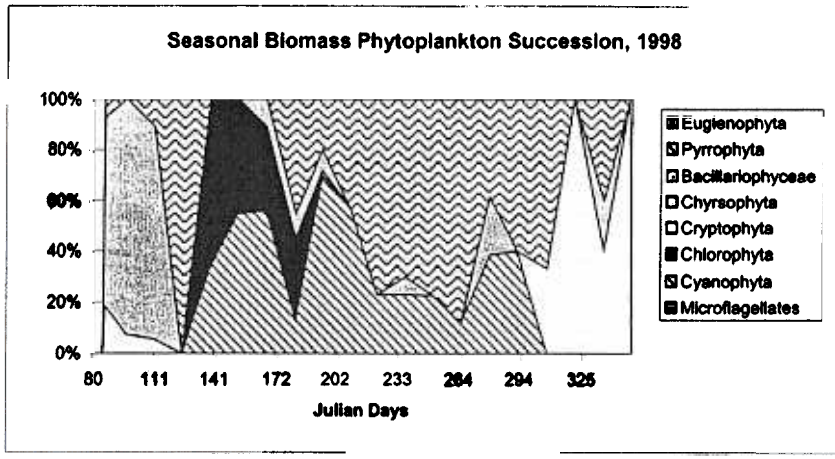
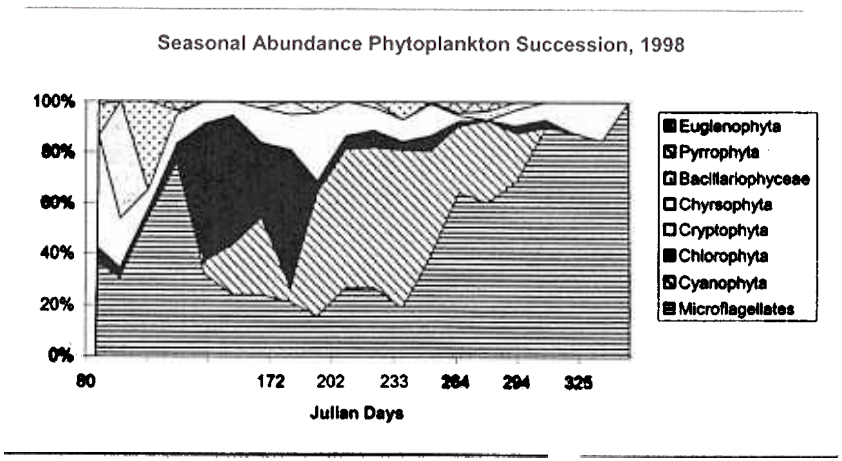
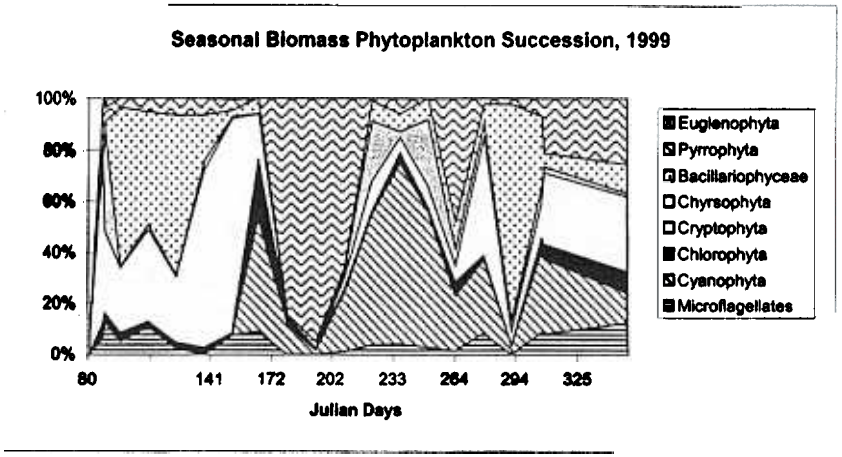


FIGURE 7-3c.(cont) Seasonal phytoplankton succession, abundance, 1992 - 1999


Seasonal Biomass Phytoplankton Succession, 1998
100%
80%
60%
40%
20%
0%
80
111
141
172
202
233
264
294
325
Julian Days
Euglenophyta
Pyrrophyta
Bacillariophyceae
Chyrsophyta
Cryptophyta
Chlorophyta
Cyanophyta
Microflagellates


Seasonal Abundance Phytoplankton Succession, 1998
100%
80%
60%
40%
20%
0%
80
172
202
233
264
294
325
Julian Days
Euglenophyta
Pyrrophyta
Bacillariophyceae
Chyrsophyta
Cryptophyta
Chlorophyta
Cyanophyta
Microflagellates


Seasonal Biomass Phytoplankton Succession, 1999
100%
80%
60%
40%
20%
0%
80
141
172
202
233
264
294
325
Julian Days
Euglenophyta
Pyrrophyta
Bacillariophyceae
Chyrsophyta
Cryptophyta
Chlorophyta
Cyanophyta
Microflagellates

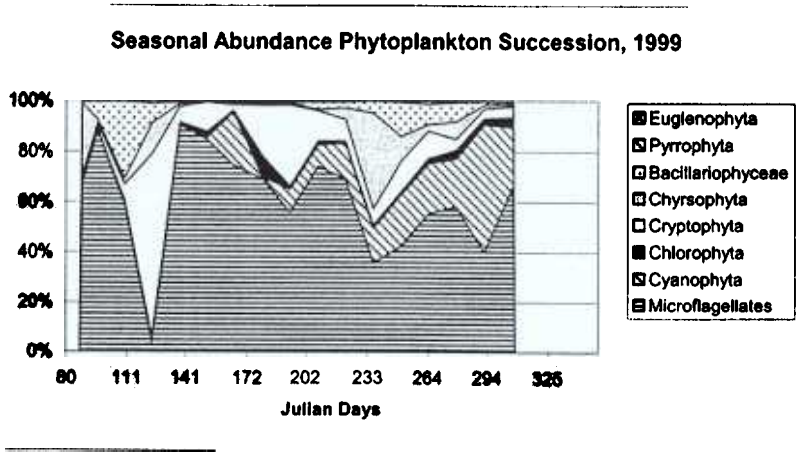

Seasonal Abundance Phytoplankton Succession, 1999
100%
80%
60%
40%
20%
0%
80
111
141
172
202
233
264
294
325
Julian Days
Euglenophyta
Pyrrophyta
Bacillariophyceae
Chyrsophyta
Cryptophyta
Chlorophyta
Cyanophyta
Microflagellates

Figure 7-4

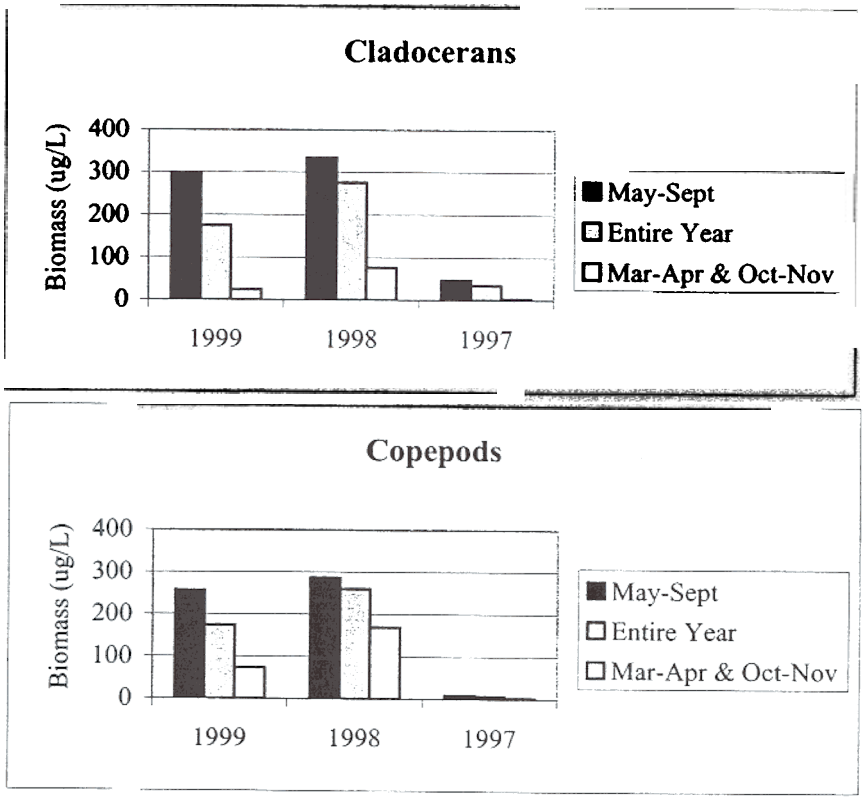


Figure 7-5. Average biomass (ug/l) of cladoceran and copepod zooplankton during various time periods of 1997 - 1999.

TABLE 7-1

Trophic status classification based on water quality variables (after Vollenweider and Carekes, 1980)

Variable	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus			
mean	8	27	84
range (n)	3-18 (21)	11-96 (19)	16-390 (71)
Total nitrogen			
mean	660	750	1,900
range (n)	310-1600 (11)	360-1400 (8)	390-6100 (37)
Chlorophyll *a*			
mean	1.7	4.7	14
range (n)	0.3-4.5 (22)	3-11 (16)	2.7-78 (70)
Peak chlorophyll *a*			
mean	4.2	16	43
range (n)	1.3-11 (16)	5-50 (12)	10-280 (46)
Secchi depth (m)			
mean	9.9	4.2	2.4
range (n)	5.4-28 (13)	1.5-8.1 (20)	0.8-7.0 (70)

Note: units are µg/L (or mg/m^3), except Secchi depth; means are geometric means (log 10), except peak chlorophyll *a*.

TABLE 7-2

Potential Phytoplankton Metrics
1999 Annual Report
Onondaga County Department of Drainage and Sanitation

Metric	Response to Stress
Percent cyanobacteria Percent greens	Elevated under eutrophication
Percent diatoms Percent chrysophytes	Depressed under eutrophication
Percent *Anabaena, Aphanizomenon, Microcystis* Percent centric diatoms (of total diatoms) Percent pennate diatoms (of total diatoms) Percent colonial greens (Volvocales) Percent euglenophyta Percent dinoflagellates	Blue-green algae and colonial greens are elevated in response to eutrophication
Number of taxa	Low under stress
Diversity	Low under stress
Percent dominance	High under stress
Lange-Bertalot index (pollution tolerance index, Bahls 1993)	Lower value under organic pollution
Indicator taxa (presence or percentage)	Respond to specific stressors

Source: USEPA. 1998. Lake and Reservoir Bioassessment and Biocriteria. Technical Guidance Document. EPA/ 841-B-98-007

Table 7-3(A) . Percent contribution by biomass of phytoplankton during different time frames in 1999.

Taxa	May-Sept	Entire Year	Mar-Apr & Oct-Nov
Cyanobacteria	30.0	23.4	11.3
Pyrrhophyta	28.3	22.7	12.6
Cryptophyta	18.3	21.1	26.2
Bacillariophyceae	10.6	16.2	26.6
Chlorophyta	8.3	7.4	5.6
Microflagellates	2.5	4.8	9.1
Chrysophyta	2.1	3.5	6.2
Euglenophyta	0.1	0.9	2.4

Table 7-3 (B) . Percent contribution by biomass of phytoplankton during different time frames in 1998.

Taxa	May-Sept	Entire Year	Mar-Apr & Oct-Nov
Cyanobacteria	14.4	12.3	10.4
Pyrrhophyta	6.2	7.0	0.3
Cryptophyta	0.1	0.1	0.1
Bacillariophyceae	0.0	0.0	0.0
Chlorophyta	38.7	30.9	0.9
Microflagellates	32.0	25.4	6.8
Chrysophyta	1.2	1.6	3.2
Euglenophyta	7.5	18.8	41.6

Table 7-3 (C). Percent contribution by biomass of phytoplankton during different time frames in 1997.

Taxa	May-Sept	Entire Year	Mar-Apr & Oct-Nov
Cyanobacteria	6.9	8.8	11.1
Pyrrhophyta	0.2	0.1	0.0
Cryptophyta	3.9	2.9	1.6
Bacillariophyceae	0.3	0.5	0.8
Chlorophyta	73.8	72.5	70.8
Microflagellates			
Chrysophyta	2.5	2.6	2.8
Euglenophyta	3.1	7.3	12.6

Table 7-3 (D) . Percent contribution by biomass of phytoplankton during different time frames in 1996.

Taxa	May-Sept	Entire Year	Mar-Apr & Oct-Nov
Cyanobacteria	44.4	44.4	44.2
Pyrrhophyta	8.7	6.4	2.5
Cryptophyta	15.6	12.9	7.9
Bacillariophyceae	7.2	10.9	17.5
Chlorophyta	22.8	23.7	25.3
Microflagellates			
Chrysophyta	1.3	1.7	2.5
Euglenophyta	0.0	0.0	0.1

TABLE 7-4

Potential Zooplankton Metrics

1999 Annual Report
Onondaga County Department of Drainage and Sanitation

Metric	Response to Stress
Percent large *Daphnia* (> 1 mm)	Low under planktivorous fish predation
Number of taxa	Reduced under contamination or stress
Percent dominance	High under stress
Trophic structure measurements: • Number of trophic links • Complexity measures • Percent large predators • Number of predator species	Simplified trophic structure under stress

Source: USEPA. 1998. Lake and Reservoir Bioassessment and Biocriteria. Technical Guidance Document EPA/ 841-B-98-007

TABLE 7-5

Average zooplankton size, 1996 – 1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

Year	Averaging Period		
	May - Sept	Ice-free Monitoring Period	March and April; October and November
1996	0.56	0.57	0.59
1997	0.64	0.66	0.72
1998	0.48	0.47	0.42
1999	0.56	0.48	0.48

TABLE 7-6
Trophic State Criteria based on Fish Community

1999 Annual Monitoring Report
Onondaga County Department of Drainage and Sanitation

TSI Range	Summer TP Range (µg/l)	Dominant Fish Community
TSI < 40 – 50	< 24	Salmonids
TSI 50 –60	24 – 48	Percids
TSI 60 - 80	48 – 192	Centrarchids
TSI > 70 – 80	>192	Cyprinids

Source: Ogelsby et al. 1987

CHAPTER 8

ASSESSING COMMUNITY STRUCTURE OF LOWER TROPHIC LEVELS IN ONONDAGA LAKE, NEW YORK IN 1999

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8. Introduction

Onondaga Lake is a well-studied urban lake in which detailed limnological investigations have documented water quality changes over the past several decades (Murphy 1978; Effler 1996; Stearns and Wheler 1996, Stearns and Wheler 1997). The lake (20.5 m maximum depth) is a highly eutrophic water body situated at the northern edge of the city of Syracuse in central New York State. The lake has relatively steep sides with two basins, a northern one 18 m deep and a southern one 19 m deep separated by a slightly shallower "saddle" 17 m deep. Since the 1960s, summer blooms of planktonic algae have been associated with the highly eutrophic conditions of the lake. Recent studies have shown that overall phytoplankton abundance has been low compared to the period before 1988, and there has been a change in the composition of the algal community (Stearns and Wheler 1996). Flagellated green algae have been common during the growing season, while non-flagellated green algae and diatoms have become less important in blooms from 1986 through 1990 (Effler 1996, Mills and Keats 1998). Cyanobacteria, commonly known as blue green algae, contributions to the phytoplankton community decreased in the mid-1970's, associated with a state-wide ban of phosphates in detergents (Effler 1996). The blue green algae *Aphanizomenon flos-aquae* was undetected from 1974 through 1986 and did not become common until 1990 (Effler 1996). Cyanobacteria blooms, typically dominated by *A. flos-aquae*, were also common from 1996 through 1998, although the duration of the blooms declined each year over this period (Mills and Keats 1998).

The composition of the zooplankton community has been documented since the late 1960s (Waterman 1971; Auer et al. 1990; Siegfried et al. 1994; Makarewicz et al. 1995; Hairston et al 1999). *Daphnia* was present in 1969, very rare in 1978, absent 1979-1981 and present again 1986-1989. The exotic *Daphnia exilis*, invaded the lake in the 1920s and 1930s and persisted until the late 1970s. *Daphnia exilis* has not been observed in Onondaga Lake since the early 1980s (Hairston et. al 1999). The introduction of this species, its successful colonization, and subsequent disappearance corresponded with distinct events in the history of industrial activity in Onondaga Lake. The return of *Daphnia pulicaria* and *Daphnia galeata mendotae* in the late 1980s in large numbers has been credited with substantial increases in water clarity (Auer et al. 1990) in accordance with the "trophic cascade" hypothesis (e.g. Carpenter and Kitchell 1988; Gulati et al. 1990). Other temporal patterns in Onondaga Lake zooplankton have been the continued presence of the cladocerans *Ceriodaphnia quadrangula* and *Bosmina longirostris*, the copepod *Diacyclops thomasi* and a variety of rotifers. A few zooplankton species have only appeared recently: *Diaphanosoma leuchtenbergianum*, *Chydorus sphaericus* and *Diaptomus siciloides* (now *Leptodiaptomus siciloides*) (Siegfried et al. 1994).

The objective of this report is to present data on phytoplankton community structure, biomass, and abundance in Onondaga Lake in 1999 and to make comparisons with the data from 1998. We also present 1999 data on species composition, biomass, and size structure of the crustacean zooplankton community as well as the presence/absence of dreissenid veliger larvae.

8.2 Methods

Phytoplankton samples were collected from the surface, 3 m depth, and from integrated epilimnetic samples and preserved in Lugol's solution. Phytoplankton samples were processed by Ann St. Amand at PhycoTech, Inc. (620 Broad St., Ste. 100, St. Joseph, MI 49085). Raw water samples were run through filtration towers and the filters from these towers were then made into slides. The method used in counting the phytoplankton depended on the relative importance of soft algae and diatoms in the samples as well as

alga size. Phytoplankton were identified to species when possible and density and biovolume estimates were made. In 1999, phytoplankton samples were collected from two depths (0 m and 3 m) and from an integration of the epilimnion (March through November). Integrated epilimnetic samples were collected using 2 cm i.d. tygon tubing stretched from the surface to the top of the thermocline.

Individual phytoplankton species were converted to biomass based on estimates of biovolume and density. In this study, we report biomass in µg/L. PhycoTech reported biomass as biovolume in $\mu m^3/mL$. We converted total biovolume ($\mu m^3/mL$) to total biomass (µg/L) by multiplying total biovolume by 1×10^{-3}. For 1998 samples, biomass concentrations were incorrectly reported. To correct phytoplankton biomass concentrations for 1998, we multiplied all biovolume values by 10^{-6}. The 1998 data are presented in this report for comparison with the 1999 data.

Calculations of zooplankton density, species composition, size structure, and biomass were based on a single vertical haul using a 0.50 m diameter 80 micron mesh nylon net. The zebra mussel veliger densities were based on a single vertical haul using a 53 micron mesh 0.50 m diameter nylon net. Veliger samples were preserved in sugar-formalin (Haney and Hall 1973). Flow-meter readings to determine the volume of water strained in each plankton haul were taken on 60% of the samples collected. Since 40% of the zooplankton samples did not have flow measurements, we chose to estimate density and biomass based on sample depth. Zooplankton samples were preserved in 70% ethyl alcohol. Zooplankton samples were collected at a southern site throughout the year and at northern sites on several dates. Vertical tows were taken from the epilimnion and 0-12m of the water column. Additionally, on August 17, three zooplankton samples were collected from the Seneca River, which receives outflow water from Onondaga Lake.

Zooplankton were identified to species when possible and a dry weight conversion was used to estimate biomass. For each site, one to three 1-mL subsamples were withdrawn with a Henson-Stemple pipette from a known volume of sample, until at least 100 individual zooplankton were counted. Using a microprojector at 20X magnification, images from these subsamples were projected onto a digitizer interfaced with a computer that made it possible to measure zooplankton length.

Veliger larvae were concentrated by allowing a portion of each sample to settle through a column of sugar solution, a method attributed to Shaner (1991). One 10-mL subsample was allowed to settle for 20 min, after which the veligers were decanted, measured, and counted using a compound microscope at 40X magnification.

8.3 Results and Discussion

Phytoplankton

Community Structure. The raw phytoplankton data from the analyses done by PhycoTech, Inc. for 1999 are presented in Appendix A. The phytoplankton community of Onondaga Lake is comprised of Cyanophyta, Cryptophyta, Pyrrophyta, Euglenophyta, Bacillariophyceae, Chrysophyta, Chlorophyta and "other microflagellates". The dominant cyanobacteria in 1999 were dominated by *Oscillatoria limnetica* (biomass) and *Microsystis aeruginosa* (density). Unlike 1999, *Aphanizomenon flos-aquae* was the dominant cyanobacteria in 1998. However, *Aphanizomenon flos-aquae* was a prominent cyanophyte in Onondaga Lake in 1999, along with *Synechococcus elongatus* and *Microcystis aeruginosa*. The most frequently occurring algal species of other taxonomic groups (determined by the highest abundance and biomass) were *Cyclotella radiosa*, and *Stephanodiscus hantzschii* 22 µm and 8 – 11 µm (Bacillariophyceae), *Erkenia subaequiciliata, Uroglena* sp., and cysts of a chrysophyte (Chrysophyta), *Euglena* (Euglenophyta), *Rhodomonas minuta* v. *nannoplanctica, Cryptomonas rostratiformis* and *Cryptomonas erosa* (Cryptophyta), *Gymnodinium* sp. and *Ceratium hirundinella* (Pyrrophyta), and *Ankistrodesmus falcatus, Kirchneriella subsolitaria, Oocystis parva, Pandorina morum, Scenedesmus* sp. 2, *Sphaerocystis schroeteri*, and *Lagerheimia quadriseta* (Chlorophyta).

Abundance and biomass. The abundance and biomass of phytoplankton in Onondaga Lake for 1999 are summarized in Appendix B. Algal abundance was highest in the spring during the diatom bloom and in mid-summer and early fall when cyanophytes dominated the phytoplankton community (Figures 8.1, 8.2). This pattern was consistent in both 1998 and 1999. However, the increased abundance of microflagellates throughout 1999 lead to higher overall algal abundances compared to 1998. However, despite higher algal densities in 1999, algal biomass in 1999 tended to be lower compared to 1998. The seasonal pattern of algal biomass in Onondaga Lake was similar in both 1998 and 1999, with peaks in spring, mid-June to early July (primarily Pyrrophyta, 1998 and 1999), and late August (Cyanophyta, 1998 and 1999) (Figures 8.3, 8.4).

The biomass of each taxonomic group exhibited distinct temporal patterns (Figure 8.5). Early spring blooms (March – April) were dominated by diatoms (Bacillariophyceae) (Figure 5F) and cryptomonads (Figure 8.5D) in both 1998 and 1999. Euglenoids (Figure 8.5G) additionally contributed to the 1999 spring bloom, although they were not detected in 1998. Pyrrophyta (Figure 8.5B) and Chlorophyta (greens) (Figure 8.5C) peaked in biomass in early summer (June – early July) of 1999. One of two cyanophyte (blue-green) blooms (Figure 8.5A), which occurred in early June, also contributed to early summer biomass in 1999. The timing of the chlorophyte bloom was similar in both 1998 and 1999 (Figure 8.5C). Interestingly, in 1998 the pyrrophyte bloom (Figure 8.5B) occurred much later (late August to early October) and the blue-greens dominated from mid-July to mid-August, although the magnitude of the blue-green bloom was markedly lower than in 1999 (Figure 8.5A). A second peak in blue-green biomass occurred in late August 1999 (Figure 8.5A), following another cryptomonad peak in July (Figure 8.5D). Elevated chrysophyte biomass was measured from late July to late September, peaking in mid-August 1999 (Figure 8.5E). Suprisingly, the 1998 chrysophyte peak occurred in April (Figure 8.5E), albeit a much smaller peak than 1999. The 1999 chrysophyte bloom was followed by a peak of Bacillariophyceae in late September (Figure 8.5F). Microflagellates were quite abundant throughout 1998 and 1999, but they contributed very little to the total biomass of the phytoplankton community (Figures 8.1, 8.2).

We subdivided phytoplankton into netplankton (> 50 μm) and nannoplankton (<50 μm) based on cell or colony size and examined seasonal changes in these two functional groups. For example, the cyanophyte *Aphanizomenon flos-aquae* (size range in 1999: 55 - 193 μm) was considered net plankton, while the chlorophyte *Oocystis parva* (size range in 1999: 4.4 - 33 μm) was placed in the nannoplankton category. Patterns of nanno- and netplankton biomass in 1999 differed greatly from 1998. In 1998, nannoplankton biomass dominated March through May after which the algal community shifted to netplankton (Figure 8.6). In 1999, biomass concentrations for nanno- and netplankton were similar from early April to early June (Figure 8.7). Netplankton biomass dominated from mid-June to mid-July, as a result of a bloom of the pyrrophyte *Ceratium hirundinella*. Nannoplankton biomass was dominant only in August of 1999, during the cyanophyte bloom. However, nannoplankton was generally more abundant than netplankton throughout 1998 and 1999 (Figures 8.6, 8.7). The only exceptions were algal blooms in mid-July 1998 and mid-June 1999 that were associated with high densities of netplankton.

8.4 Zooplankton

Community structure. A summary of the zooplankton community in Onondaga Lake from March 29 to December 14, 1999 is presented in Appendix C. A total of eleven species as well as nauplii and copepodites were identified in Onondaga Lake in 1999. The dominant cladocerans were *Daphnia galeata* and *Bosmina longirostris*. Other cladocerans included *Eubosmina coregoni*, *Ceriodaphnia quadrangula*, *Diaphanosoma leuchtenbergianum*, *Holopedium gibberum*, and *Chydorus sphaericus*. The dominant copepods during the year were *Diacyclops thomasi*, *Leptodiaptomus sicilis*, *Leptodiaptomus siciloides*, *Mesocyclops edax*, and nauplii and copepodites. A total of ten species as well as nauplii and copepodites were identified in the Seneca River on August 18, 1999. The Seneca River zooplankton community differed from that of Onondaga Lake due to the presence of *Leptadora kindtii* and *Chydorus sphaericus* in late August.

Overall zooplankton density and biomass was found to be considerably lower in the Seneca River when compared to Onondaga Lake for this time period.

Abundance and Biomass. A summary of seasonal changes in the biomass and abundance of the total zooplankton community, cladocerans, copepods, and individual species is presented in Table 8.1. Total zooplankton abundance was higher in spring than both summer and fall (Table 8.1). Zooplankton densities were lowest in late March and were highest in mid June (Figure 8.8A). Total zooplankton biomass was also low in late March, increasing in May and ranged between approximately 1200 and 1600 μg/L in June (Figure 8.8B). Additionally, in the late fall both total zooplankton density and biomass increased slightly after low levels persisted throughout the late summer and early fall (Figure 8.8A, 8.8B).

We analyzed the zooplankton community by assessing the relative proportion in density and biomass by taxa and by species. By taxa, copepod abundance was higher than cladoceran abundance in the zooplankton community from late March to early August, and cladoceran abundance was higher than copepod abundance for the remainder of the sampling period (Figure 8.9B). The proportion of zooplankton biomass occupied by cladocerans and copepods fluctuated throughout the year. The cladoceran zooplankton community was dominated by *Daphnia galeata* from spring to mid summer, and *Bosmina longirostris* from mid summer to late fall (Figure 8.10A). *Eubosmina coregoni* and *Diaphanasoma leuchtenbergianum* did not represent a major component of the cladoceran community at any time period. The importance of *Daphnia galeata* and *Bosmina longirostris* was consistent with our observations in 1997 and 1998, but unlike previous years *Daphnia galeata* disappeared from the community in the fall of 1999. Nauplii and copepodites possessed the largest proportion of copepod community biomass in April and August through early September in 1999. For the remainder of the sampling period, copepod community dominance fluctuated between *Diacyclops thomasi, Mesocyclops edax,* and diaptomids (Figure 8.10B). Cyclopoid copepods, *Daphnia galeata, Bosmina,* and calanoid copepods each exhibited periods of dominance on different dates throughout the year (Figure 8.11).

Zooplankton Community Size Structure. A summary of mean size of the crustacean zooplankton community is shown in Table 8.1. The mean size of the crustacean community was 0.61 mm in the spring, 0.47 mm in the summer, and 0.37 in the fall. The mean size of all Onondaga Lake zooplankton from late March through December in 1999 was 0.49 mm. The highest mean size of zooplankton (0.98) was observed on June 29, while body lengths ranged from 0.23 to 0.82 mm for the rest of 1999 (Table 8.1 and Figure 8.12). These small mean sizes are due to the preponderance of nauplii present in every sample. Zooplankton samples in Onondaga Lake were collected with a 80 micron mesh net which is nearly one-half the mesh size (153 micron) Mills and Schiavone (1982) used in their studies. Consequently, the average size of Onondaga Lake zooplankton would be expected to be lower compared to a 153 micron net because of the likelihood of retaining higher numbers of small zooplankters like nauplii. If we exclude all nauplii, in order to approximate zooplankton catches in a 153 micron mesh net, mean zooplankton size becomes 0.63 for the entire sampling period. A distinct temporal shift in average zooplankton size to small bodied forms occurred in late August. Average zooplankton size excluding nauplii was 0.84 mm from late March to late August and reflected the dominance of *Daphnia galeata.* For the period from late August through December, the zooplankton community shifted to smaller-bodied *Bosmina* and a mean size of 0.36 mm. These data suggest that zooplanktivory was relatively low through late August and subsequently intensified to high levels for the remainder of the year. For comparison, in Lake Ontario mean zooplankton lengths in the range of 0.30 to 0.40 mm are common due to heavy zooplanktivory by alewife (*Alosa pseudoharengus*) (O'Gorman et al. 1991).

We compared mean zooplankton size in Onondaga Lake during 1999 with Oneida Lake. For this comparison, we adjusted zooplankton size for both lakes based on an 153 micron mesh net. Our results indicated that temporal patterns in zooplankton size were remarkably similar between the two lakes (Figure 8.12). Average zooplankton size was largest for Oneida Lake in early spring (1.01 mm), largest for Onondaga Lake in late spring (1.06 mm), and smallest for both lakes in early fall (Oneida Lake mean = 0.37 mm, Onondaga Lake mean = 0.29 mm) (Figure 8.12).

Dreissenid Veliger Larvae. Samples were collected for larvae of *Dreissena* from late March to December 1999. Veligers were absent from the plankton community at all stations for all dates. The absence of veligers from Onondaga Lake is consistent with our findings in 1997 and 1998.

8.5 Overview

Onondaga Lake remains productive as evidenced by its high algal biomass and periodic late summer blooms of cyanobacteria including *Aphanizomenon flos-aquae*. Since 1996 the duration of the cyanobacteria blooms has become markedly shorter. For example, *A. flos-aquae* dominated the algal community July through August in 1997 and 1998, whereas similar blooms occurred July through October in 1996. In 1999, however, the dominant cyanophyte bloom occurred from late July through August, but the predominant cyanobacteria were *Oscillatoria limnetica* and *Microcystis aeruginosa*. Limited cyanophyte blooms during the past three years could signal improved water quality conditions or merely year to year variability. If improved water quality conditions are occurring in Onondaga Lake, we should continue to observe cyanobacteria blooms of shorter duration in the future. Average total zooplankton biomass in nearby Oneida Lake (Cornell Biological Field Station unpublished data) was 197 µg/L for the March through October time period of 1999, while it averaged 417 µg/L in Onondaga Lake for the same time period. This finding would be expected given the high productivity of Onondaga Lake. Temporal patterns in mean zooplankton size were remarkably similar between Oneida and Onondaga Lakes in 1999. Both lakes exhibited average zooplankton size peaks in early spring and early summer, and depressions in mid spring and early fall. We hypothesize that predation pressure on zooplankton was most intense from late August through December in Onondaga Lake as evidenced by the shift in zooplankton composition from large-bodied *Daphnia* to smaller bodied *Bosmina*. In Oneida Lake, the dominance of small-bodied zooplankton in late summer and fall was associated with predation by large numbers of young emerald shiners.

Literature Cited

Auer, M.T., M.L. Storey, S.W. Effler, N.A. Auer, and P. Sze. 1990. Zooplankton impacts on chlorophyll and transparency in Onondaga Lake, NY, USA. Hydrobiologia 200:603-617.

Carpenter, S.R. and J.F. Kitchell. 1993. The trophic cascade in lakes. Cambridge University Press, Cambridge, UK. 358pp.

Effler, S.W. 1996. Limnological and engineering analysis of a polluted urban lake. Springer, New York, New York. 832 p.

Gulati, R.D., E.H.R.R. Lammens, M.L. Meijer, and E. van Donk (eds.). 1990 Biomanipulation-Tool for water management. Kluwer Academic publishers, Belgium.

Hairston, N.G., L.J. Perry, A.J. Bohonak, M.Q. Fellows, and C.M. Kearns. 1999. Population biology of a failed invasion: Paleolimnology of Daphnia exilis in upstate New York. Limnol. Oceangr. 44(3):477-486.

Haney, J.G. and D.J. Hall. 1973. Sugar-coated *Daphnia*: preservation technique for Cladocera. Limnol. Oceanogr. 18:331-333.

Makarewicz, J.C., B. Cady, T. Lewis, J. Buttner, and J. Haynes. 1995. Phytoplankton, zooplankton, macrobenthos, and ichthyoplankton abundance, biomass, and species composition in Onondaga Lake, 1994. Onondaga Management Conference, Syracuse, New York.

Mills, E.L. and A. Schiavone. 1982. Evaluation of fish communities through assessment of zooplankton populations and measurement of lake productivity. North American Journal of Fisheries Management. 2:14-27.

Mills, E.L. and R.A. Keats. 1998. Assessing Community Structure of Lower Trophic Levels in Onondaga Lake, New York in 1998. Onondaga Lake Monitoring Program 1998 Annual Report: Report and Appendix A. (Chapter 5).

Murphy, C.B. 1978. Onondaga Lake. In: J.A. Bloomfield (ed.) Lakes of New York State, Vol. II. John Wiley & Sons, New York, p. 223-363.

O'Gorman, E.L. Mills, and J.S. DeGisi. 1991. Use of zooplankton to assess the movement and distribution of alewife (*Alosa pseudoharengus*) in south-central Lake Ontario in spring. Can. J. Fish. Aquat. Sci. 48:2250-2257.

Shaner, T. 1991. Detection of zebra mussel veligers in plankton samples using sugar solution. Lake Ontario Fish Unit 1990 Annual Report. LOA 91.1 (Chapter 6).

Siegfried, C.A., N.A. Auer, and S.W. Effler. 1994. Zooplankton (Chapter 6) Biology. In S.W. Effler (ed.), Onondaga Lake: Lessons in limnology and engineering analysis for a polluted system. Springer-Verlag., NY.

Stearns & Wheler. 1996. Onondaga Lake monitoring program 1995 annual report. Report and Appendix A. July 1996. Prepared for Onondaga County.

Stearns & Wheler. 1997. Onondaga Lake monitoring program 1996 annual report. Report and Appendix A. July 1997. Prepared for Onondaga County.

Waterman, G. 1971. Onondaga Lake zooplankton. P. 361-384. In Onondaga Lake Study, project No. 1106, FAE4/71. Water Quality Office, Environmental Protection Agency, Onondaga County, Syracuse, NY.

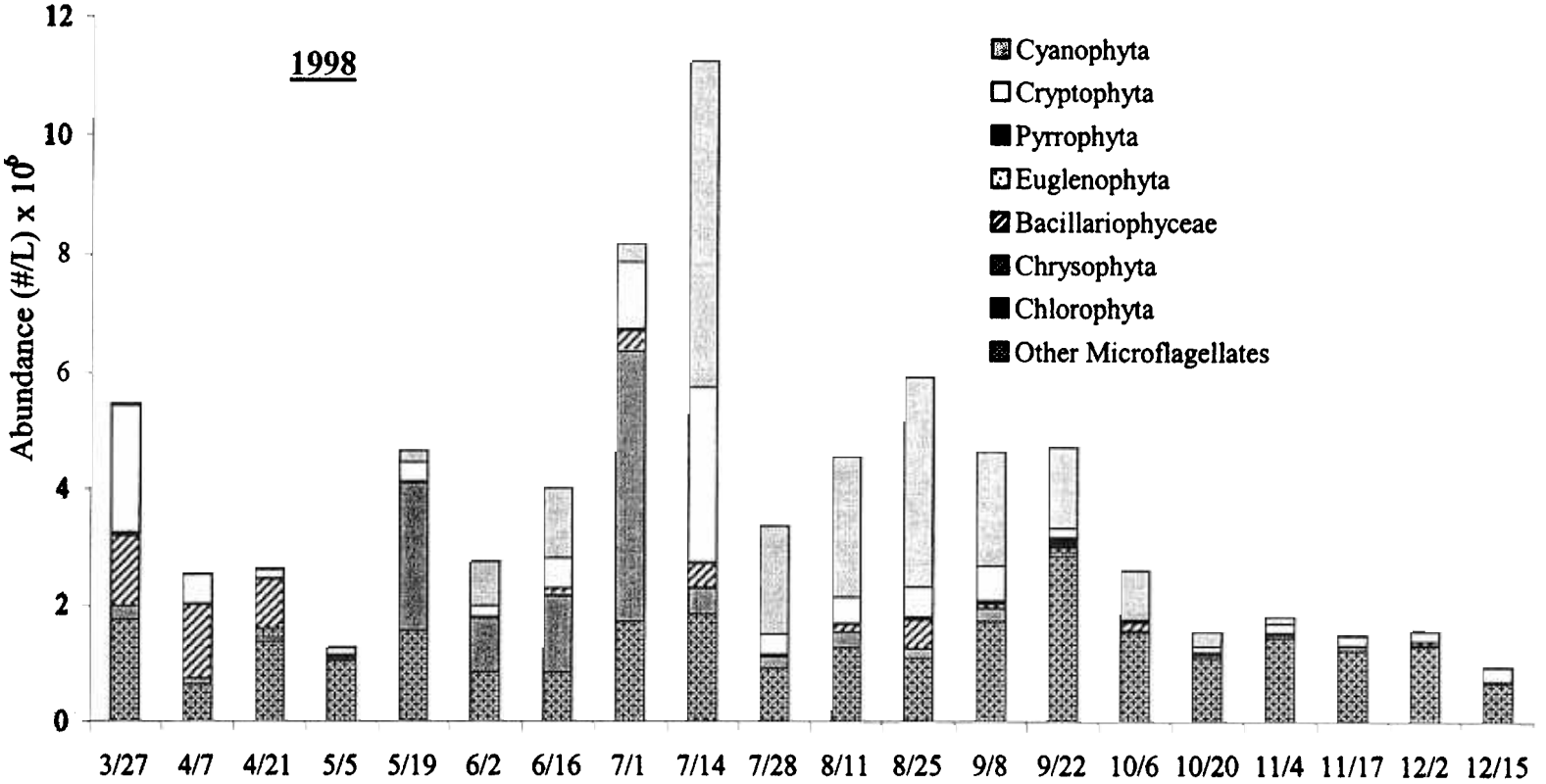


Figure 8.1. Abundance (#/L) x 10 of seven major groups of phytoplankton collected from Onondaga Lake, 3/27/98 - 12/15/98. Data are averages of 0m, 3m, and integrated epilimnetic samples (3/27, 4/7, 4/21, 5/5, 5/19, 6/2, 6/16, 7/1*, 7/28, 8/11, 8/25, 9/22*, 10/6, 10/20, 11/4, 11/17*, 12/2, 12/15) or averages of 0m and 3m samples only (9/8). An asterix indicates "North" station samples were taken in addition to "South" station samples.

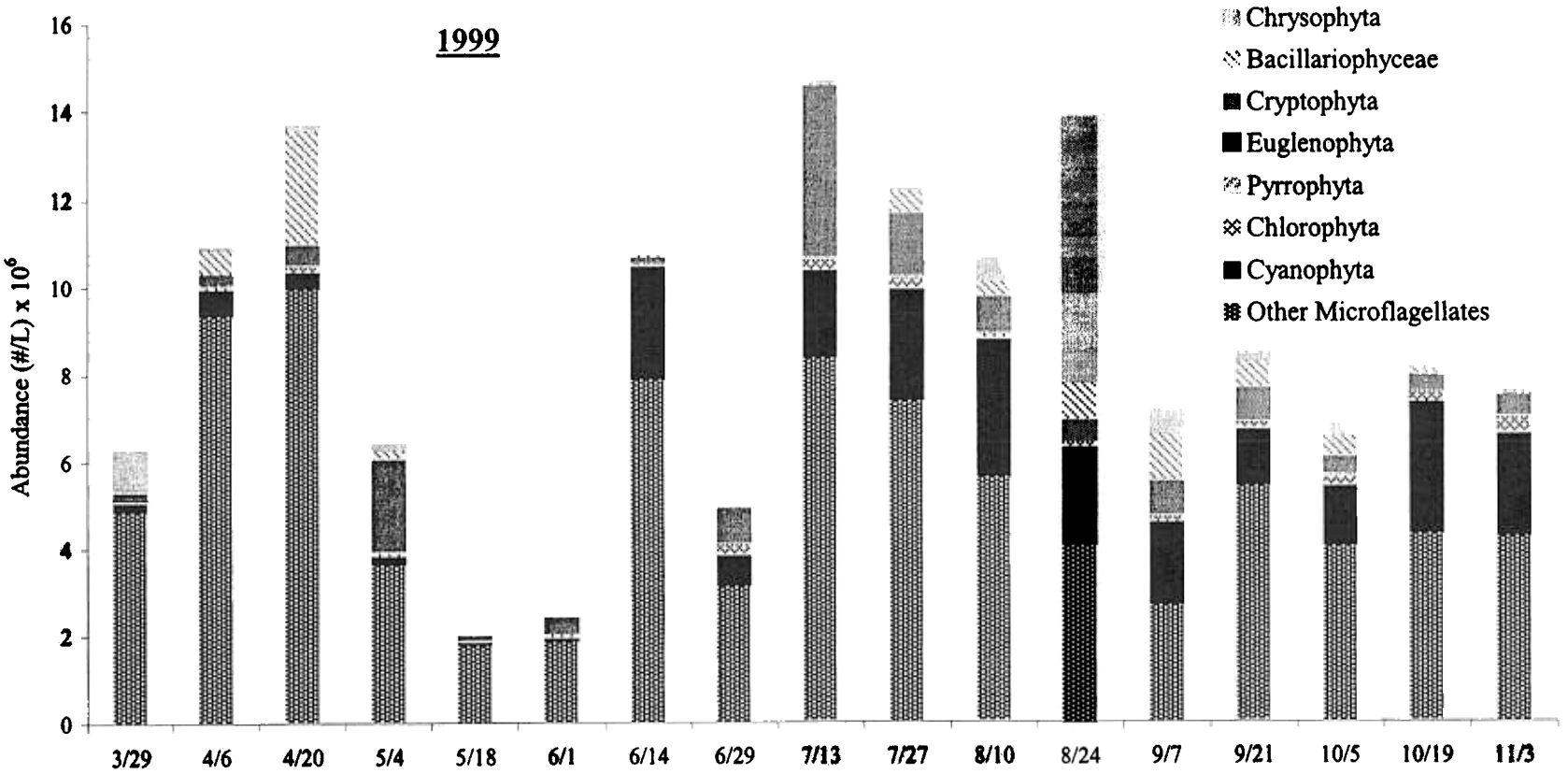


Figure 8.2. Abundance (#/L) x 10^6 of eight major groups of phytoplankton collected from Onondaga Lake, 3/29/99 - 11/3/99. Data are averages of 0m, 3m, and integrated epilimnetic samples (3/29, 4/6*, 4/20, 5/4, 5/18, 6/1, 6/14, 6/29, 7/13*, 7/27, 8/10, 8/24, 9/7, 9/21*, 10/5, 10/19, 11/3). An asterix indicates "North" station samples were taken in addition to "South" station samples.

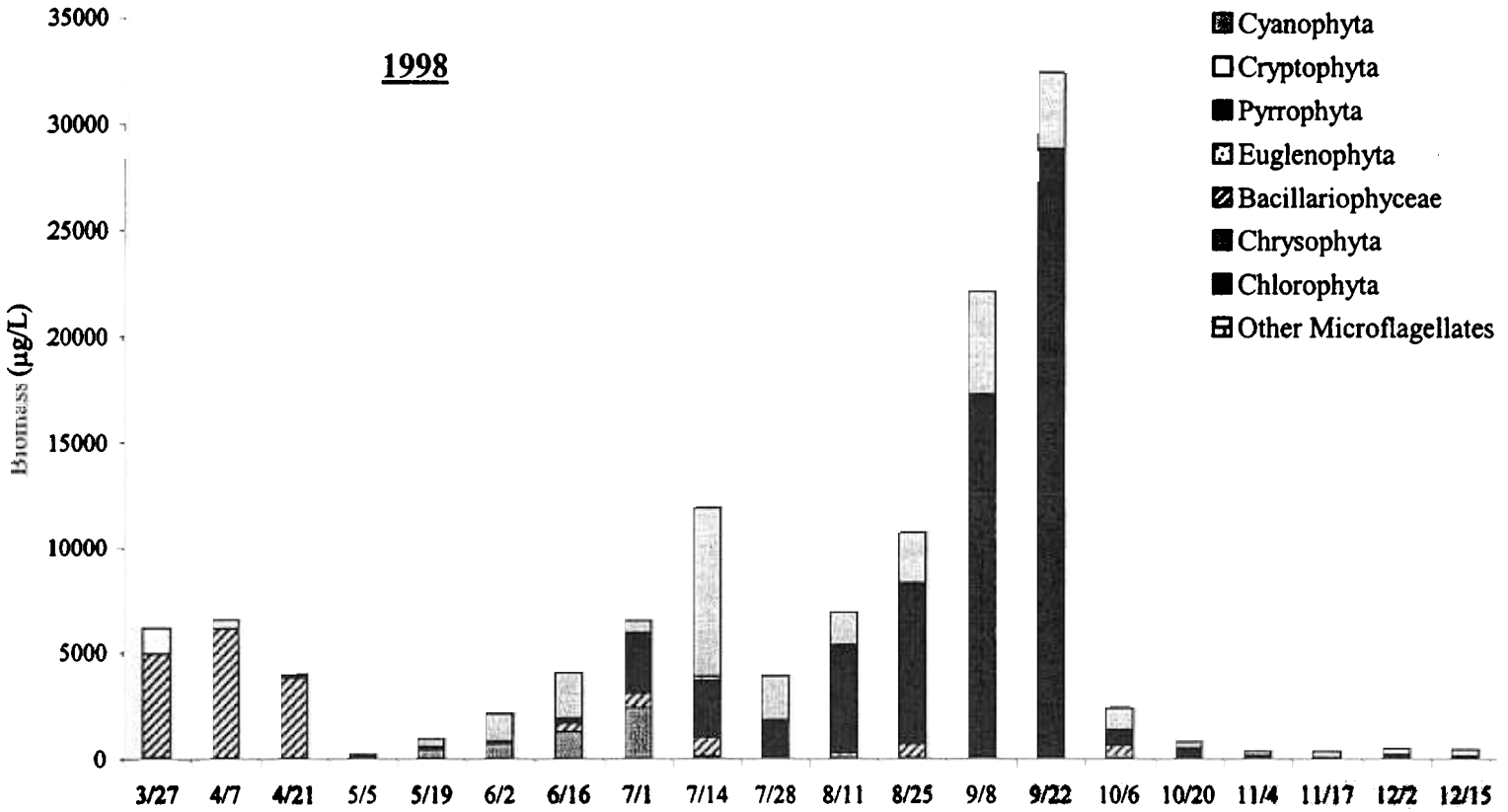


Figure 8.3. Biomass (µg/L) of six major groups of phytoplankton collected from Onondaga Lake, 3/27/98 - 12/15/98. Data are averages of 0m, 3m, and integrated epilimnetic samples (3/27, 4/7, 4/21, 5/5, 5/19, 6/2, 6/16, 7/1*, 7/28, 8/11, 8/25, 9/22*, 10/6, 10/20, 11/4, 11/17*, 12/2, 12/15) or averages of 0m and 3m samples only (9/8). An asterix indicates "North" station samples were taken in addition to "South" station samples.

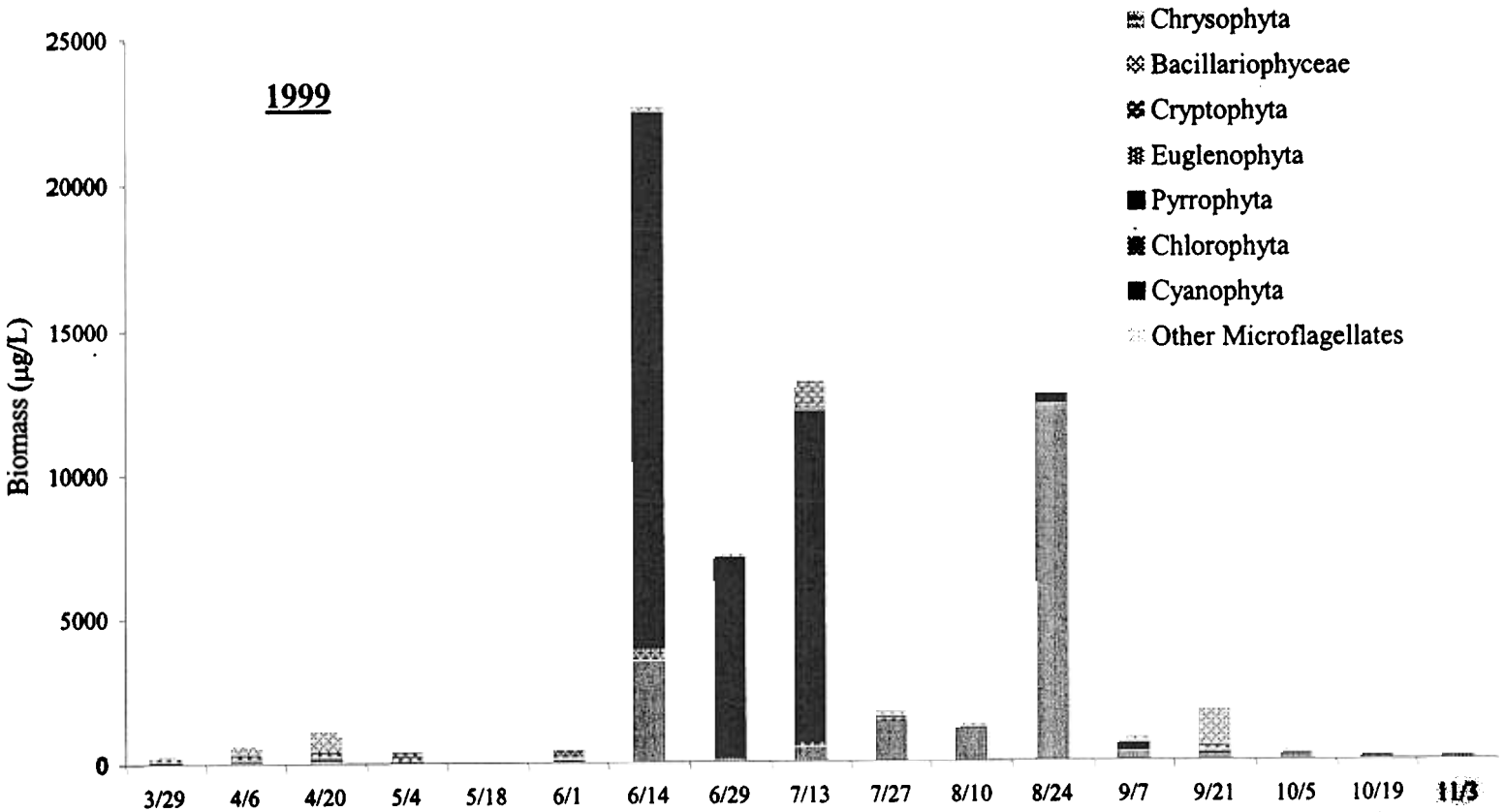


Figure 8.4. Biomass (µg/L) of eight major groups of phytoplankton collected from Onondaga Lake, 3/29/99 - 11/3/99. Data are averages of 0m, 3m, and integrated epilimnetic samples (3/29, 4/6*, 4/20, 5/4, 5/18, 6/1, 6/14, 6/29, 7/13*, 7/27, 8/10, 9/7, 9/21, 10/5, 10/19, 11/3). An asterix indicates "North" station samples were taken in addition to "South" station samples.

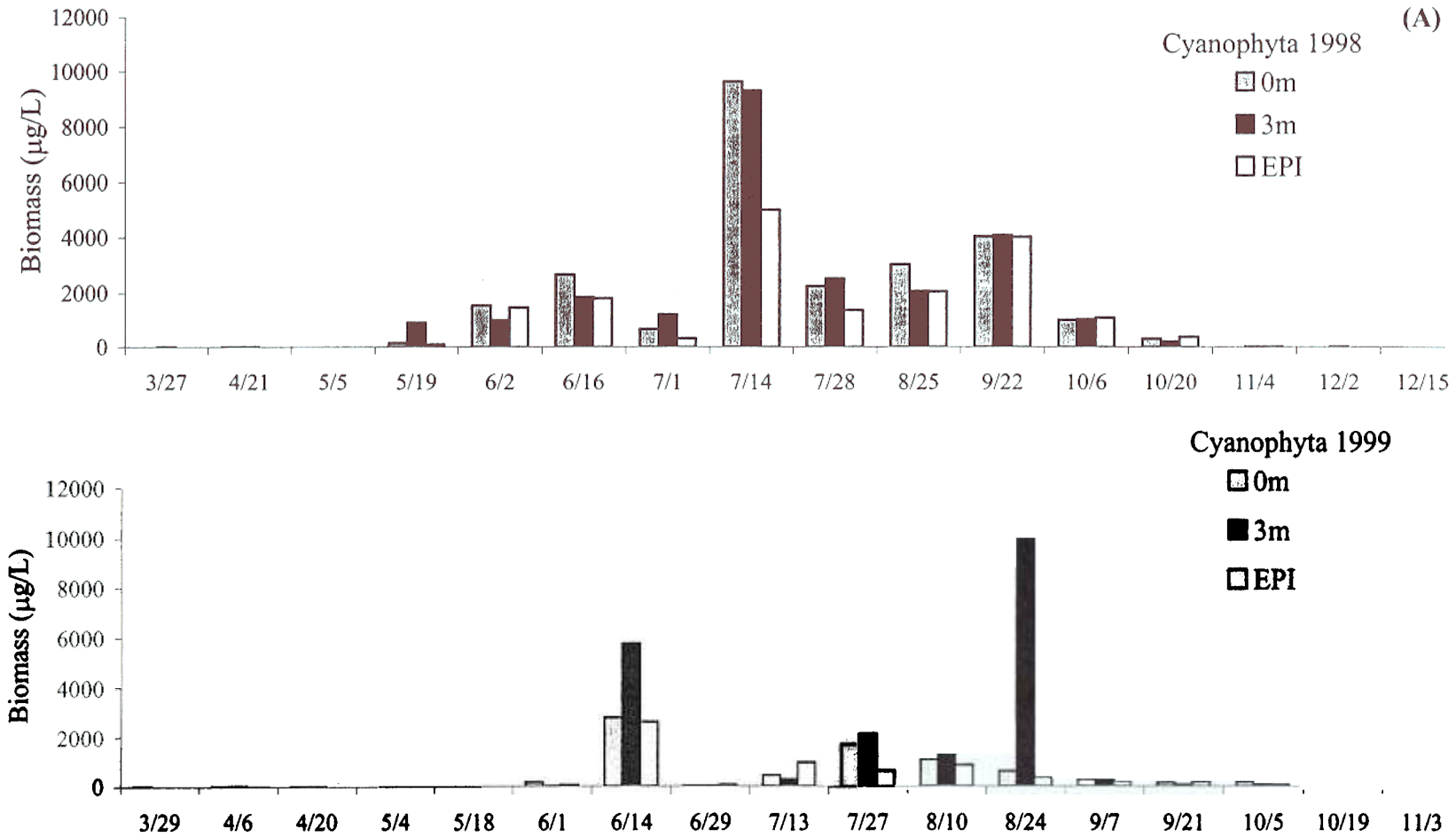
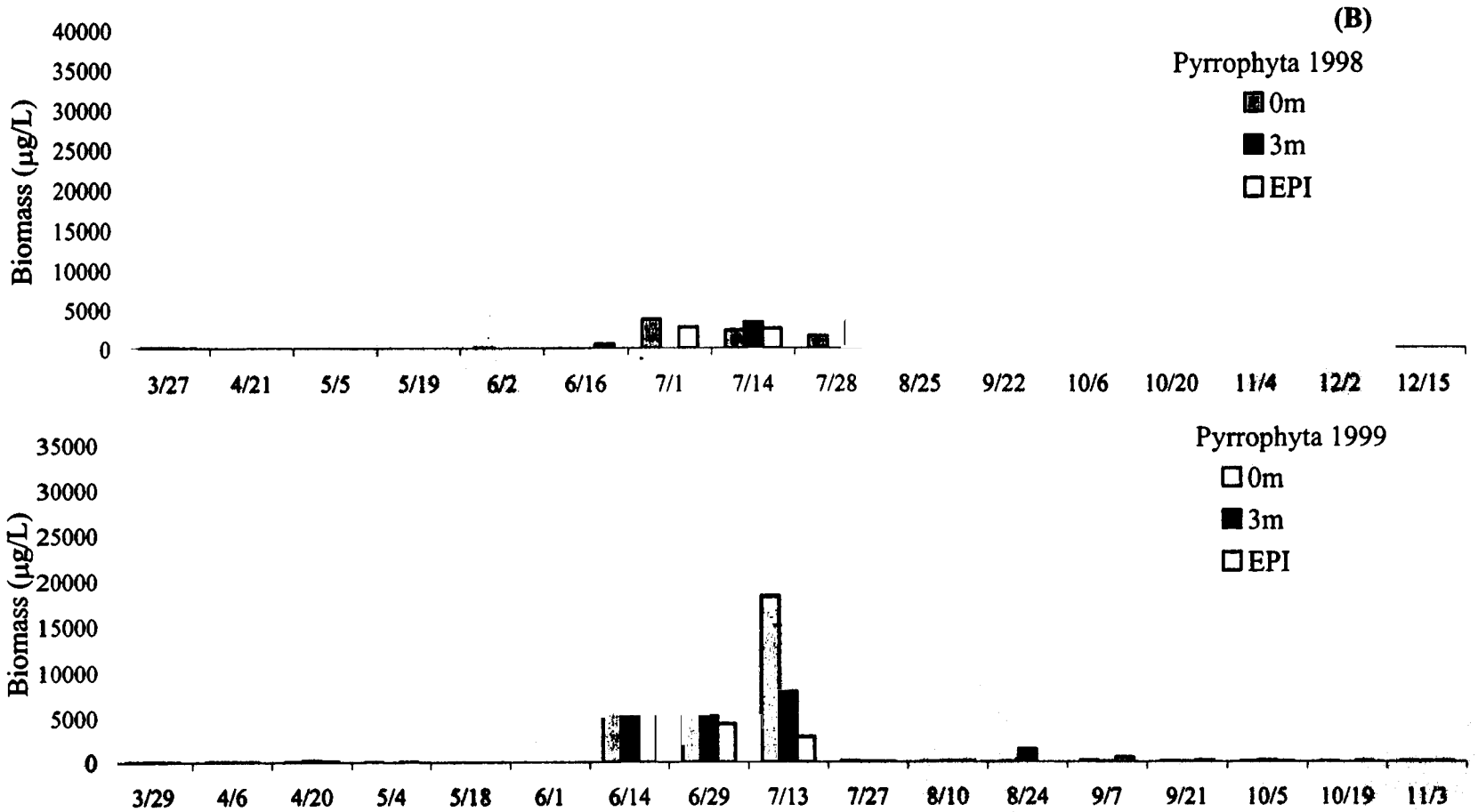


Figure 8.5. Biomass (ug/L) of Cyanophyta 1998, 1999 (A), Pyrrhophyta 1998, 1999 (B), Chlorophyta 1998, 1999 (C), Cryptophyta 1998, 1999 (D), Chrysophyta 1998, 1999 (E), Bacillariophyceae 1998, 1999 (F), and Euglenophyta 1999 and Other Microflagellates 1999 (G) from 0m, 3m, and integrated epilimnion samples from Onondaga Lake "South" stations.


(B)
Pyrrophyta 1998
0m
3m
EPI
Biomass (µg/L)
40000
35000
30000
25000
20000
15000
10000
5000
0
3/27
4/21
5/5
5/19
6/2
6/16
7/1
7/14
7/28
8/25
9/22
10/6
10/20
11/4
12/2
12/15
Pyrrophyta 1999
0m
3m
EPI
Biomass (µg/L)
35000
30000
25000
20000
15000
10000
5000
0
3/29
4/6
4/20
5/4
5/18
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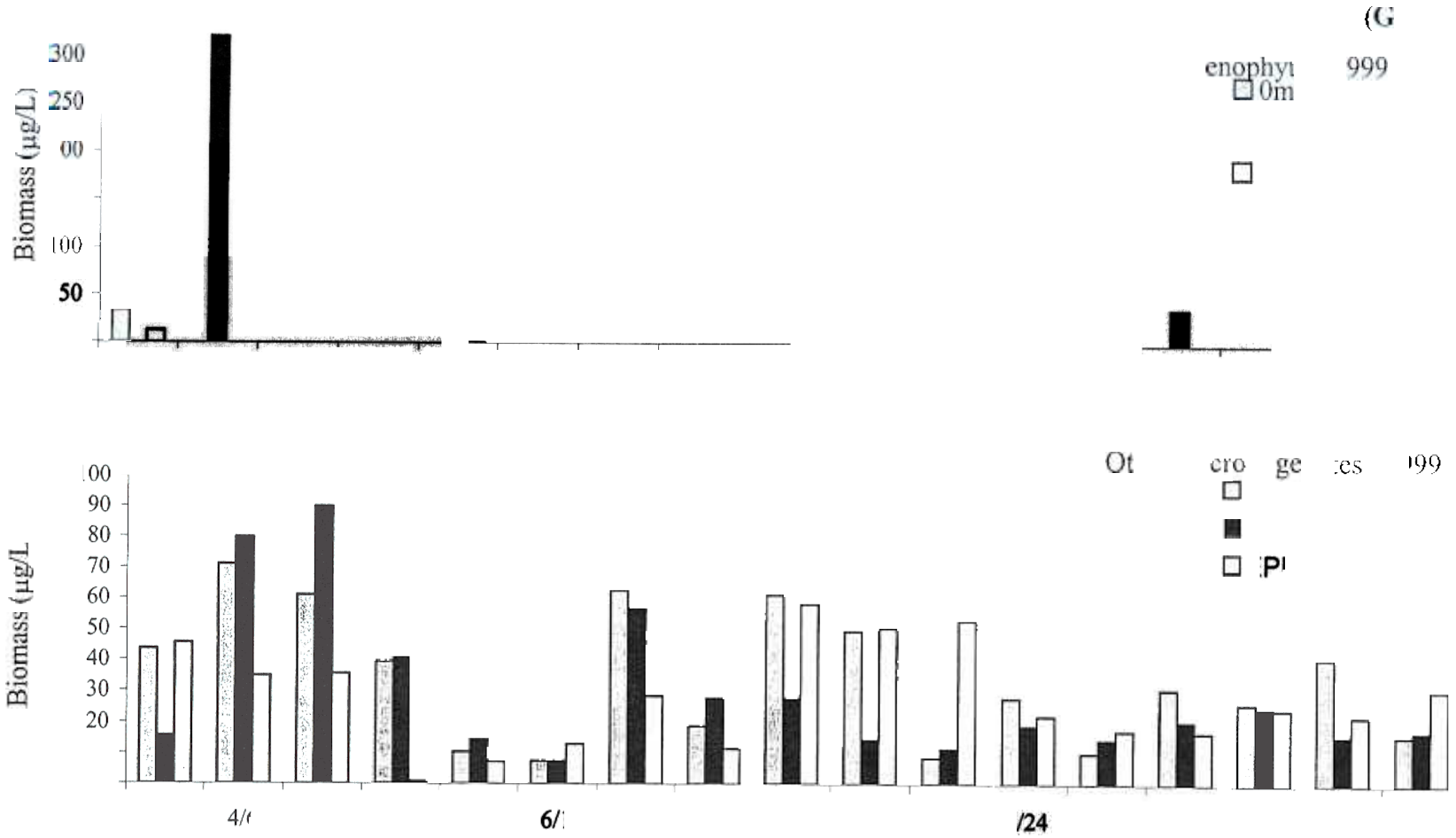
10/19
11/3



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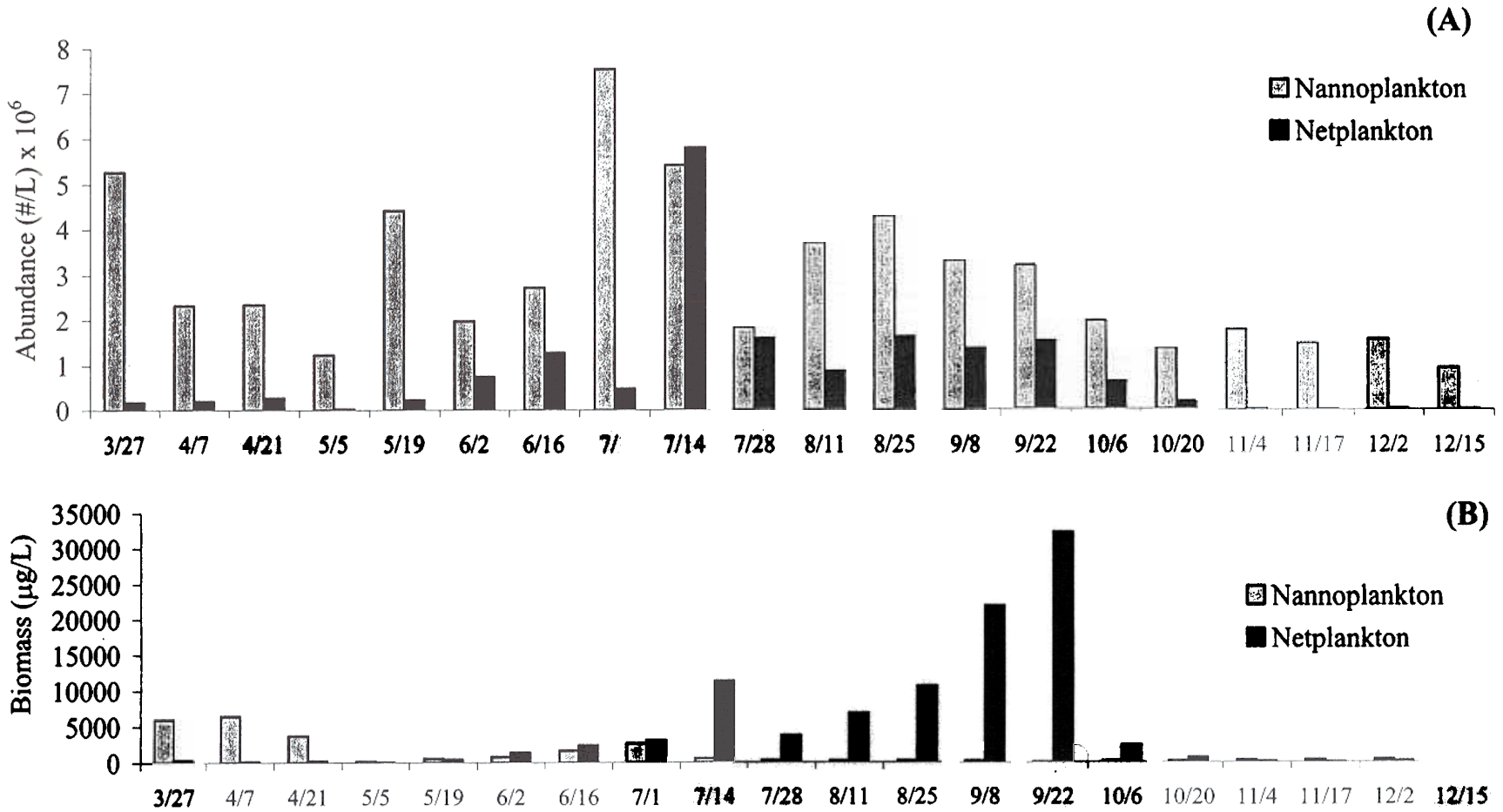


Figure 8.6. (A) Abundances (#/L) x 10^6 and (B) biomass (µg/L) of nannoplankton and net plankton collected from Onondaga Lake, 3/27/98 - 12/15/98. Data are averages of 0m, 3m, and integrated epilimnetic samples (3/27, 4/7, 4/21, 5/5, 5/19, 6/2, 6/16, 7/1*, 7/28, 8/11, 8/25, 9/22 *, 10/6, 10/20, 11/4, 11/17*, 12/2, 12/15) or averages of 0m and 3m samples only (9/8). An asterix indicates "North" station samples were taken in addition to "South" station samples.

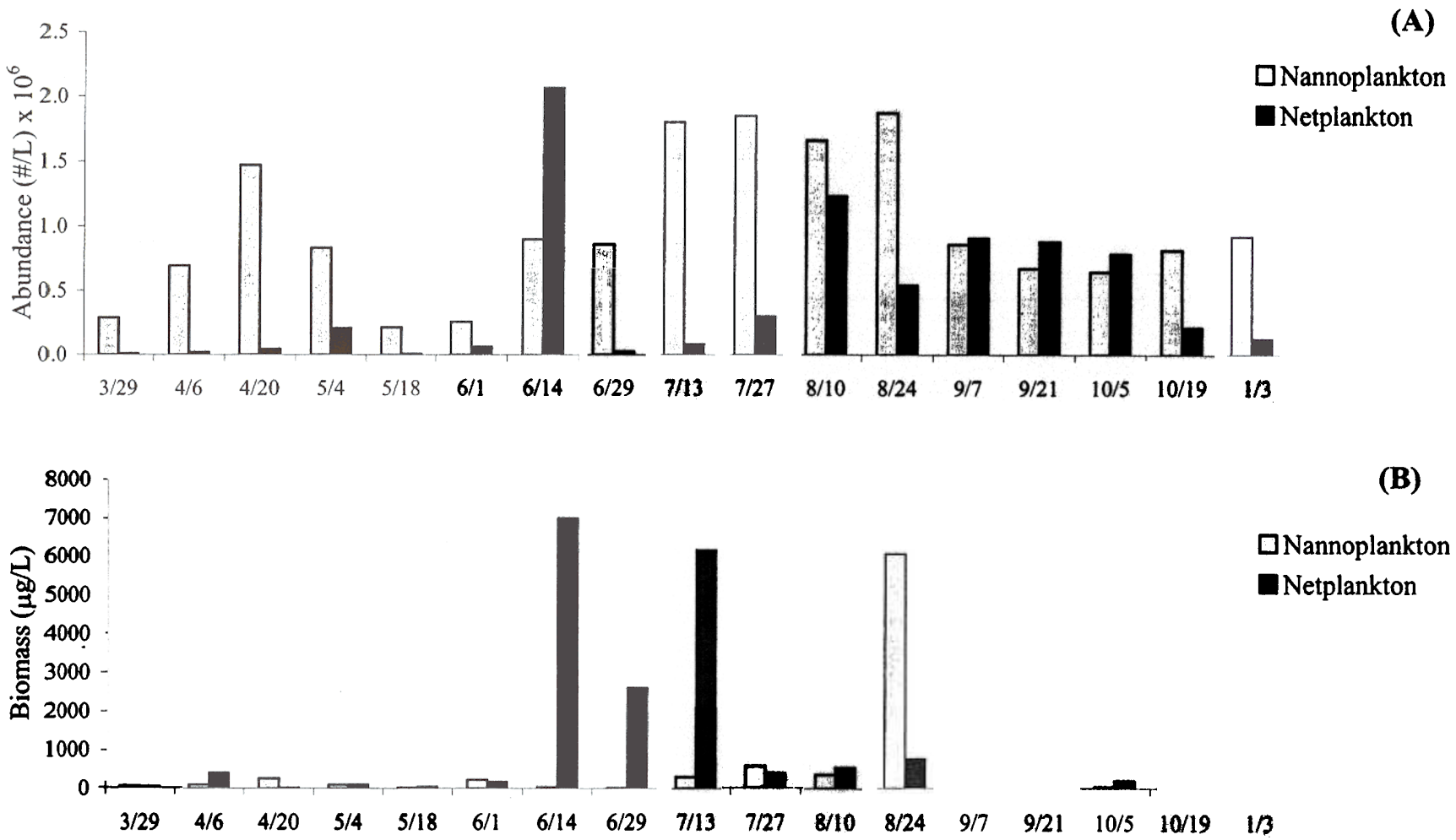


Figure 8.7. (A) Abundances (#/L) x 10^6 and (B) Biomass (µg/L) of nannoplankton and netplankton collected from Onondaga Lake, 3/29/99 - 11/3/99. Data are averages of 0m, 3m, and integrated epilimnetic samples (3/29, 4/6*, 4/20, 5/4, 5/18, 6/1, 6/14, 6/29, 7/13*, 7/27, 8/10, 8/24, 9/7, 9/21*, 10/5, 10/19, 11/3). An asterix indicates "North" station samples were taken in addition to "South" station samples.

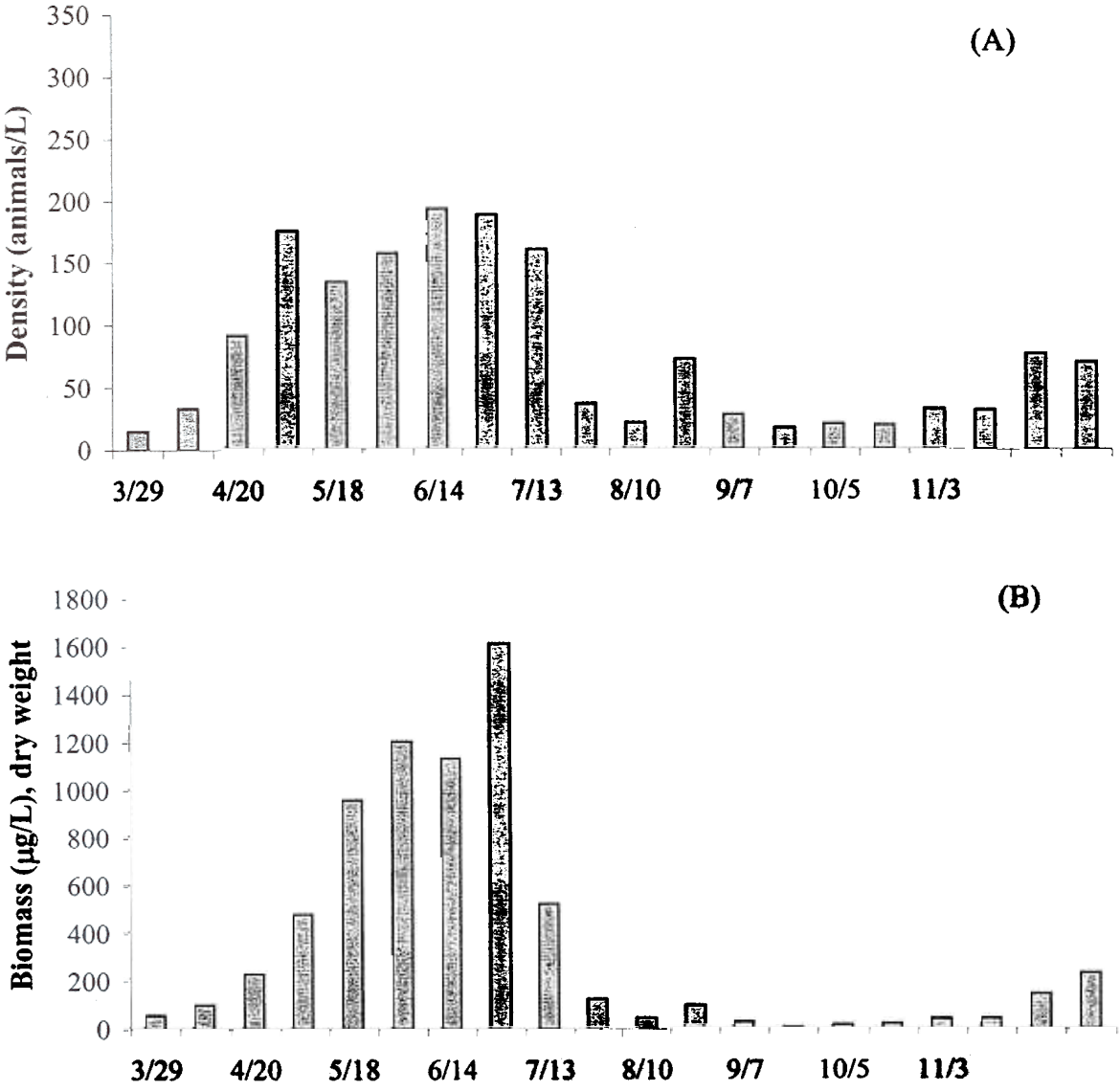


Figure 8.8. (A) Density (#/L) and (B) biomass (ug/L) of zooplankton community in Onondaga Lake, April-August 1999.

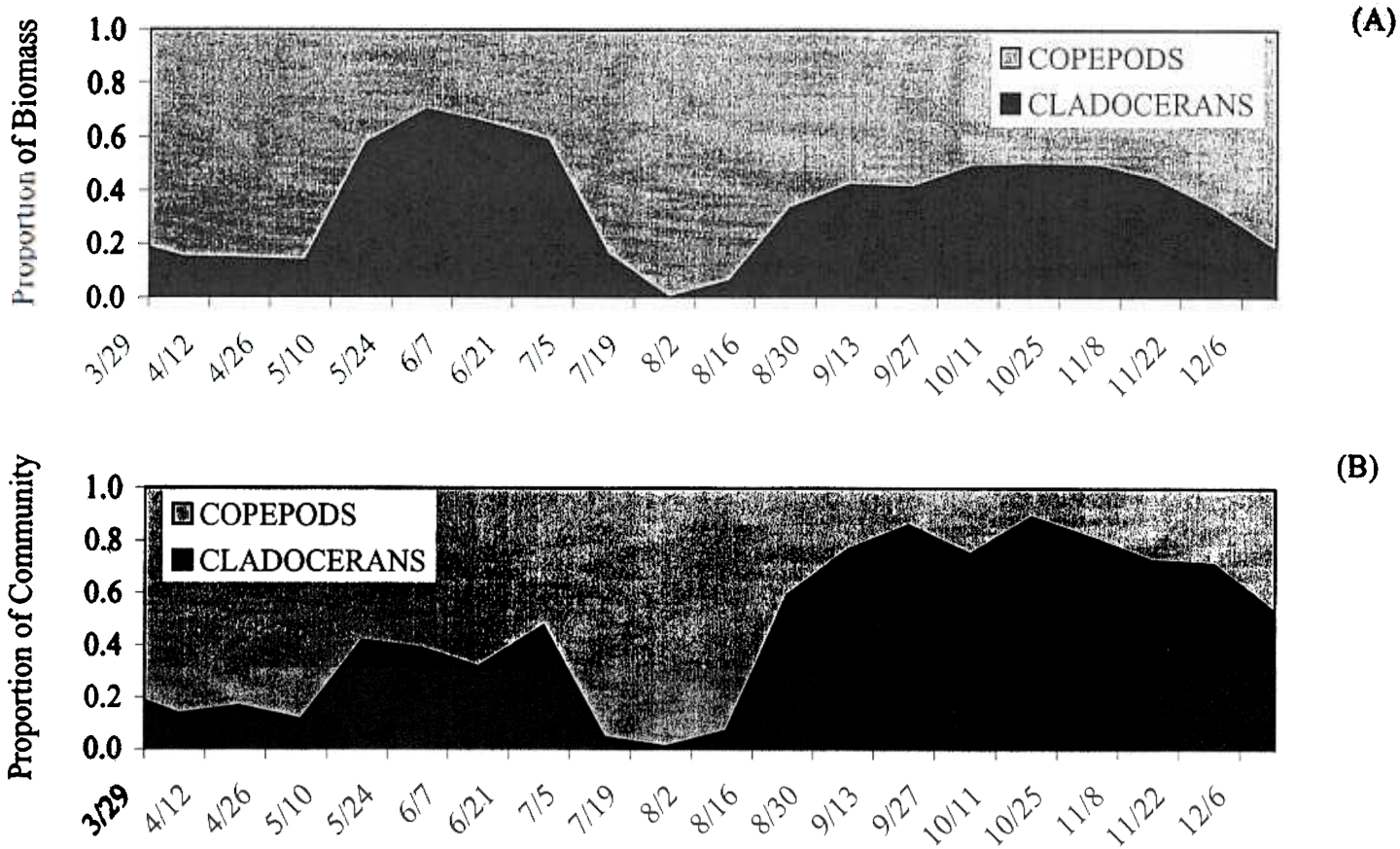


Figure 8.9. (A) Relative biomass and (B) relative abundance of cladocerans and copepods in Onondaga Lake during 1999.

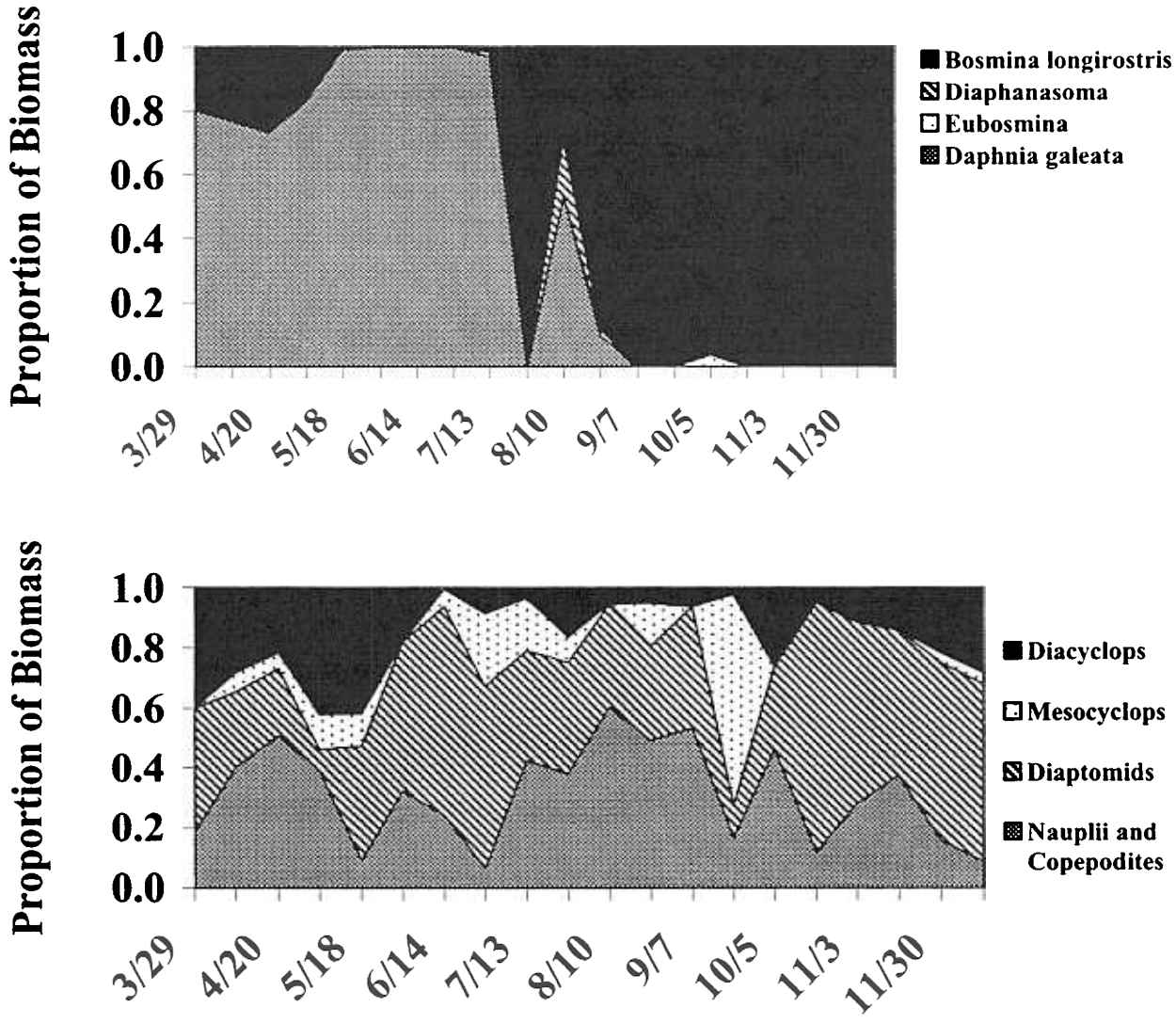
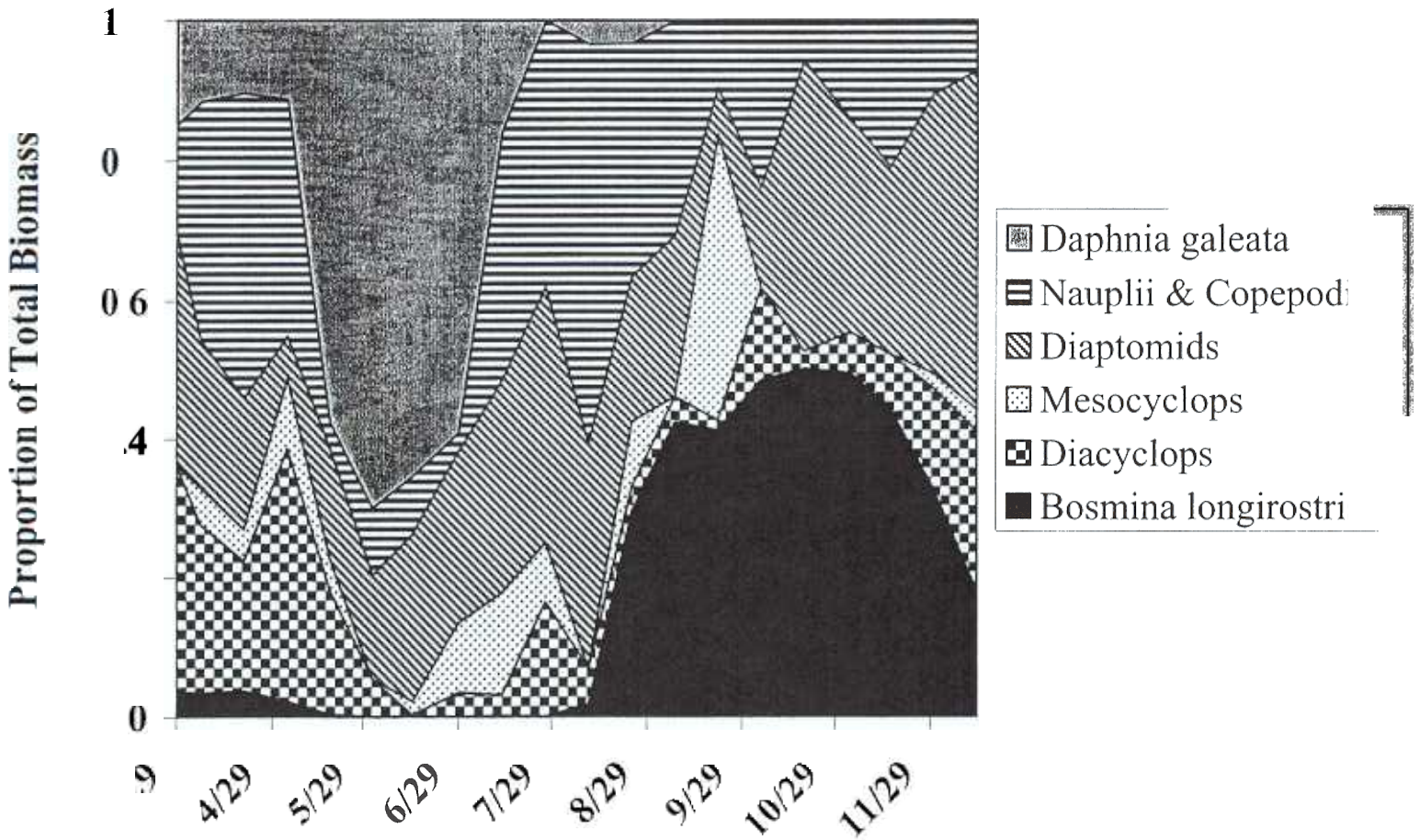


Figure 8.10. (A) Proportion of total cladoceran biomass of *Daphnia galeata*, *Bosmina longirostris*, *Diaphanosoma sp*. and *Eubosmina coregoni* in the Onondaga Lake zooplankton community from April to December in 1999. (B) Proportion of total copepod biomass of *Diacyclops thomasi, Mesocyclops edax*, Nauplii and Copepodites, and Diaptomids during this same time period in



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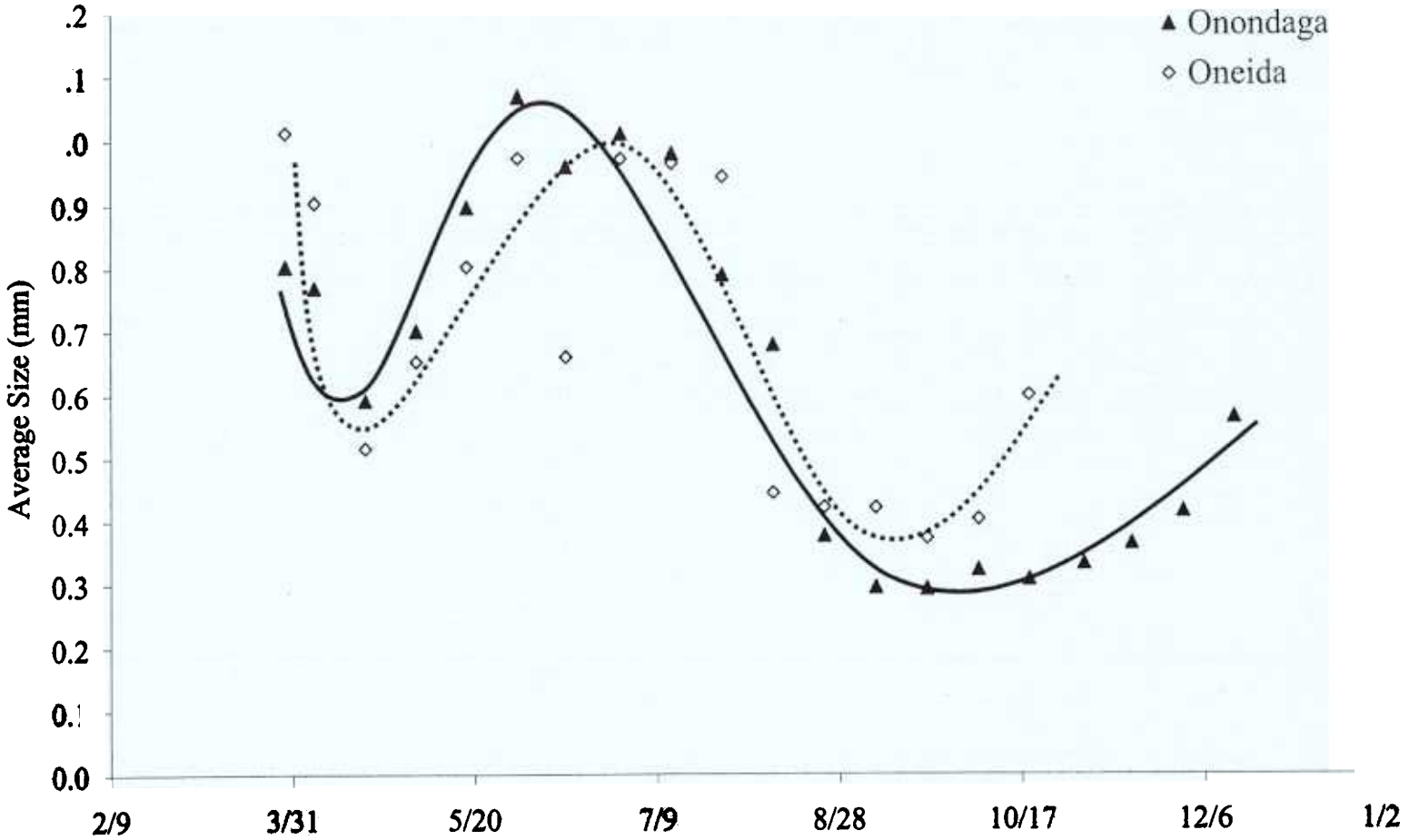


Figure 8.12. Average zooplankton lengths (mm) in both Oneida and Onondaga Lake, March - December 1999. Trend lines reflect size changes over the year.

Table 8.1. Density (animals/L), average size (mm), and biomass (µg/L) of the total zooplankton community, cladocerans, copepods, and individual taxa collected from Onondaga Lake, NY, 3/29/99-12/14/99. Data are grouped by season into Spring (n=7), and Summer (n=7), and Fall (n=6). An asterix ("*") indicates that the sample is an average of "North" and "South" sites collections. All averages are generated from epi and 12m tows. Data are mean and standard errors (SE).

Taxa or Species	Statistic	Spring (3/29,4/6*,4/20,5/4, 5/18,6/1, 6/14) n = 7		Summer (6/29,7/13*,7/27,8/10, 8/24,9/7 ,9/21*) n = 7	
		Mean	SE	Mean	SE
Total Community	Density (animals/L)				
	Ave. Size (mm)				
	Biomass (µg/L)				
Cladocerans	Density (animals/L)	32.74	10.51	26.78	12.73
	Biomass (µg/L)	328.99	142.95	160.04	135.02
Copepods	Density (animals/L)	84.74	19.88	51.64	22.12
	Biomass (µg/L)	277.23	61.71	201.04	98.33
Bosmina longirostris	Density (animals/L)	5.24	1.59	12.10	6.16
	Ave. Size (mm)	0.29	0.01	0.27	0.02
	Biomass (µg/L)	4.97	1.52	8.23	4.19
Daphnia galeata	Density (animals/L)	26.11	11.05	25.13	22.75
	Ave. Size (mm)	1.11	0.08	0.94	0.08
	Biomass (µg/L)	322.38	143.42	264.88	234.39
Diacyclops thomasi	Density (animals/L)	19.46	7.96	3.72	1.79
	Ave. Size (mm)	0.83	0.04	0.83	0.04
	Biomass (µg/L)	73.08	28.33	14.58	7.75
Mesocyclops edax	Density (animals/L)	2.12	0.84	3.82	1.73
	Ave. Size (mm)	1.22	0.06	1.08	0.07
	Biomass (µg/L)	27.09	9.16	54.46	30.23
Nauplii and Copepodites	Density (animals/L)	45.45	11.84	26.84	15.07
	Ave. Size (mm)	0.23	0.01	0.25	0.01
	Biomass (µg/L)	80.92	21.45	51.90	25.36
Diaptomidae	Density (animals/L)	18.31	10.91	18.35	8.50
	Ave. Size (mm)	0.98	0.04	0.86	0.06
	Biomass (µg/L)	103.89	37.67	95.66	56.17

CHAPTER 9

MACROINVERTEBRATE SAMPLING

This chapter is an executive summary of the report "1999 ONONDAGA LAKE AND TRIBUTARY MACROINVERTEBRATE COMMUNITY ASSESSMENT AND RECOMMENDATIONS FOR YEAR 2000 PROGRAM" dated April 2000 and prepared for Onondaga County Department of Drainage and Sanitation by EcoLogic, LLC. The complete report is available at the Department offices.

Objectives

Macroinvertebrate sampling is among the requirements of the Amended Consent Judgment signed in January 1998. Onondaga County is required to assess the macroinvertebrate communities of selected tributaries and the littoral zone of the Lake. Sampling in the tributaries will be conducted every two years and sampling in the lake's littoral zone will be conducted every five years through the Ambient Monitoring Program (AMP). The objectives of monitoring this element of the aquatic ecosystem are to characterize the existence and severity of use impairment, and evaluate the effectiveness of improvements to wastewater collection and treatment.

The formal macroinvertebrate program began in 2000. Presampling was completed in 1999 to finalize design of the program with respect to sites, equipment and methodology for collecting representative samples. Many replicate samples were analyzed to characterize variability of community composition; these results were used to determine adequate sample size for detecting changes in the community as improvements to the system are implemented. The extensive data set generated by the 1999 program was also used to characterize baseline conditions in the lake and tributaries.

Methods

Tributary sampling. 14 sites were sampled in the tributary system of Onondaga Lake, six sites on Onondaga Creek, four sites on Ley Creek; and four sites on Harbor Brook (Figure 9-1). Multiplate samplers were used as the primary sampling device at each site. Five replicates were processed at each location. Kick sampling was employed where conditions were appropriate; the number of replicates was two or three depending on substrate availability.

Littoral Zone Sampling. Five sampling locations were selected in the lake's littoral zone (Figure 9-2). Sampling was conducted at three depths of overlying water (0.5 m, 1.0 m and 1.5 m) at each location. These sites were selected to reflect major sediment characteristics and proximity to point source discharges. Six replicate samples were collected at each of the three water depths using a petite ponar dredge for a total of 180 lake samples. An array of five multiplate samplers was also deployed near the waste beds at 1.5m water depth.

Sorting. *Tributary kick samples* were washed through a sieve to remove fine sediments. The remaining material was stained and transferred to a metal pan where contents were examined under magnification. Organisms were sorted into major groups, placed in labeled vials containing 90% ethyl alcohol, and counted. Sorting continued until 100 organisms had been removed. Labeled vials were sent to Aquatic Resources Center (ARC) of College Grove Tennessee for identification.

Identification All organisms were sent to ARC for identification except for chironomids collected in the lake, which were sent to Dr. Leonard Ferrington at the University of Kansas. All organisms were identified to the lowest possible taxonomic level. Generally, chironomids and oligochaetes needed to be cleared, slide mounted and viewed through a compound microscope for proper identification. Most other organisms could be identified using a dissecting stereomicroscope. Identified organisms were returned to Onondaga County for an archived reference collection.

Calculations Biological monitoring programs using benthic macroinvertebrates to assess water quality rely on several different indices of community composition to evaluate ecological status and infer water quality conditions. Each index should contribute different information to the assessment to avoid redundancy and minimize conflicting results. A number of indices were calculated as part of this assessment. The purpose was to determine the level of impairment in the tributaries under existing conditions as well as to conclude which indices would be best for determining the impacts of control actions over time. Analysis of variance (ANOVA) was performed on log (x+1) transformed data to help discriminate changes in values across sites.

Results of multiplates and kick samples in tributaries were compared with NYSDEC riffle habitat criteria and lake samples were compared to NYSDEC ponar criteria. Tributary criteria were calculated using a combined index incorporating species richness, EPT richness, Hilsenhoff Biotic Index (HBI), and Percent Model Affinity (PMA) (kick samples only) and diversity (multiplates only). Lake criteria were calculated by using another combined index incorporating species richness, diversity, HBI, dominance-3, and PMA. For both tributary and lake samples, an overall assessment for each site was calculated by averaging results of the individual metrics, accomplished through a scaled ranking of the index values. The values were converted to a common scale of water quality ranging from 0-10. The score resulted in a designation of the sampling site into one of four categories: non-impacted, slightly impacted, moderately impacted, or severely impacted.

Results

Onondaga Creek's macroinvertebrate community was slightly to moderately impacted at all sampling sites according to NYSDEC criteria. Site 1 (the most upstream site), just downstream of mudboils, was deemed slightly impacted. The macroinvertebrate community at Sites 2 and 3 reflected moderate impacts to water quality, indicating that some type of degradation occurred between sites 1 and 2 even though no CSO enter between these sites. The stream improved to a designation of slightly impacted at sites 4 and 5, which are in the City of Syracuse downstream of CSO discharges. These values were comparable to upstream Site 1, which is well above CSO discharges. Site 6 showed a marked decrease in water quality to a moderate - severe level of impact. .

The macroinvertebrate community in *Ley Creek* was consistent with moderately impacted water quality and habitat conditions at all monitoring points based on NYSDEC criteria. Moderate impairment was evident upstream and downstream of CSO discharge points. Tolerant chironomids, gastropods and oligochaetes dominated the community at all sites. Evidence of CSO impacts was apparent as the macroinvertebrate fauna shifted from a community dominated by chironomids and gastropods to a community dominated by oligochaetes and chironomids downstream of CSO discharges. No sensitive species of the EPT group (Ephemeroptera, Plecoptera, and Trichoptera) were collected at Sites 1 through 3. Two moderately tolerant ephemeropterans (*Caenis spp.*) were collected at Site 4. The absence of these important indicator organisms was consistent with poor water quality and/or habitat quality throughout the stream's length.

Hilsenhoff Biotic Index (HBI) tests for evidence of organic pollution. HBI results rose steadily from Site 1 to Site 4, indicative of steadily increasing impacts to the macroinvertebrate community from organic and nutrient enrichment. CSO discharges do not enter into the stream until Site 3 however, suggesting that nonpoint sources such as urban or industrial runoff are affecting the macroinvertebrate community.

The macroinvertebrate community of *Harbor Brook* was slightly to severely impacted. Sites 1 (most upstream site and above CSOs) and 4 (most downstream site and below CSOs) were both moderately impacted. Site 2, which is in close proximity to Site 1, was considered slightly impacted. Site 3 was

deemed severely impacted based on NYSDEC criteria. This site exhibited low scores for species richness, EPT richness, diversity, and HBI. This may be a result of poor habitat at this site; the stream bottom is silt covered concrete. There was evidence of impacts from organic enrichment well upstream of CSO discharges as well as below and toxic impacts at the two most downstream sites. Community composition varied by site, but was dominated by combinations of tolerant chironomids, gastropods, isopods and oligochaetes. HBI values indicated generally moderate to severe impacts from organic enrichment, with highest values downstream of CSO discharges.

The macroinvertebrate community in *Onondaga Lake* is characterized as slightly to severely impacted and varied with location in the lake. Although 63 distinct taxa of macroinvertebrates were collected in the lake, the combined relative abundance of oligochaetes and chironomids accounted for 81 to 98 % of the taxa present. Most of the oligochaete and chironomid species abundant in the lake tolerate wide ranges of both eutrophication and salinity. Two taxa of oligochaete worms abundant in Onondaga Lake, *Tubifex spp.* and *Limnodrilus hoffmeisteri*, typically dominate in systems that receive high volumes of organic waste

Site 1 at the south end of the lake was the most adversely impacted area receiving a severely impacted rating based on NYSDEC criteria. This site may be influenced by toxic effects of sediments. Site 4 on the northeast shore was least impacted of the lake sites. The combined influence of eutrophication, habitat degradation and sediment toxicity are likely the major structuring elements of the benthic community in Onondaga Lake. A substantial number of chironomid larvae exhibited mouthpart deformities, a characteristic often found in systems with a history of industrial pollution.

Conclusions and Recommendations

Number of Replicate Samples, Sample Methods, and Number of Stations. The existing sampling program design for lake and tributary benthic invertebrates is adequate to resolve spatial variations and provide a level of precision that achieves the AMP objective, except for abundance measurements using tributary multiplates. The latter is within the range of that achieved for the other biological parameters.

The final Phase II Statistical Framework was submitted to NYSDEC in early 2000. Based on the 1999 investigation and subsequent reviews of the findings, we recommend using kick samples in Onondaga Creek and Harbor Brook and jab samplers on Ley Creek where no suitable habitat is available. Fewer stations will be sampled with four replicates per station. This design meets the statistical design criteria to detect changes in the macroinvertebrate community over time as discussed in the work of Dr. William Walker.

Indices for Tracking Improvements over Time The long-term objective of monitoring this component of the biological community is to assess the "recovery" of the invertebrate communities as wastewater collection and treatment are improved. We recommend tracking the community using NYSDEC standard indices in combination with two specific metrics selected to be diagnostic of the water quality issues associated with this system. The metrics HBI and percent oligochaetes were selected because they are most likely to be directly impacted by changes in organic loading.

Statistical Analysis. Analysis of covariance (ANCOVA) should be used to compare slopes of curves plotting changes in each of the selected metrics over time. The slope of the curve of an impacted site (for example, downstream of CSOs) can be compared to the slope of the curve of a reference site. Data analysis would first plot the measured value of this index for each sampling point (year) in the monitoring program.

Comparing the slope of the curve at a reference site versus impacted sites forms the basis for detecting change in community composition. The ANCOVA compares the slopes of these two curves. Data for each metric will likely need to be transformed to conform to the assumptions of the ANCOVA - normality and homogeneity of residuals. One would expect the reference site to stay the same and the impacted site to improve, if the County's remedial program for sewage collection and treatment were working (the slopes would be statistically different). It is only appropriate to test for main effects if the slopes are the same (e.g., the impact site does not improve). Then one can test whether the metric (in this case, percent oligochaetes) differs between the two sites (intercepts differ).

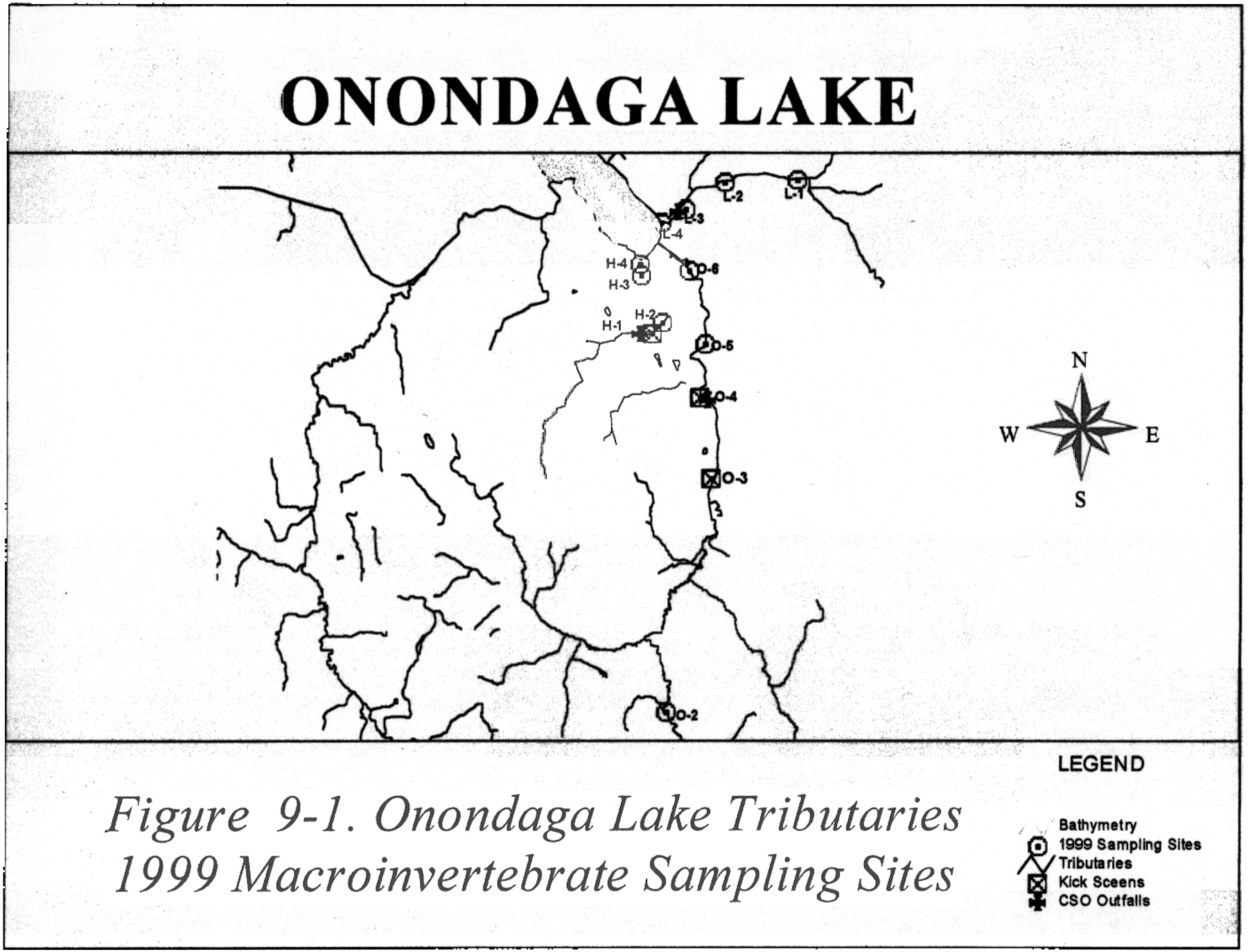


Figure 9-1. Onondaga Lake Tributaries 1999 Macroinvertebrate Sampling Sites

ONONDAGA LAKE

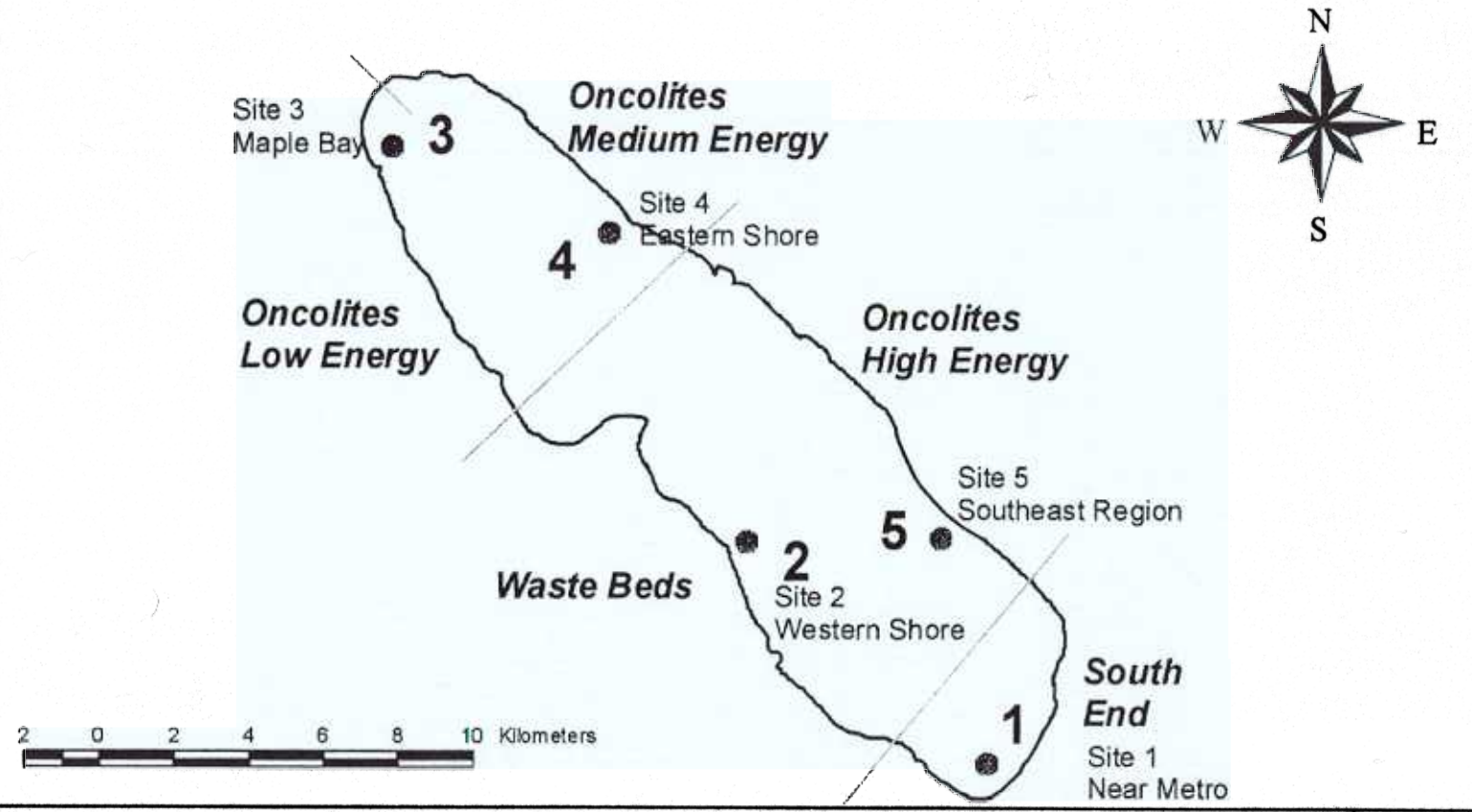


Figure 9-2. Onondaga Lake
1999 Macroinvertebrate Sampling Sites

LEGEND

Strata Lines
Onondaga Lake
Sampling Sites

CHAPTER 10

1999 Seneca River Dreissenid Mussel Assessment Program

Distribution of Zebra Mussels Along a Selected Reach of the Seneca River

In August 1999, the County of Onondaga Department of Drainage and Sanitation (County) retained Beak Consultants Incorporated (Beak) to conduct an assessment of the dreissenid mussel population on the Seneca River system as a part of the County's Ambient Monitoring Program (AMP). The objective of the study was to determine the distribution and abundance of zebra mussels (*Dreissena spp*) along an approximately 30 mile reach of the Seneca and Oneida Rivers from just east of Cross Lake eastward to near Schroeppel Island about four miles east of the confluence of the Seneca, Oswego and Oneida Rivers. The initial task of the study was to map the habitat of the river as it related to potential colonization by zebra mussels (i.e., habitat assessment). Based on the results of that task, reaches of the river that contained comparable contiguous habitat were mapped. These zones were referred to as zebra mussel habitat zones. Within each habitat zone, standardized techniques using SCUBA were employed to collect samples of the substrate and zebra mussels present. Subsequently, analyses were performed to determine the density, size distribution and biomass of the zebra mussel populations that were present in each habitat zone as well as in each substrate type. The results of this investigation will be used in conjunction with two laboratory investigations also performed by Beak to develop information on aspects of the Seneca River mussel physiology (e.g., oxygen uptake, ammonia excretion, phosphorus and nitrogen mobilization). These results will be used to update the kinetic framework of the County's Seneca River model.

Two principal methodologies were used to perform the habitat assessment; (1) a sonar survey to profile the bottom contour and general substrate type (i.e., hard or soft); and, (2) a semiquantitative assessment of substrate composition and zebra mussel presence/abundance along transects set at regular intervals throughout the study reach using a petit ponar dredge. Water quality sampling for selected parameters was performed in conjunction with the ponar sampling.

Following the determination of available habitat in the study reach, Beak scientists met with County personnel and Dr. Ray Canale (developer of existing Seneca River model) to review the results of the assessment and come to a consensus on sampling locations and level of effort for the quantitative measurements of the dreissenid population in the study reach.

SCUBA techniques were employed to sample dreissenid densities along transects set within each habitat zone (Figure 10-1). Within each habitat zone, a minimum of three transects were sampled. In habitat zones that had a more complex substrate mix or were much longer than average, five transects were sampled. At each transect, three samples were collected; one about mid-channel and one about midway between each marker buoy and the corresponding shore.

At each sampling location, the diver carefully placed a 10-inch diameter (0.051 m^2) open center ring on a random location on the bottom. All substrate, including zebra mussels within the ring, was carefully removed from the ring and placed into a macroinvertebrate wash bucket fitted with a 583-micron mesh bottom which was attached to a line and buoy. All zebra mussels were placed into labeled plastic bags. The plastic bags were carefully placed into coolers with ice and transported to Beak's Lancaster, New York, Biological Laboratory for further processing.

The sonar recorded large differences in bottom depth, bottom regularity and substrate type. It was found that the petit ponar sampling provided a much better measure of habitat so the sonar data was used only to verify habitat breaks (i.e.: where significant changes in habitat occurred).

A total of 19 habitat zones was present in the 31.67 mile study area. The habitat zones ranged in length from 0.48 miles to 4.5 miles and occupied a mean area of between 0.018 and 0.220 square miles. A total of 189 samples was collected within the project area to assess the population characteristics of the dreissenids in the portions of the Seneca and Oneida Rivers of concern to the County. Dreissenids were present in 93 (49.2 percent) of the samples

analyzed. All of the dreissenids collected were zebra mussels (*Dreissena polymorpha*); no quagga mussels (*D. bugensis*) were present.

The overall mean density of mussels present in the project area was 1,945 individuals/m^2 in Zone III. The mean density of zebra mussels ranged from 9 mussels/m^2 in Zone I to 12,977 mussels/m^2 in Zone III. The highest density of mussels in any individual sample was 43,937/m^2 which occurred in Zone III that includes the State Ditch Cut.

The overall mean weight of zebra mussels per unit area in the project area was 1,356 grams/m^2. The mean weight of mussels ranged from 0.7 grams/m^2 in Zone I to 3,511 grams/m^2 in Zone V. The greatest weight of zebra mussels in any sample was 23,957 grams/m^2 (approximately 52.8 lb) in a sample collected in Zone V.

There were three different community structures evident from an examination of the length frequency data. One community type was dominated by zebra mussels that were 10 mm or less in total length. The second community type was a community dominated by large individuals (i.e., 20 mm and greater). The third community type had a more balanced size structure which included a mix of mussels of different sizes.

The striking differences in the length frequency distributions of the zebra mussel populations present among habitat zones in this relatively short river reach were unexpected. The most interesting distributions were found in Zones I, II and III, where the population was almost exclusively made up of individuals less than 10 mm long. Individuals less than 10 mm generally are young-of-year mussels, which for this study were mussels that settled during 1999.

The lack of live mussels that would have settled prior to 1999 in Zones I, II and III suggests that some catastrophic event occurred in this reach which killed or displaced the existing population of mussels. Since the majority of successful zebra mussel settlement events in temperate fresh water occur between June and October of each year, the unimodal distribution of young-of-year mussels indicates that the event occurred after the 1998 year class had settled (i.e., fall 1998), but had ended some time prior to the occurrence of appreciable settlement in 1999. The existence of multiple year classes of mussels in Zone IV located just downstream of the Cut, indicated that whatever contributed to the die off in the State Ditch Cut did not impact the population of mussels in Zone IV. A similar die off was reported to have occurred in the Cut in 1994. The presence of large numbers of byssusses from adult mussels found in the Cut and the rafts of adult shells downstream indicates that the catastrophic die offs in the Cut are not annual events.

A similar event also likely occurred in the Outlet to Onondaga Lake (Zone XIV). Over 87 percent of the mussels in Zone XIV were less than 10 mm and only 7.6 percent were larger than 20 mm. A notable observation made by the field personnel was that the cobbles and other hard substrate examined in the Outlet lacked the carpet of byssusses from detached adults. This would suggest that there is an annual low survivorship of adults in the Outlet.

The results of this study strongly suggests that there are appreciable changes in the population of mussels in portions of the study area that could greatly impact the population's influence on water quality since many impacts on water quality caused by a zebra mussel population (e.g., oxygen depletion, ammonia excretion) are dependent on both the numbers of mussels and their size. This would suggest that periodic evaluation of the status of the zebra mussel populations in the Seneca River may be warranted to determine their impact to the water quality model.

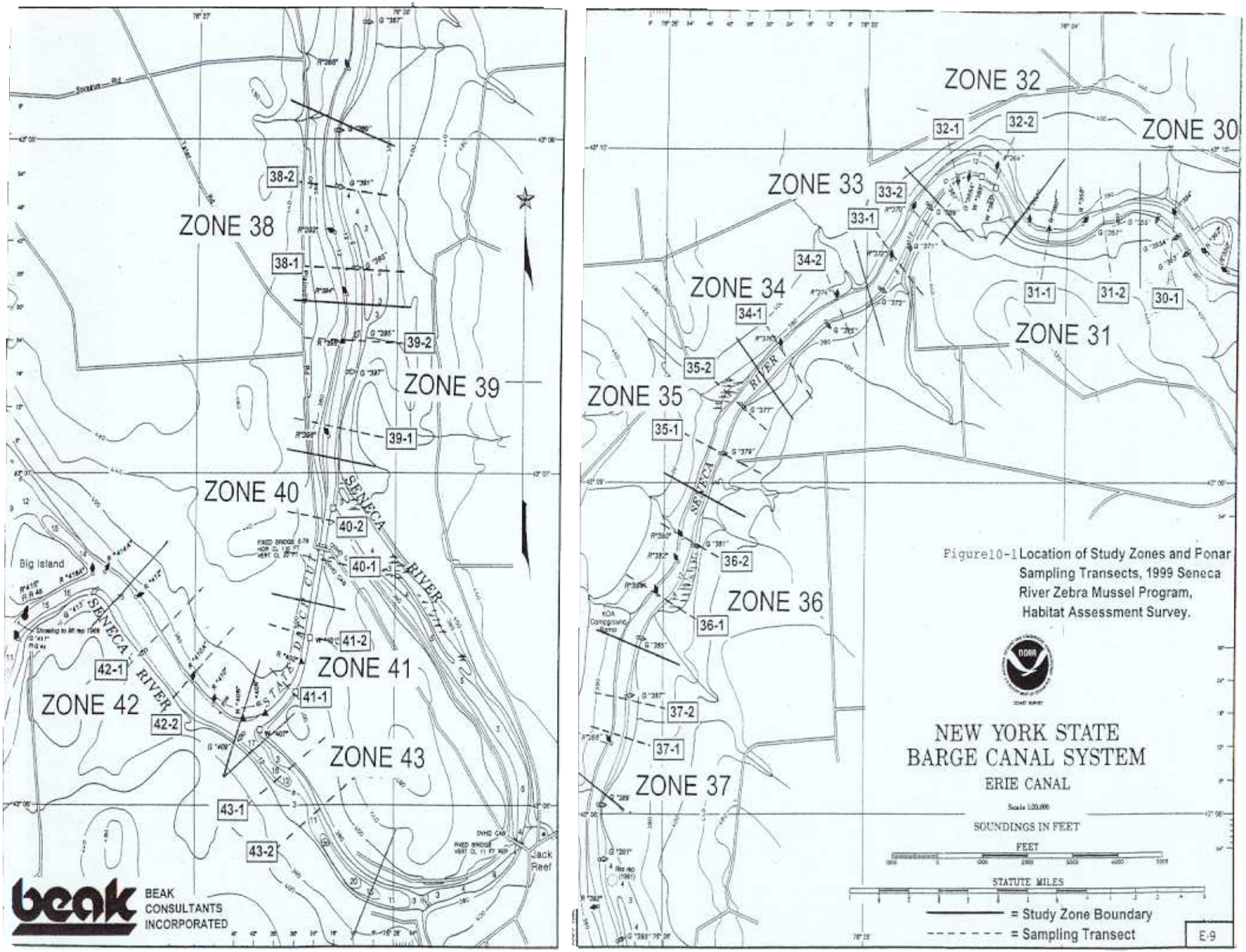
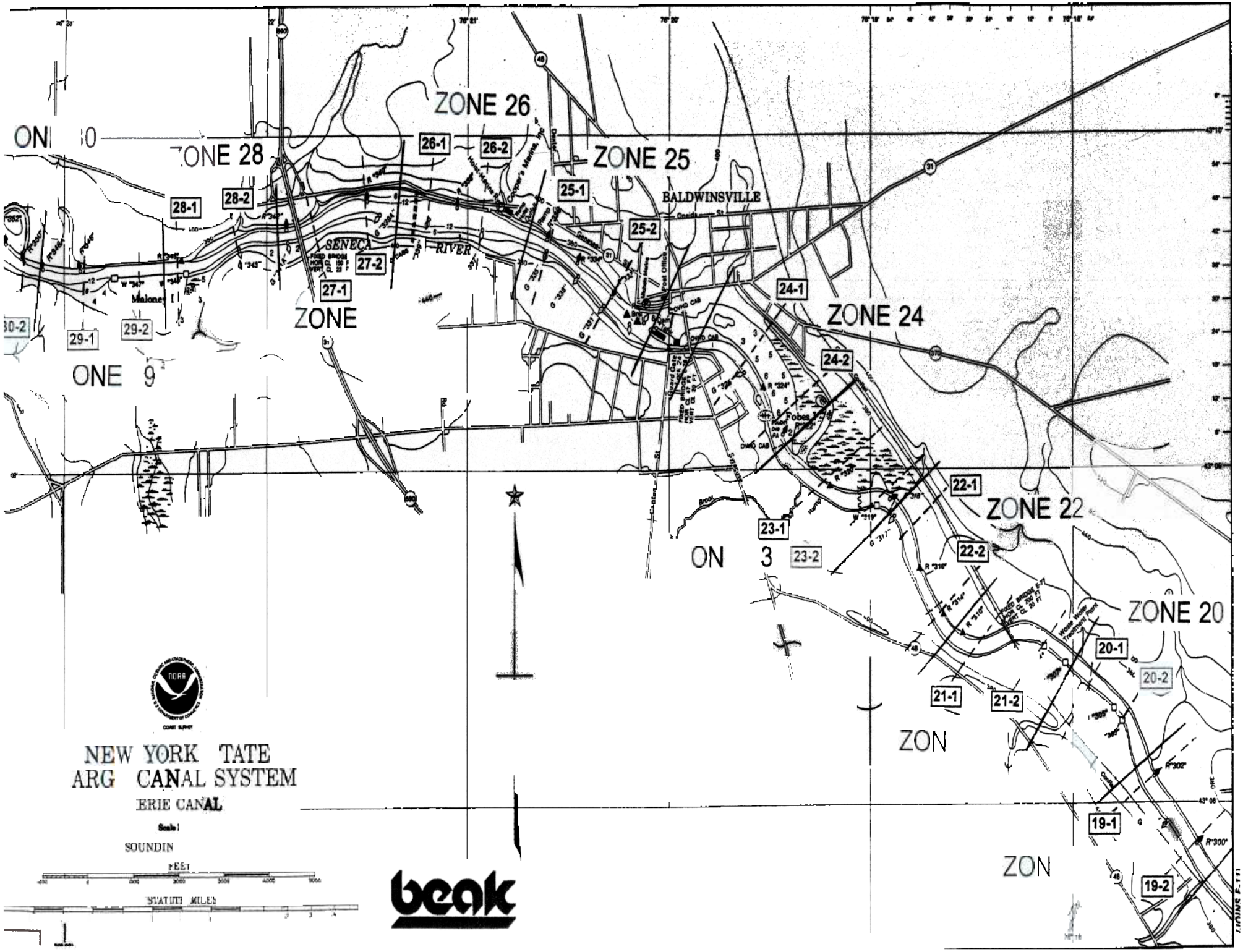


Figure10-1 Location of Study Zones and Ponar Sampling Transects, 1999 Seneca River Zebra Mussel Program, Habitat Assessment Survey.

beak CONSULTANTS INCORPORATED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ONE 9
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BALDWINSVILLE
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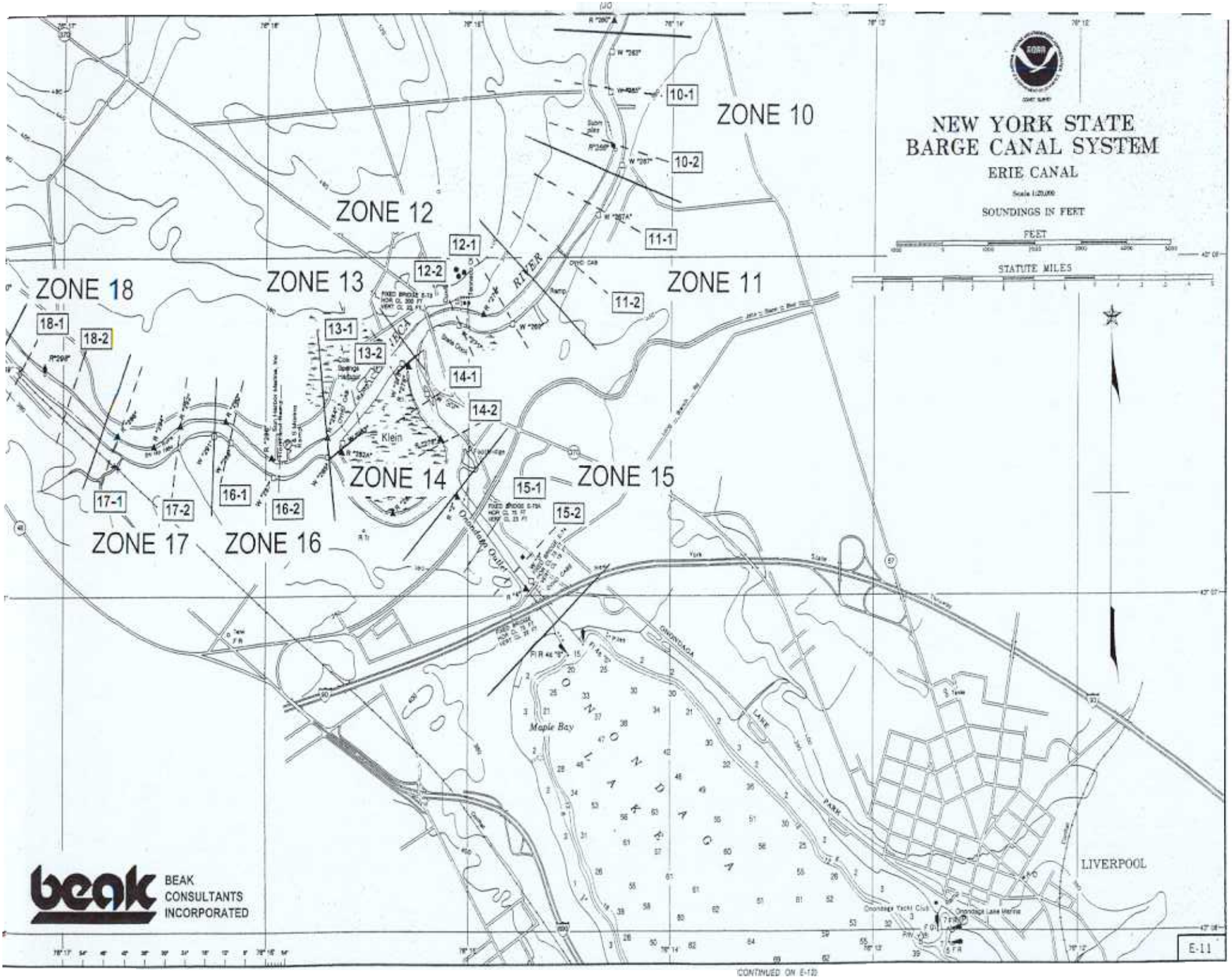

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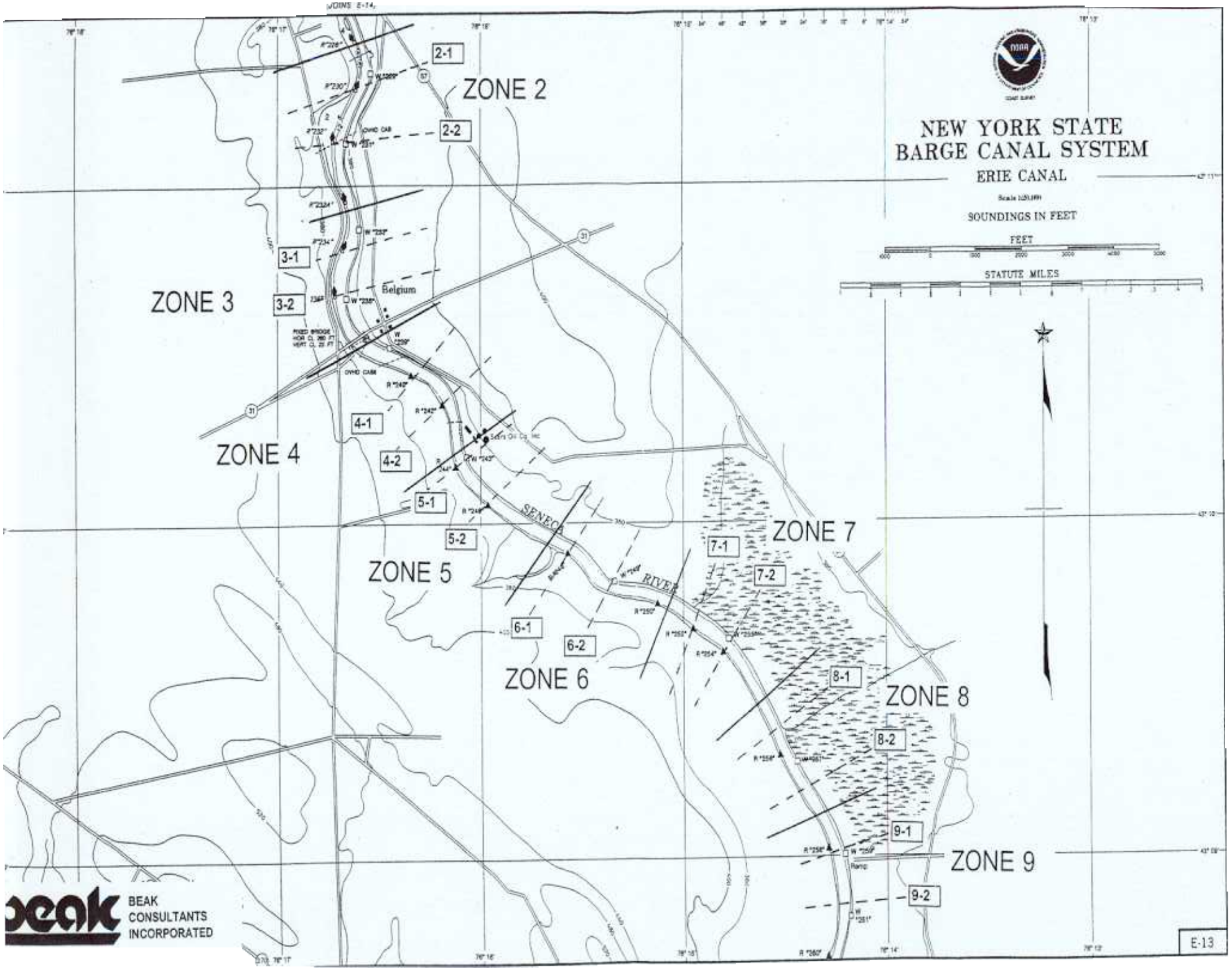
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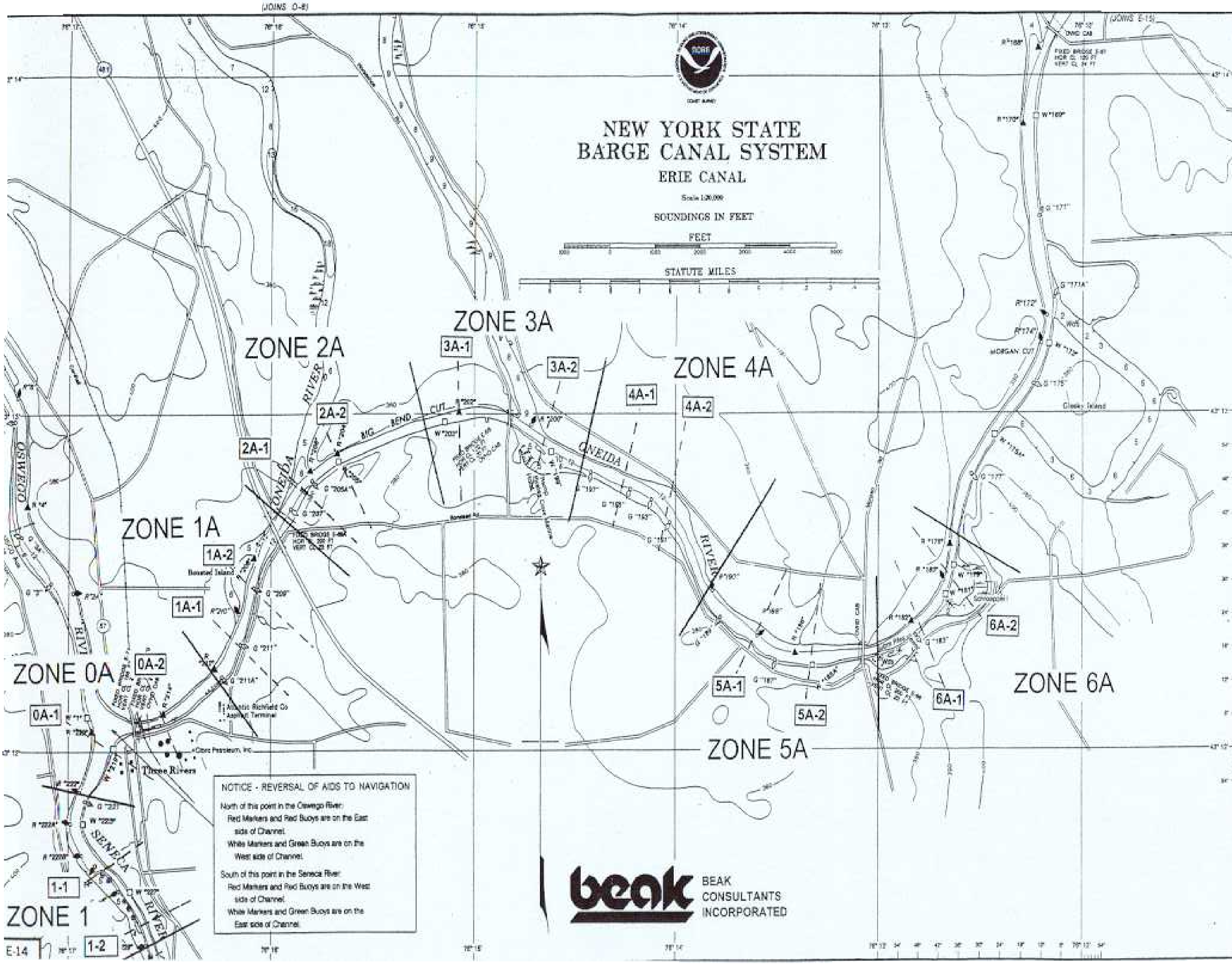
NEW YORK STATE
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STATUTE MILES
ZONE 0A
ZONE 1
ZONE 1A
ZONE 2A
ZONE 3A
ZONE 4A
ZONE 5A
ZONE 6A
0A-1
0A-2
1-1
1-2
1A-1
1A-2
2A-1
2A-2
3A-1
3A-2
4A-1
4A-2
5A-1
5A-2
6A-1
6A-2
BIG BEND CUT
ONEIDA
RIVER
OSWEGO
SENECA
MORGAN CUT
Three Rivers
Atlantic Richfield Co Asphalt Terminal
Bonsted Island
(JOINS O-8)
(JOINS E-15)
E-14
NOTICE - REVERSAL OF AIDS TO NAVIGATION
North of this point in the Oswego River:
Red Markers and Red Buoys are on the East side of Channel.
White Markers and Green Buoys are on the West side of Channel.
South of this point in the Seneca River:
Red Markers and Red Buoys are on the West side of Channel.
White Markers and Green Buoys are on the East side of Channel.
beak
BEAK
CONSULTANTS
INCORPORATED

CHAPTER 11

THREE RIVERS WATER QUALITY RESULTS
(By Dr. Raymond Canale)

11.1 INTRODUCTION

Onondaga County has sampled the water quality of the Seneca, Oneida and Oswego Rivers at key locations since 1994. Water quality conditions in these Rivers are of interest to Onondaga County because alternatives for upgrading treatment at METRO and possible relocation of this outfall are currently under discussion with NYSDEC. In addition, Onondaga County operates three other wastewater treatment plants -- Baldwinsville, Wetzel Road, and Oak Orchard -- which also currently discharge into the Seneca and Oneida River system.

The potential capability of the Seneca River to accommodate waste load discharges from METRO and other point sources was estimated by Canale et al., 1995 using a mass balance model based on extensive data collected in 1991. Sometime after this effort, Zebra mussels invaded the River. This has created a new oxygen sink in the system and has dramatically impacted overall water quality conditions (Effler and Siegfried 1994). As a result, many of the biochemical mechanisms and coefficients in the 1995 water quality model are no longer valid. Thus, the current model cannot be used to reliably evaluate the assimilative capacity of the River. However, some aspects of the model, such as the hydraulic structure, remain fundamentally sound. The County has engaged QEA to conduct a comprehensive review of the Canale model and make recommendations to upgrade the model mechanisms and improve its predictive capabilities.

The main purpose of the Onondaga County river monitoring program is to define ambient water quality conditions in the Seneca River between Cross Lake and the Three Rivers junction. This data collection effort can also be used to identify the impacts of the Baldwinsville and Wetzel Road WWTPs and the Onondaga Lake outlet on the Seneca River. The program also seeks to define existing water quality conditions in the Oneida and Oswego Rivers near and downstream from the Oak Orchard WWTP. One of the overall long-term goals of the program has been to use the data to support the current efforts to improve the reliability of the model to calculate the assimilative capacity of the Rivers and identify appropriate discharge limits for the WWTPs.

Measurements were made at 17 stations on 3 separate dates during 1999. Diurnal sampling of Hydrolab parameters were also made in 1999 at several key locations. The chemical and field parameters included in the 1999 study are listed with justification for their incorporation in Table 11-1. Most of the analytical parameters were measured at 1 meter below the water surface and 1 meter above the channel bottom in order to evaluate possible density stratification effects on water quality. Chlorophyll and BOD5 measurements were water column composite samples. Vertical profiles of several Hydrolab field parameters were measured to define possible chemical and temperature stratification in more detail. Measurements of various field parameters were taken at 1-meter intervals from surface to bottom. The station locations for the 1999 surveys are shown on the attached map (Figure 11-1) and are listed with distance from the Cross Lake outlet in Table 11-2.

11.2 RESULTS

A. River Flow Rates. Figures 11-2 and 11-3 show 1998 and 1999 flow rates in the Seneca River measured by the USGS at Baldswinsville. The 1998 and the 1999 surveys are indicated in the Figures and are listed in Table 11-3. Note that the lowest survey flow in 1999 was 148 cfs less than the lowest survey flow in 1998. It is seen that the River flow during mid-August 1999 was about 23% higher than the 10 year 7 day low flow rate of 427 cfs.

B. Dissolved Oxygen. Figures 11-4A and 11-4B show the measured longitudinal variations of surface and bottom dissolved oxygen concentrations for 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The measured data demonstrate a generally

consistent pattern, and have similar concentrations in each year. Water entering the surface of the River from Cross Lake has a relatively high average concentration of dissolved oxygen as a result of algal activities in the lake (between approximately 8 and 10 mg/l). The oxygen concentration is depleted in both the surface and bottom waters to an average of about 4 to 6 mg/l just above the Baldwinsville dam. The cause of the depletion is likely related to Zebra mussel respiration and reduced algal photosynthesis. One goal of Beak 2000a,b studies and the current QEA modeling program is to provide a quantitative understanding of the mechanisms that result in the observed dissolved oxygen concentration decreases. The variations at each station are the consequence of changes in River flow rate and temperature and sunlight conditions. Figure 11-4C shows measured diurnal variations at each sampling date at Station 294. The magnitude of the diurnal variations at this and other stations is generally around 1 to 3 mg/l. This range is somewhat higher than the 1998 measurements. Low bottom water dissolved oxygen concentrations downstream of the Onondaga Lake outlet are likely associated with the oxygen demand of Lake water and stratified conditions in the River. Many of the dissolved oxygen measurements in both 1998 and 1999 violate either the Instantaneous or Daily Average NYSDEC Minimum Standard. Zebra mussel respiration, reduced algal photosynthesis, oxidation of organic carbon and ammonia, sediment oxygen demand, and algal respiration likely cause these violations. The significance of these factors and their impact on the assimilative capacity of the River are being evaluated by the current QEA modeling project.

C. **Ammonia.** Figures 11-5A and 11-5B show measured longitudinal patterns of surface and bottom ammonia concentrations in 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The survey results for both years suggest that Zebra mussel activity in the CUT approximately double ammonia levels in the River. Also, the Onondaga Lake outlet introduces significant amounts of ammonia into the River. Density stratification results in large vertical differences between surface and bottom concentrations. The concentrations of these parameters change as the River flows downstream as a result of complex mixing patterns and biological nitrification. Ammonia concentrations observed in 1999 were somewhat lower than those measured in 1998. One goal of Beak 2000a,b studies and the current QEA modeling program is to provide a quantitative understanding of the mechanisms that result in high ammonia concentrations.

D. **Nitrite.** Figures 11-6A and 11-6B show measured longitudinal patterns of surface and bottom nitrite concentrations in 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The data indicate that some nitrification may occur between Cross Lake and Baldwinsville because increases in nitrite and nitrate concentrations are observed. The Onondaga Lake outlet also introduces significant amounts of nitrite into the River. Density stratification results in significant vertical differences between surface and bottom concentrations. The concentrations of nitrite change as the River flows downstream as a result of complex mixing patterns and biological nitrification. The nitrite water quality standard of 0.1 mg/l was violated on several occasions during 1999. Violations were likely a result of water from Onondaga Lake and nitrification following Zebra mussel activities near the CUT and other locations. Nitrite concentrations measured in 1999 were similar to those observed in 1998. Nitrite will be included as a dependent model variable in the current QEA modeling program.

E. **Total Phosphorus.** Figures 11-7A and 11-7B shows measured longitudinal patterns of surface and bottom total phosphorus concentrations in 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The total phosphorus concentrations in the Seneca River between Cross Lake and Three Rivers generally range from about 0.06 mg/l to 0.10 mg/l. Concentrations in the Oneida River are generally 0.01 to 0.02 mg/l lower than the Seneca River. Total phosphorus concentrations measured in 1999 were consistent with those observed in 1998. Note the unexpected high scatter in the data. This suggests that it is appropriate to screen the entire database for "outliers" and other inconsistencies prior to modeling or statistical tread analysis. It is recommended that procedures developed by Walker for Onondaga Lake also be used for the River database.

F. **Soluble Reactive Phosphorus.** Figures 11-8A and 11-8B show measured longitudinal patterns of surface and bottom soluble reactive phosphorus (SRP) concentrations in 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The surface and bottom SRP concentrations increase significantly to about 0.04 mg/l between Cross Lake and the Baldwinsville Dam. This suggests that Zebra mussel activities are important factors that accelerate the rate of recycle of biologically available

phosphorus in the River. One goal of Beak 2000a,b studies and the current QEA modeling program is to provide a quantitative understanding of the mechanisms that result in the observed increases in SRP in this section of the River. Soluble phosphorus concentrations measured in 1999 were similar to those observed in 1998.

G. **Chlorophyll *a*.** Figure 11-9A shows composite measurements of chlorophyll *a* in 1999. Figure 11-9B shows separate measured longitudinal patterns of surface and bottom chlorophyll *a* concentrations in 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The 1999 data show that the chlorophyll *a* concentrations leaving Cross Lake drop from about 0.03 mg/l to less than 0.005 mg/l near the Baldwinsville dam. These low chlorophyll *a* concentrations are well below the potential of the system to support algal populations given the high levels of biologically available nutrients and light. This drop is likely the result of Zebra mussel feeding activities. Note that chlorophyll *a* levels also increase somewhat downstream near the Onondaga Lake outlet. One goal of Beak 2000a,b studies and the current QEA modeling program is to provide a quantitative understanding of the mechanisms that result in the observed decreases in chlorophyll *a* in the River. Chlorophyll *a* concentrations and patterns measured in 1999 were similar to those observed in 1998 suggesting that the composite sampling strategy is appropriate.

H. **Turbidity.** Figures 11-10A and 11-10B show measured longitudinal patterns of surface and bottom turbidity in 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The 1999 and 1998 turbidity levels drop significantly from about 10 to 20 NTU at the outlet of Cross Lake to less than 5 NTU at the Three Rivers junction and the Oneida River. This drop is likely related to Zebra mussel feeding on suspended algal cells and is consistent with decreases in measured chlorophyll concentrations.

I. **Conductivity.** Figures 11-11A and 11-11B show measured longitudinal patterns of surface and bottom conductivity in 1998 and 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The 1999 and 1998 conductivity levels are relatively constant between Cross Lake and Baldwinsville. The Onondaga Lake outflow increases the bottom water conductivity by about a factor of 3. The high conductivity Lake water sometimes moves upstream in the bottom waters of the Seneca River. The low conductivity surface waters and the high conductivity bottom waters gradually merge as a result of vertical dispersion as the flow approaches the Three Rivers junction. The low conductivity waters of the Oneida River and the Seneca River combine to form the Oswego River. The conductivity of the Oswego River near Three Rivers is somewhat higher than the conductivity of the Seneca River near Cross Lake due to the overall impact of the Onondaga Lake outlet and the Oneida River. These measured mixing and dilution patterns must be carefully analyzed and modeled prior to the development of a water quality model for the system. Such efforts are currently underway by QEA.

J. **Chloride.** Figure 11-12 shows the measured longitudinal pattern of chloride measured in 1999. The vertical bar and point at each location represent the measured average, minimum and maximum concentrations for the sampled dates. The 1999 chloride levels are relatively constant between Cross Lake and Baldwinsville. The Onondaga Lake outflow increases the bottom water chloride by about a factor of 5. Chloride patterns are similar to those measured for conductivity shown in Figures 11-11 A and B. The measured mixing and dilution patterns of chloride must be carefully analyzed and modeled prior to the development of a water quality model and provide an important complement to the current effort by QEA to model the hydrodynamic and mixing processes in the system.

11.3 ANALYSIS OF LONGITUDINAL VARIATIONS

The purpose of this section is to identify differences in water quality for some important upstream and downstream sections of the Rivers.

Table 11-4 shows average, maximum, and minimum concentrations of several parameters measured in 1999 between Stations 412 (upstream of the CUT) and 334 (downstream of the CUT). Note that the concentrations of chlorophyll *a*, dissolved oxygen, pH, phaeophytin-*a*, total suspended solids, and turbidity are higher upstream of the CUT compared to downstream. On the other hand, the concentrations of ammonia, nitrite, nitrate, soluble reactive phosphorus, and total

dissolved phosphorus are lower upstream of the CUT compared to downstream. All these changes suggest that Zebra mussels are removing phytoplankton and releasing dissolved nutrients. As a consequence dissolved oxygen levels and turbidity decrease.

Table 11-5 shows average, maximum, and minimum concentrations of several parameters measured in 1999 between Stations 316 (upstream of the Baldwinsville WWTP and the Onondaga Lake outlet) and 269 (downstream of the Baldwinsville WWTP and the Onondaga Lake outlet). Note that the concentrations of chlorophyll *a*, conductivity, ammonia, nitrite, nitrate, organic nitrogen, total phosphorus, TKN, total suspended solids, and turbidity are higher downstream of the Baldwinsville WWTP and the Lake outlet compared to concentrations measured at the Baldwinsville Dam.

Table 11-6 shows average, maximum, and minimum concentrations of several parameters measured in 1999 between Stations 178 (upstream of the Oak Orchard WWTP) and 197 (downstream of the Oak Orchard WWTP). Note that the concentrations of nitrate, soluble reactive phosphorus, total phosphorus, and total dissolved phosphorus are similar downstream of the Oak Orchard WWTP compared to the upstream measurements at Station 178. This suggests that the Oak Orchard WWTP has relatively little impact on the River although more comprehensive analysis must be performed by QEA.

Table 11-7 shows average, maximum, and minimum concentrations of several parameters measured in 1999 between Stations 260 (upstream of the Wetzel Road WWTP) and 255 (downstream of the Wetzel Road WWTP). Note that measured changes in most parameters are mostly small or inconsistent. This suggests that the Wetzel Road WWTP has relatively little impact on the River although more comprehensive analysis must be performed by QEA.

The bar graphs in Figure 11-13 show changes in various parameters measured at the Baldwinsville dam between 1990 and 1999. The County data collected since 1994 show a consistent pattern of change compared to 1990 and 1991. The River was transformed from one with high chlorophyll and turbidity and low dissolved nutrients to one with low chlorophyll and turbidity and high dissolved nutrients. It has been generally assumed that these changes are the result of the observed zebra mussel invasion that occurred between 1991 and 1993. The main goal of Beak 2000a,b studies and the current QEA modeling program is to provide a quantitative understanding of the mechanisms and consequences of these dramatic transformations.

11.4 ANALYSIS OF ASSIMILATIVE CAPACITY

The assimilative capacity of the Seneca River in 1991 (before the Zebra mussel invasion) was calculated using a water quality model published by Canale et al., 1995. The model is based on mass balance equations for dissolved oxygen that can be expressed in the form:

Oxygen Accumulation = Reaeration + Photosynthesis - Respiration - CBOD Oxidation - NBOD Oxidation - Sediment Oxygen Demand + Oxygen Inputs + Oxygen Transport Equation 1

The validity of Equation 1 and the accuracy of the model inputs and coefficients were evaluated using data collected in 1991 before the Zebra mussel invasion. The following discussion examines Equation 1 for the purpose of estimating possible changes caused by the Zebra mussel invasion and describe the changes and improvements in the implementation of Equation 1 by the current modeling effort by QEA. The discussion assumes that temperature, sunlight, flow rates, and reaeration are unchanged from the 1991 analysis.

A. Upstream Boundary. Equation 1 requires the input of upstream boundary concentrations before it can be solved for the spatial and temporal variations of dissolved oxygen in the River. The Canale et al., 1995 model uses data from Station 316 near the Baldwinsville Dam to establish values for the upstream boundary concentrations. The new model being developed by QEA expands the range of the model will use data collected at station 412 near the Cross Lake outlet for the upstream boundary.

B. Algal Photosynthesis and Respiration. The model term for algal photosynthesis and respiration in Equation 1 can be expressed in the form:

$$P_{net} \quad \{P_{max} \times \frac{I}{I + K_I} \times \frac{SRP}{SRP + K_p} - R\} \times CHL \qquad \text{Equation 2}$$

Where P_{net} is the net chlorophyll specific photosynthesis rate ($mgO_2/\mu gChl/day$), P_{max} is the maximum net chlorophyll specific photosynthesis rate (0.60 $mgO_2/\mu gChl/day$), I is the average light intensity over the water column ($\mu E/m^2/s$), K_I is the light saturation coefficient (180 $\mu E/m^2/s$), SRP is the concentration of soluble reactive phosphorus ($\mu g/l$), K_P is the phosphorus saturation coefficient (0.7 $\mu g/l$), R is the chlorophyll specific algal respiration rate (0.04 $mgO_2/\mu gChl/day$), and CHL is the concentration of chlorophyll *a* ($\mu g/l$). The above coefficient values were estimated by Canale et al., 1995.

Preliminary analysis has shown that the Zebra mussels may decrease the assimilative capacity of the River by reducing algal production of oxygen in the surface waters. However, Zebra mussels also lower bottom water algal respiration, which increases the assimilative capacity of the River. The balance of these two factors is related to River geometry and mixing processes and is being determined by QEA by implementing full-scale model calculations. It is also important to note that the QEA modeling effort will treat chlorophyll and SRP as dependent model variables. This is a significant improvement in the model structure that was made possible by the County River monitoring program conducted since 1994.

C. CBOD Oxidation Rate. The model term for CBOD oxidation is given by - k_d (CBOD), where k_d is the CBOD decay rate coefficient (1/day). The 1994 through 1999 monitoring data show that CBOD concentrations may have increased in the system following the Zebra mussel invasion. Furthermore, it is likely that k_d has also increased because dissolved nutrient concentrations have increased and perhaps because the refractory nature of the organic carbon has decreased. However, light penetration has also increased in the River following the Zebra mussel invasion, which may lower k_d. At this time, the County is conducting laboratory studies to measure k_d directly using Seneca River water.

D. NBOD Oxidation Rate. The model term for NBOD oxidation is given by - k_n (NBOD), where k_n is the NBOD decay rate coefficient (1/day). The 1994 through 1999 monitoring data show that NBOD concentrations may have increased in the system following the Zebra mussel invasion. Furthermore, it is likely that k_n has also increased because dissolved nutrient concentrations have increased, and perhaps because the refractory nature of the organic nitrogen has decreased. However, light penetration has also increased in the River following the Zebra mussel invasion, which may lower k_n. At this time, the County is conducting laboratory studies to measure k_n directly using Seneca River water.

E. Sediment Oxygen Demand. Canale et al., 1995 reported SOD values between 1.0 and 3.0 $mg/m^2/day$ for the River before the Zebra mussel invasion. Zebra mussel feeding activities produce an organic pseudofeces that may increase the SOD and therefore decrease the assimilative capacity of the River. Beak is currently conducting studies to measure SOD in the River. These studies should provide data that will be used in the model being developed by QEA

F. Zebra Mussel Respiration. Effler et al., 1995 have determined that Zebra mussel respiration rates (ZOD) are a function of individual size, age distributions, as well as the population density. Estimated Zebra mussel populations in the Seneca River CUT resulted in a ZOD of approximately 34 $mg/m^2/day$. This value is significantly higher than measured the SOD of organic sediments. Thus, Zebra mussels have the potential to dramatically reduce the assimilative capacity of the River. The distribution of Zebra mussels both inside and outside the CUT has been measured by Beak in 1999. In addition laboratory studies are being conducted by Beak to measure the respiration, filtering and ammonia release rates as a function of temperature and size-class. This information will be used in the new model.

11.5 CONCLUSIONS AND RECOMMENDATIONS

The monitoring data and analyses presented in this section of the report suggest the following conclusions and recommendations:

Water quality conditions and the assimilative capacity of the Three Rivers system remain significantly affected by Zebra mussel activities, the Onondaga Lake outlet, and to a lesser extent, the WWTP facilities at Baldwinsville, Wetzel Road, and Oak Orchard.

2. The monitoring data show that under current point source loading conditions, the Seneca River may violate dissolved oxygen, ammonia, and nitrite NYS water quality standards.

3. The existing water quality model for the River, as developed by Canale et al. 1995, is being updated and validated by QEA using water quality data collected since 1994. The new model is expected to be able to reliably calculate the assimilative capacity of the Rivers and predict changes in water quality that might result from a diversion of METRO or changes in the NPDES permits for the Baldwinsville and Oak Orchard WWTPs. This is because the eutrophication and other kinetic mechanisms in the model are being developed and calibrated for periods both before and after the Zebra mussel invasion of the system. The basic hydrodynamic and mixing components of the existing River model are being improved and quantified. Also the inflows and water quality of Onondaga Lake affect the assimilative capacity of the River. If the location or quality of the METRO effluent is changed, water quality conditions in Onondaga Lake will change. The new QEA model is expected to link directly water quality models for Onondaga Lake and the River.

4 The County has conducted a comprehensive monitoring program that is well suited to support these new modeling efforts. New information has been collected by Beak to define the Zebra mussel population density, size-distribution, feeding activity, and respiration rates. A survey has conducted to characterize the organic content and the SOD of sediments in the River system. The County is conducting laboratory studies to improve estimates of organic oxidation in the system. It is recommended that the County continue to work with the QEA modeling team to support the model development effort.

5 Statistical analyses should be performed to screen and remove aberrant data from the Three Rivers database.

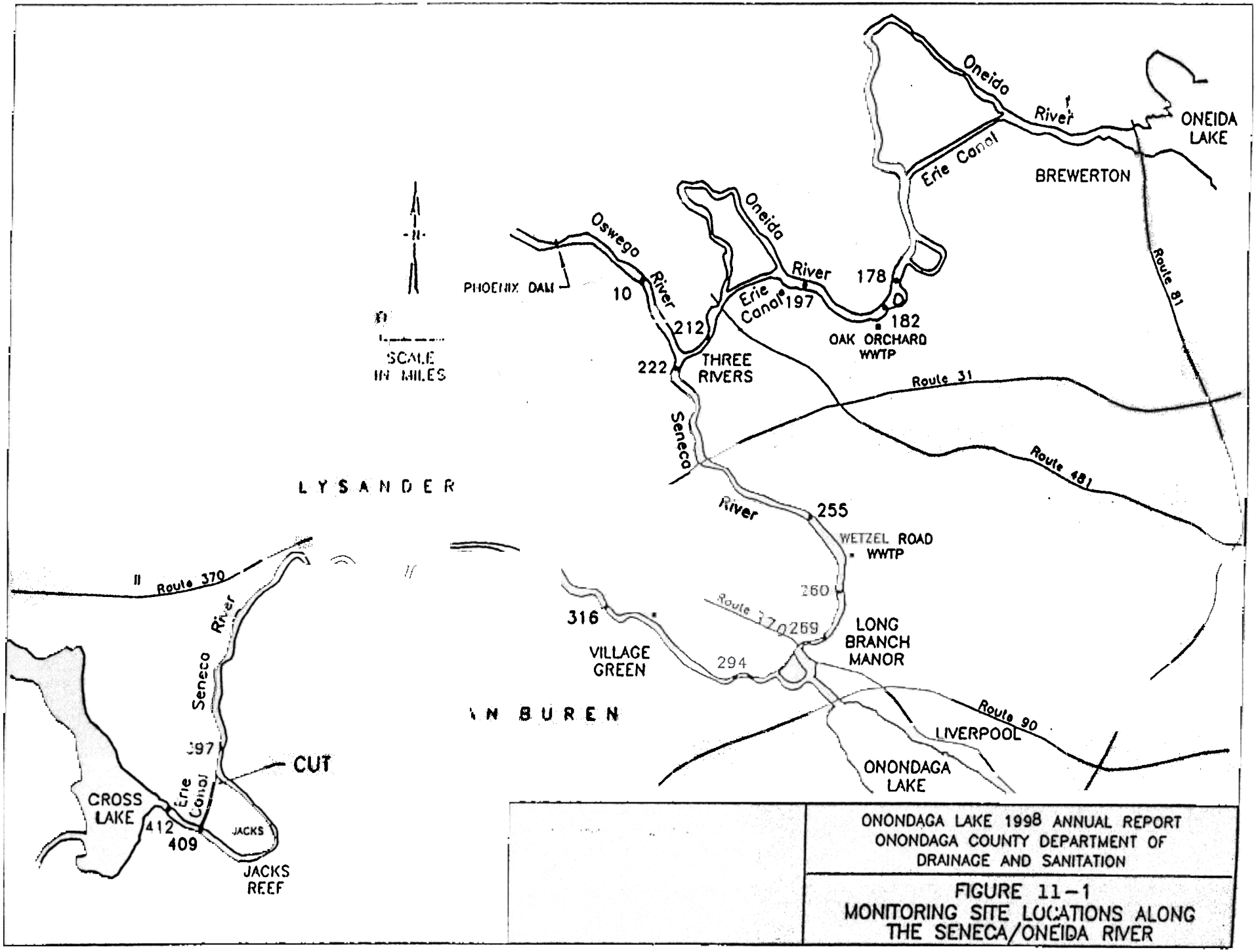
11.6 REFERENCES

Canale, R.P. et al., "Validation of Water-Quality Model for the Seneca River, New York," Journal of Water Resources Planning and Management. Volume 12, No. 3, May/June 1995.

Effler, S.W. and C. Siegfried, "Zebra Mussel Populations in the Seneca River, New York: Impact on Oxygen Resources," Environmental Science and Technology, Volume 28, No. 12, 1994.

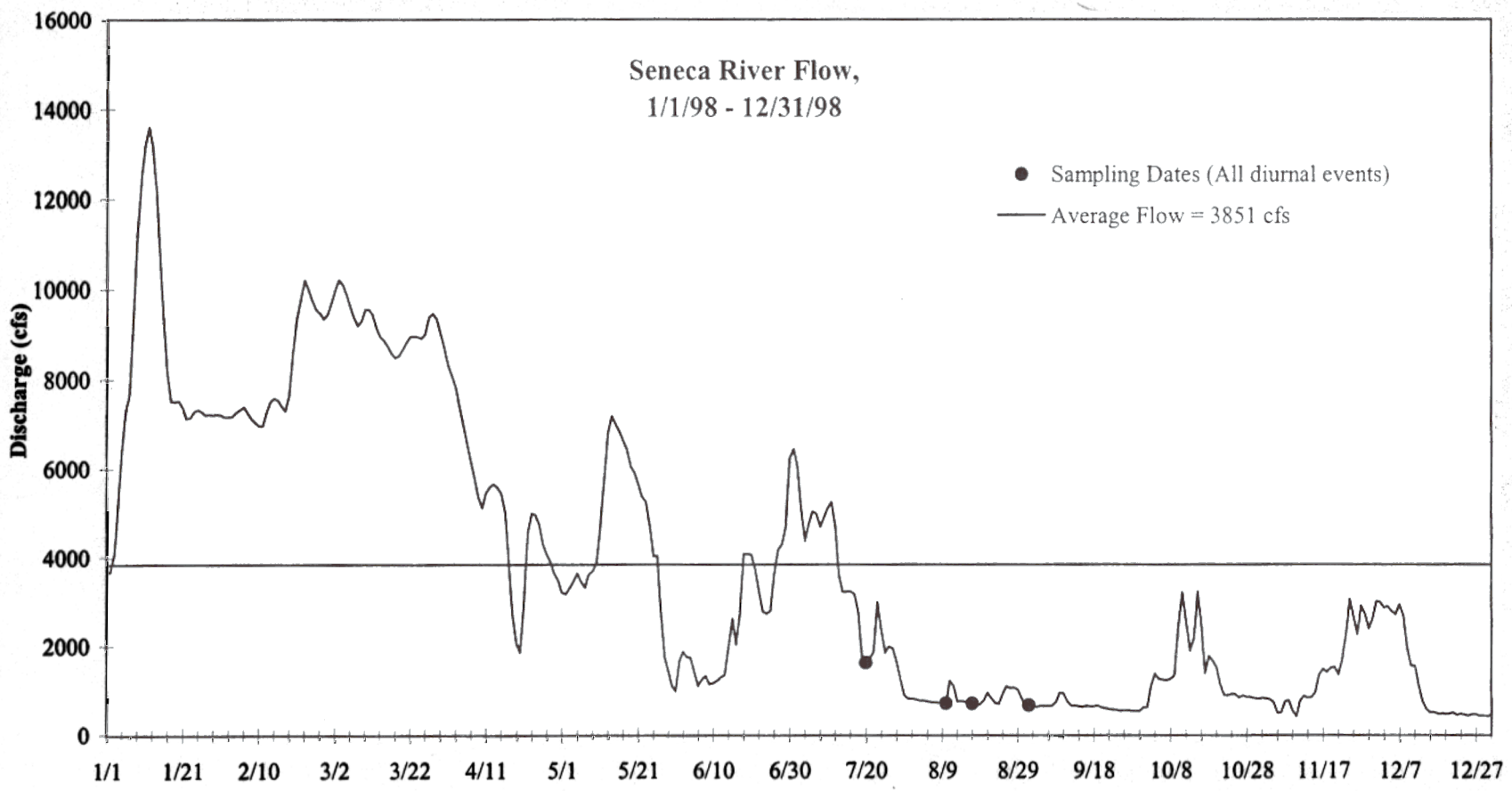
Effler, S.W. et al., "Impact of Zebra Mussel Invasion on River Water Quality," Water Environment Research, Volume 68, No. 2, March/April 1996.

Onondaga Lake Monitoring Program - 1996 Annual Report, prepared by Stearns & Wheler, LLC, October 1998



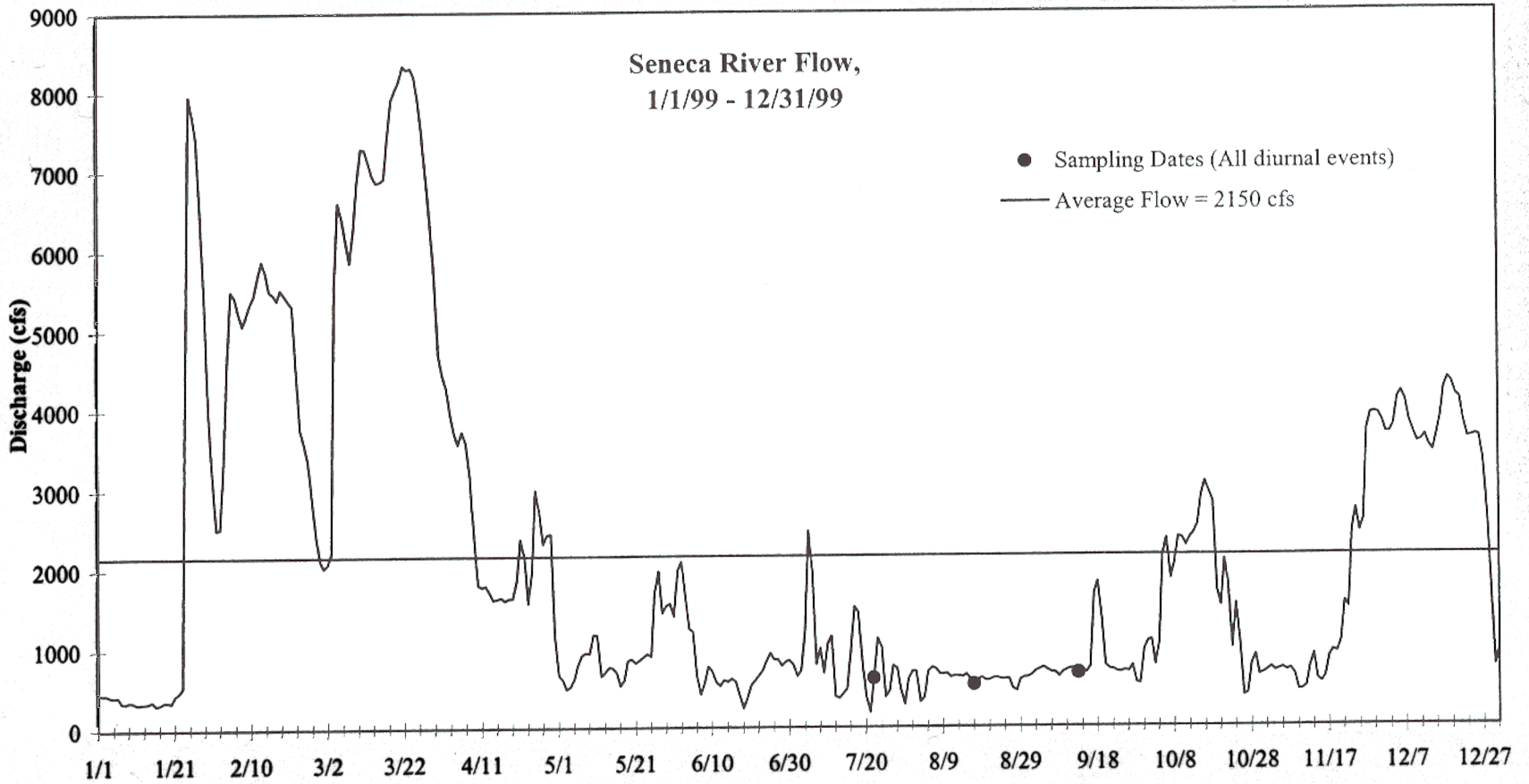
ONONDAGA LAKE 1998 ANNUAL REPORT
ONONDAGA COUNTY DEPARTMENT OF DRAINAGE AND SANITATION

FIGURE 11-1
MONITORING SITE LOCATIONS ALONG THE SENECA/ONEIDA RIVER



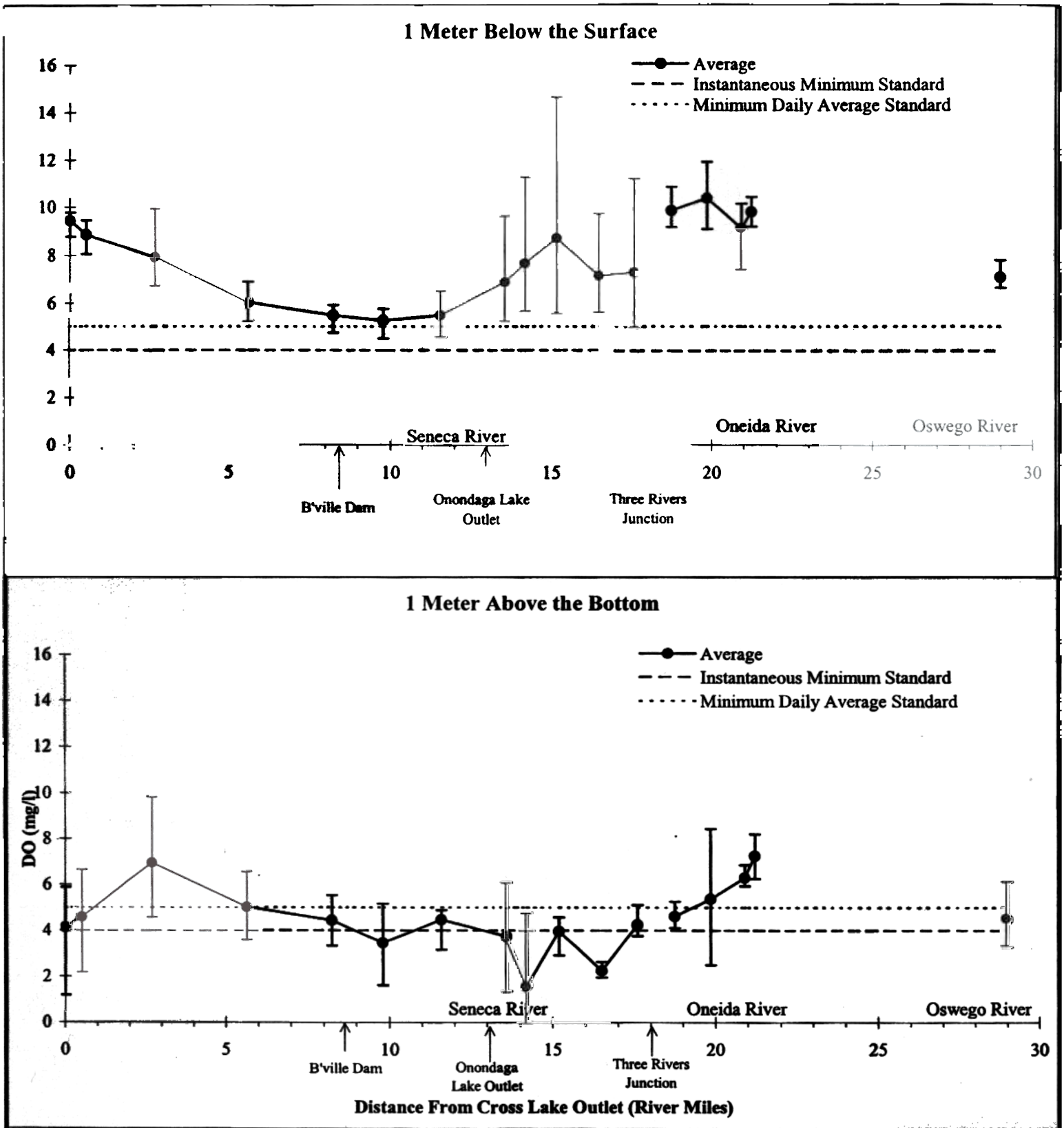
Average flow based on data from January 1 - December 31, 1998.

FIGURE 11-2 SENECA RIVER FINALIZED FLOWS RECORDED AT USGS GAGING STATION AT BALDWINSVILLE, NY, 1/1/98 -12/31/98



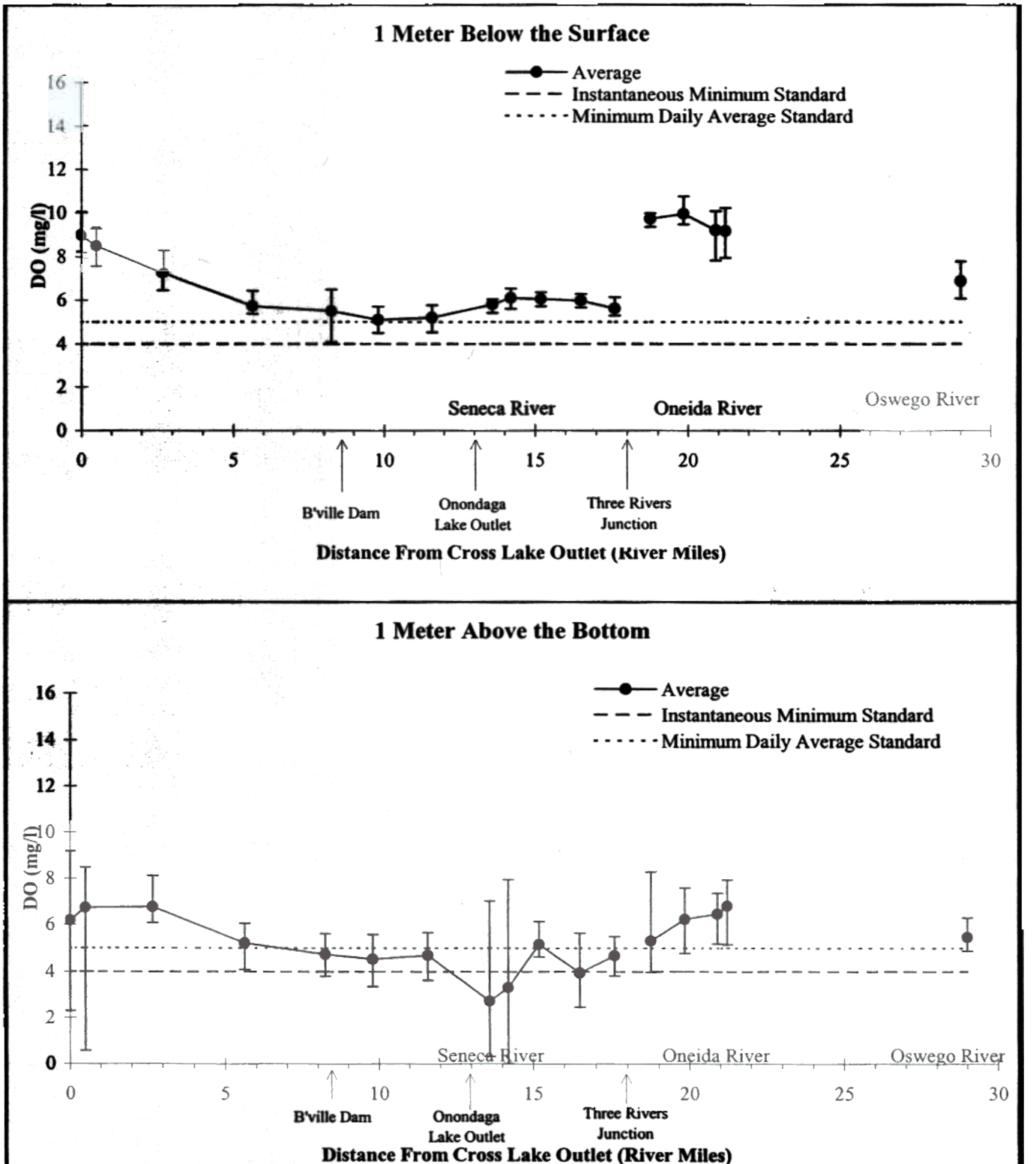
Average flow based on data from January 1 - December 31, 1999 (the range of dates currently available from the USGS).

FIGURE 11-3 SENECA RIVER FINALIZED FLOWS (1/1/99 - 9/30/99) AND PROVISIONAL FLOWS (10/1/99 - 12/31/99) RECORDED AT USGS GAGING STATION AT BALDWINSVILLE, NY.



1999 Seneca, Oneida, and Oswego River data include 3 events on July 22, August 17, and September 13, 1999.

FIGURE 11-4A AVERAGE AND RANGE OF DISSOLVED OXYGEN OBSERVED DURING THE 1999 MONITORING OF THE SENECA AND ONEIDA RIVERS.



1998 Seneca, Oneida, and Oswego River data include 4 events on July 20, August 10 and 17, and September 1, 1998.

FIGURE 11-4B AVERAGE AND RANGE OF DISSOLVED OXYGEN OBSERVED DURING THE 1998 MONITORING OF THE SENECA AND ONEIDA RIVERS.

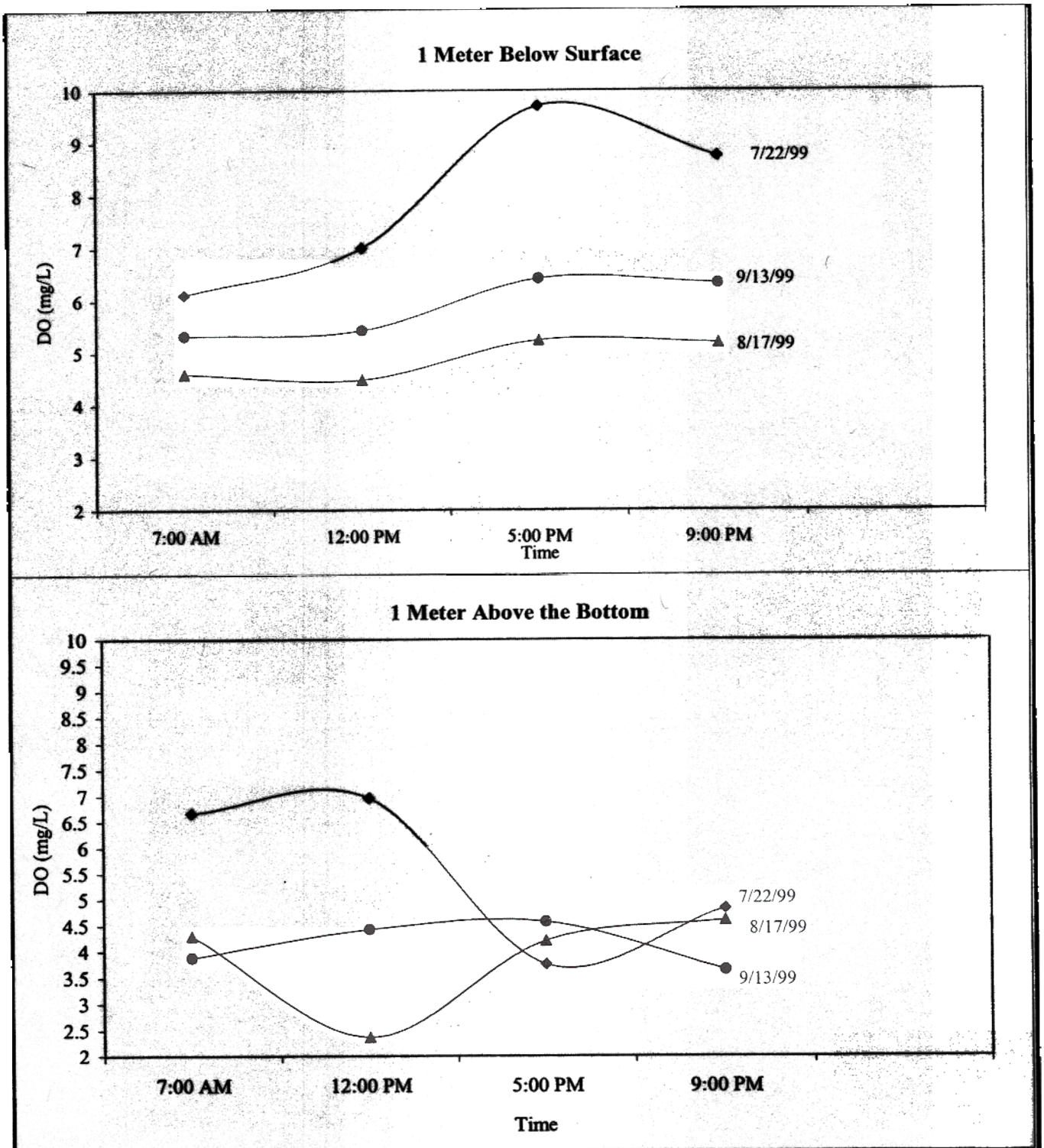
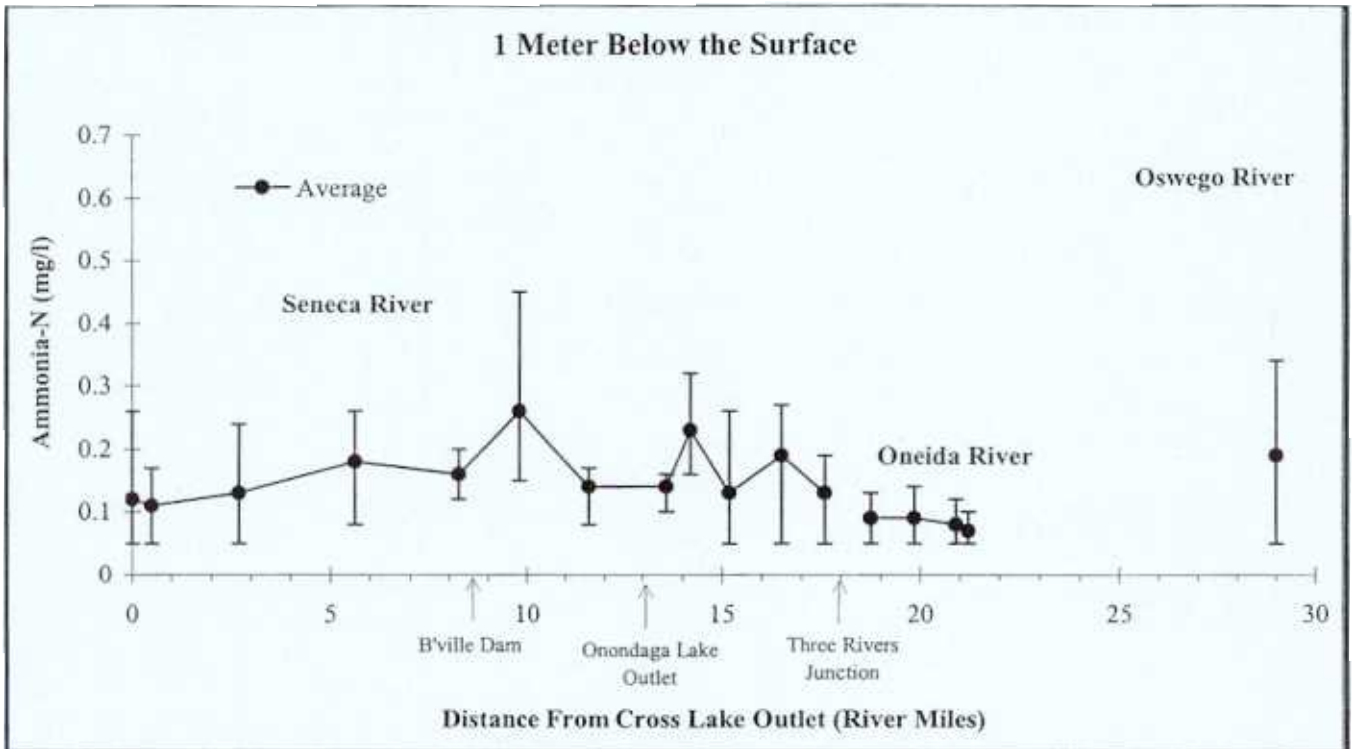
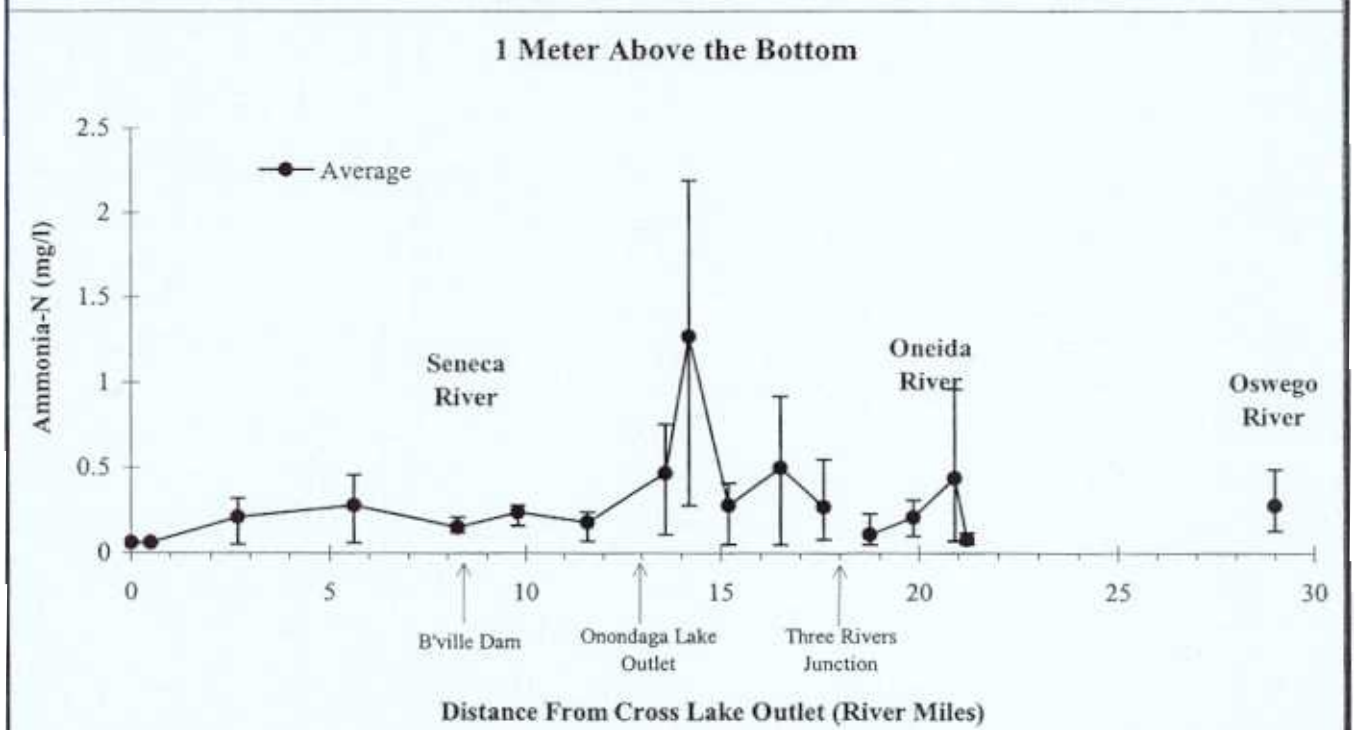


FIGURE 11-4C DISSOLVED OXYGEN OSERVATIONS DURING DIURNAL SAMPLING, JULY 22, AUGUST 17, AND SEPTEMBER 13, 1999 AT BUOY 294

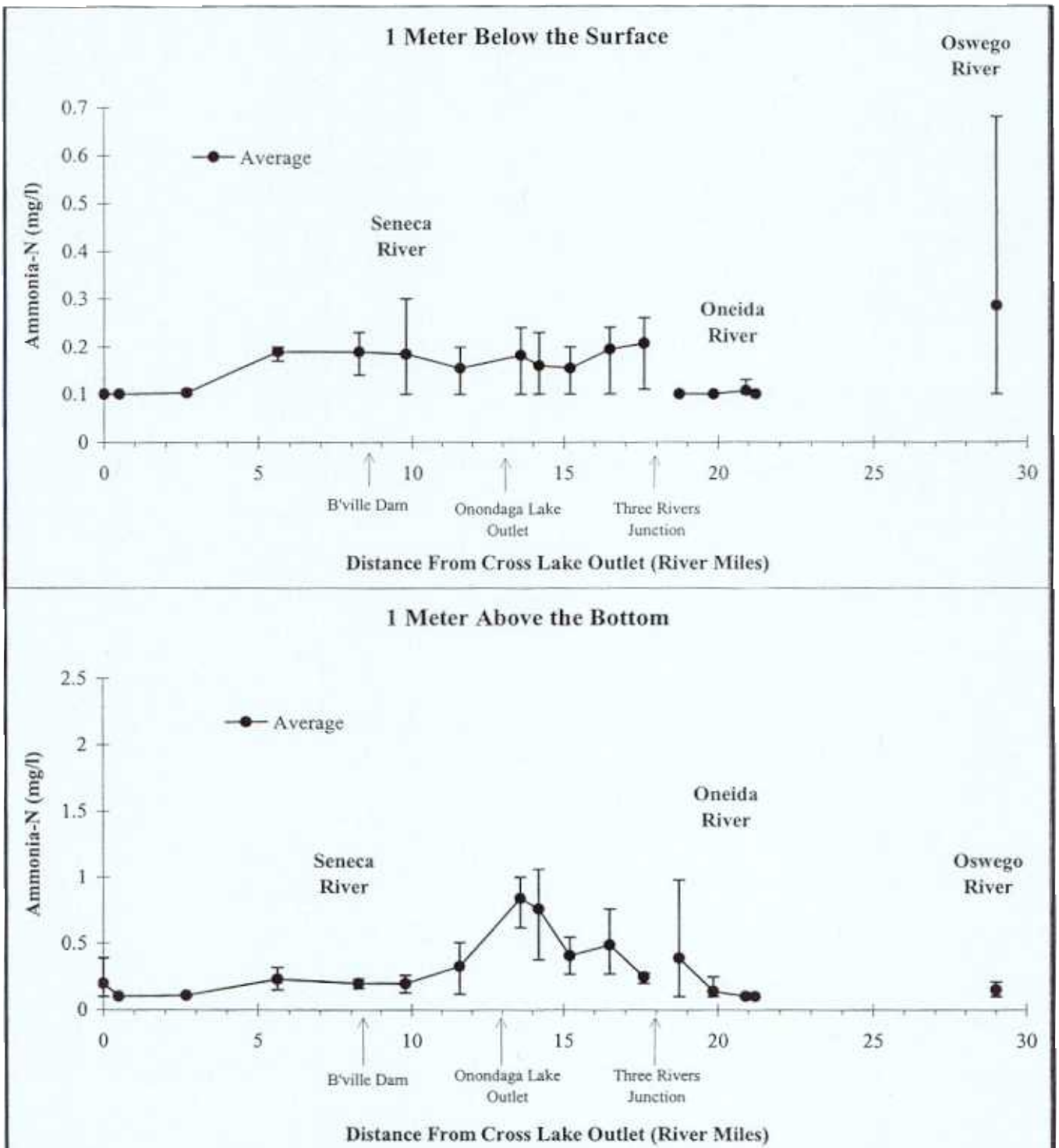




1999 Seneca, Oneida, and Oswego River data include 3 events on July 22, August 17, and September 13, 1999.

FIGURE 11-5A AVERAGE AND RANGE OF AMMONIA-N OBSERVED DURING THE **1999** MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS

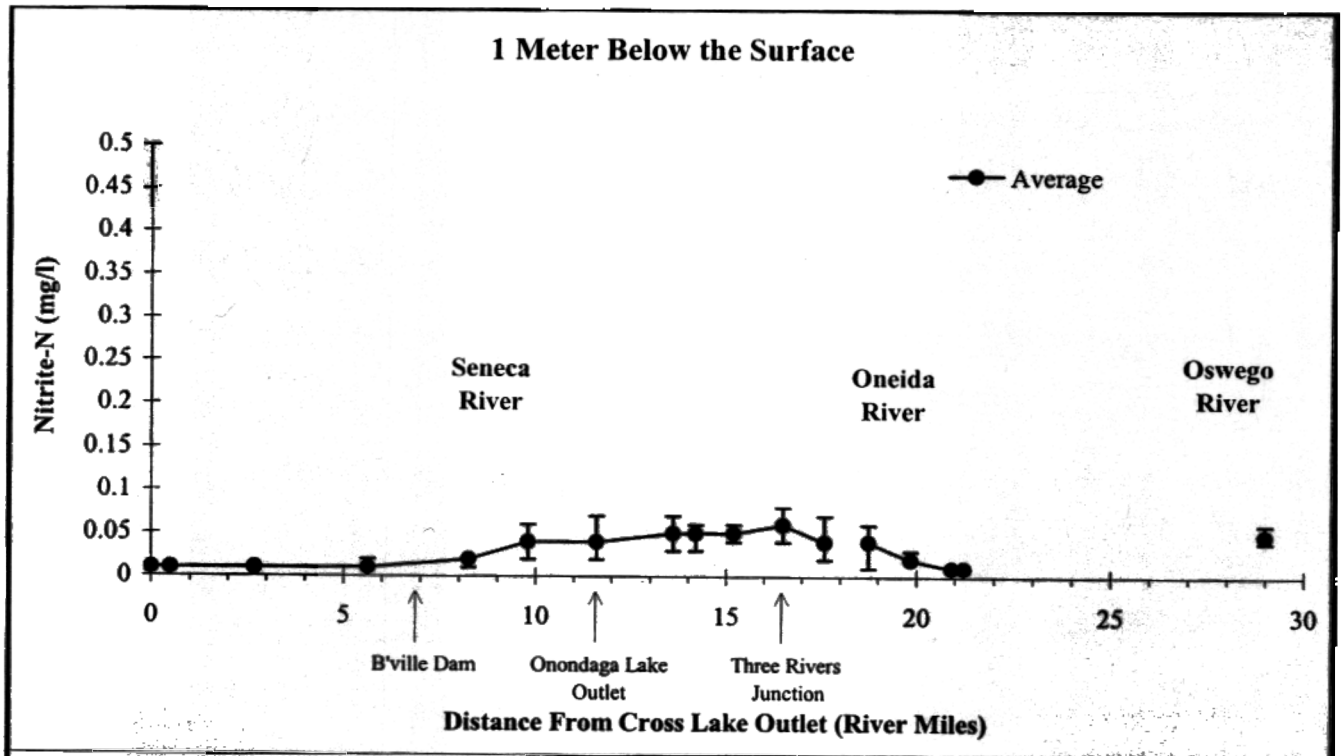
5-nh3_99/1999 plot

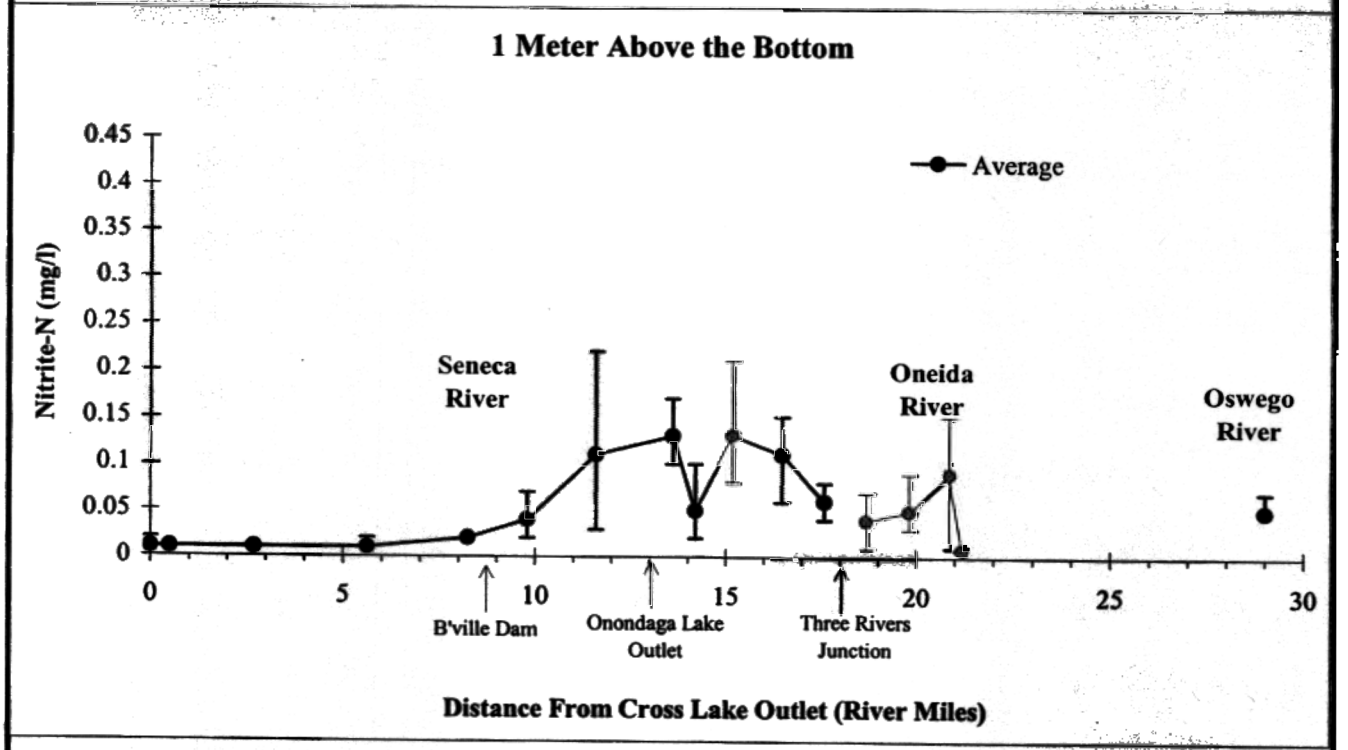


1998 Seneca, Oneida, and Oswego River data include 4 events on June 20, August 10 and 17, and September 1, 1998.

FIGURE 11-5B AVERAGE AND RANGE OF AMMONIA-N OBSERVED DURING THE **1998** MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS

5-nh3_99/1998 plot

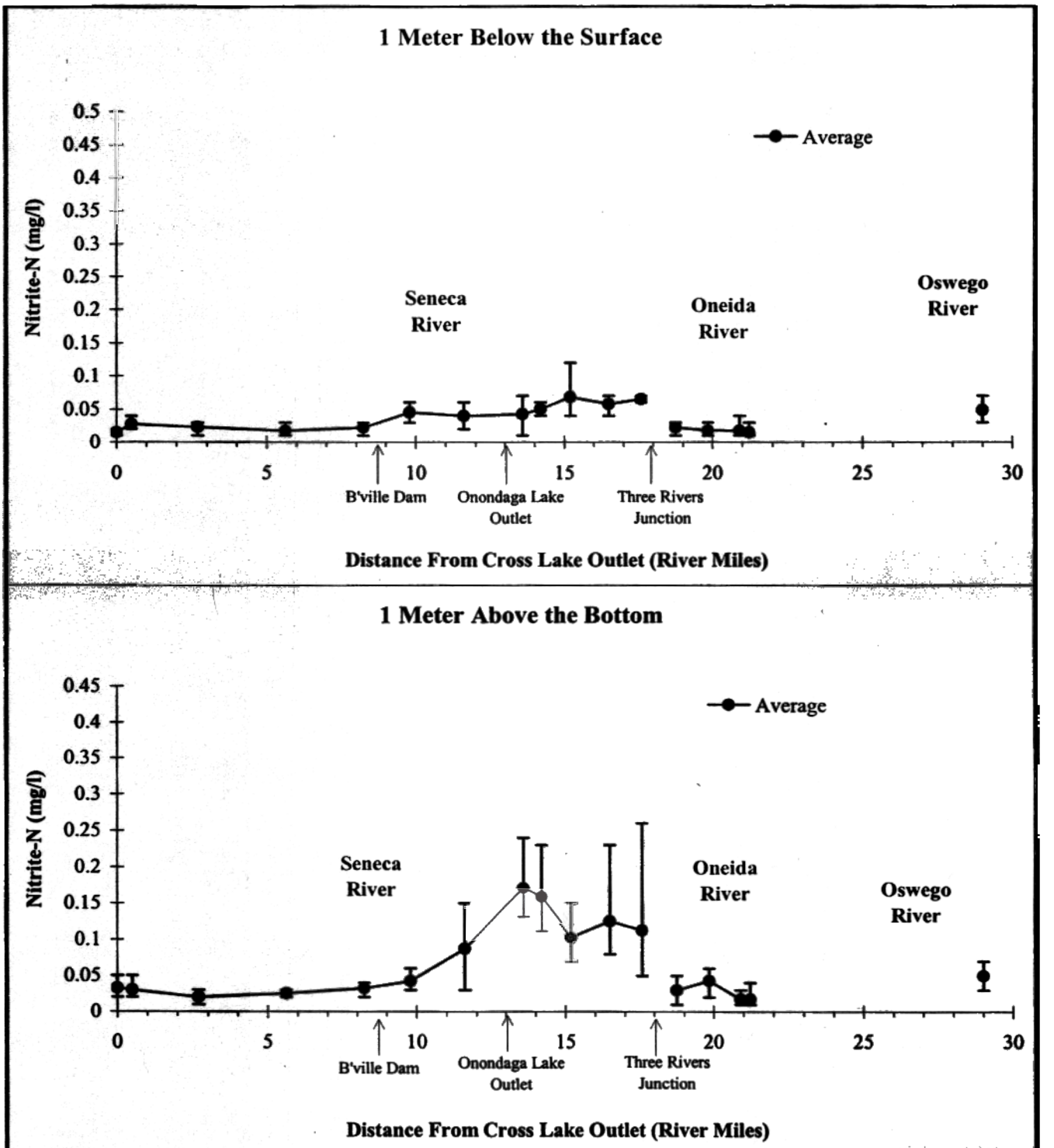




1999 Seneca, Oneida and Oswego River data include 3 events on July 22, August 17, and September 19, 1999.

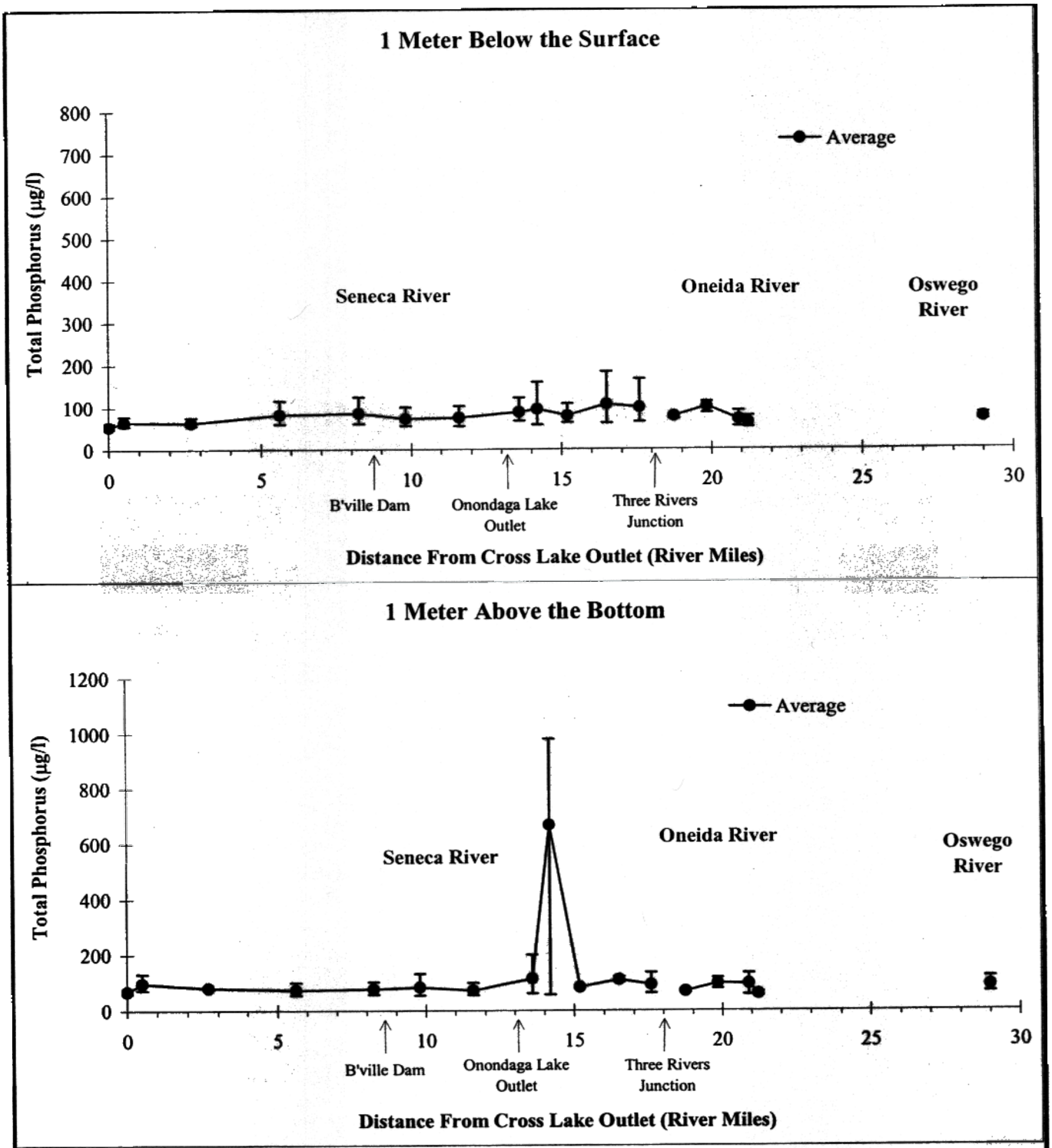
FIGURE 11-6A AVERAGE AND RANGE OF NITRITE-N OBSERVED DURING THE 1999 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS

6-no2_99/1999 plot



1998 Seneca, Oneida and Oswego River data include 4 events on July 20, August 10 and 17, and September 1, 1998.

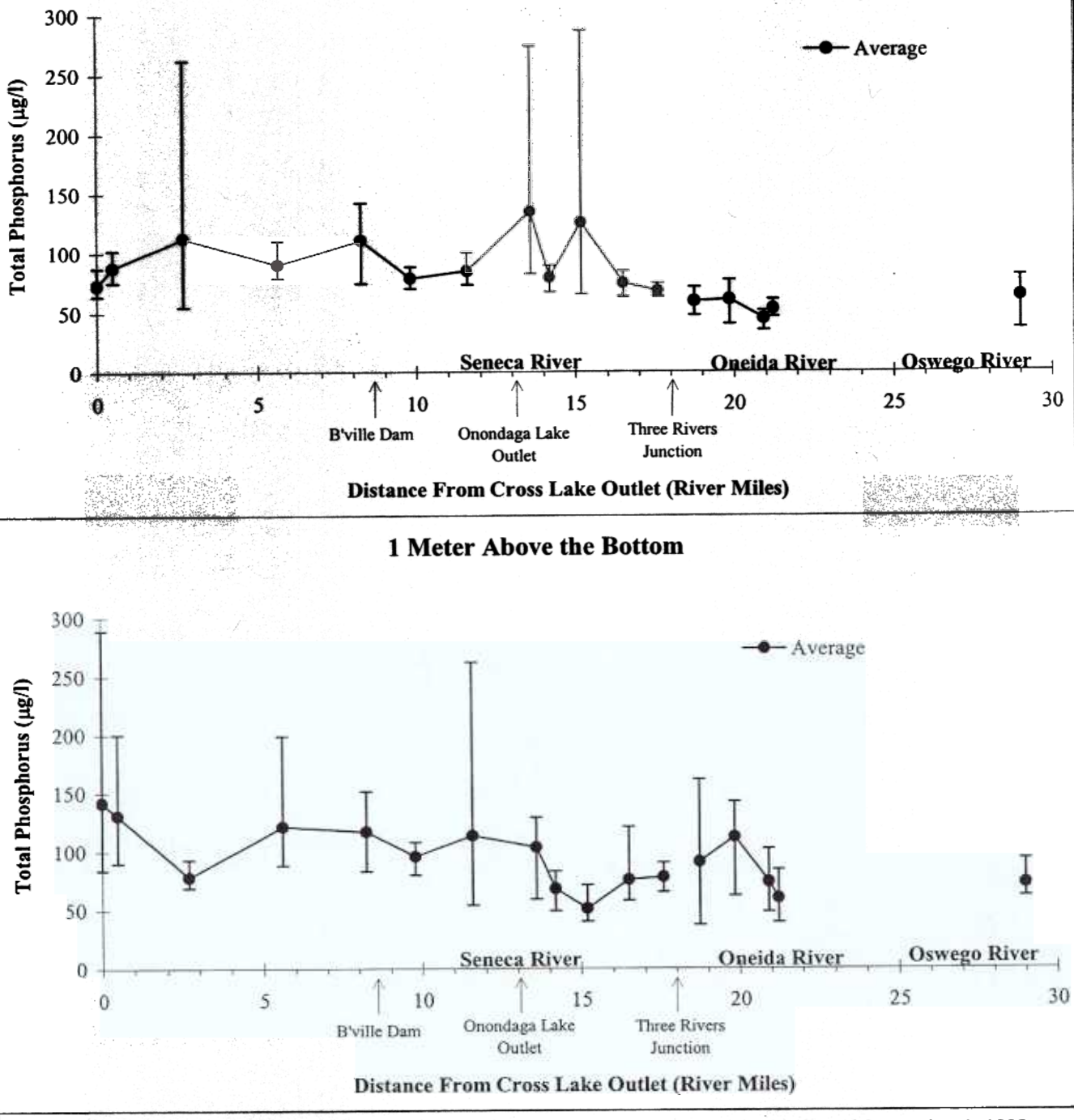
FIGURE 11-6B AVERAGE AND RANGE OF NITRITE-N OBSERVED DURING THE 1998 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS



1999 Seneca, Oneida, and Oswego River data include 3 events on July 22, August 17, and September 13, 1999.

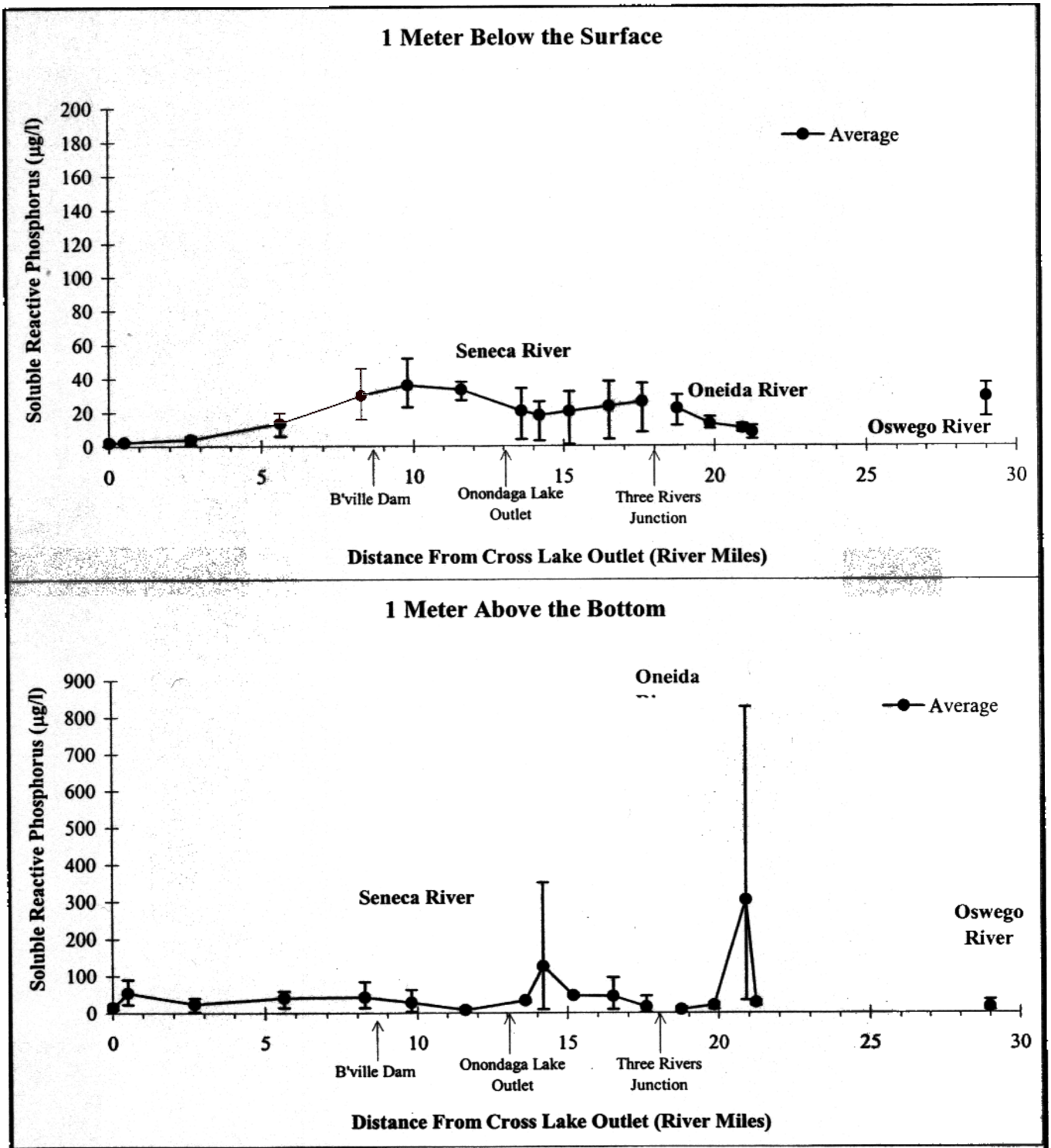
FIGURE 11-7A AVERAGE AND RANGE OF TOTAL PHOSPHORUS OBSERVED DURING THE 1999 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS

7-tp_99/1999 plot



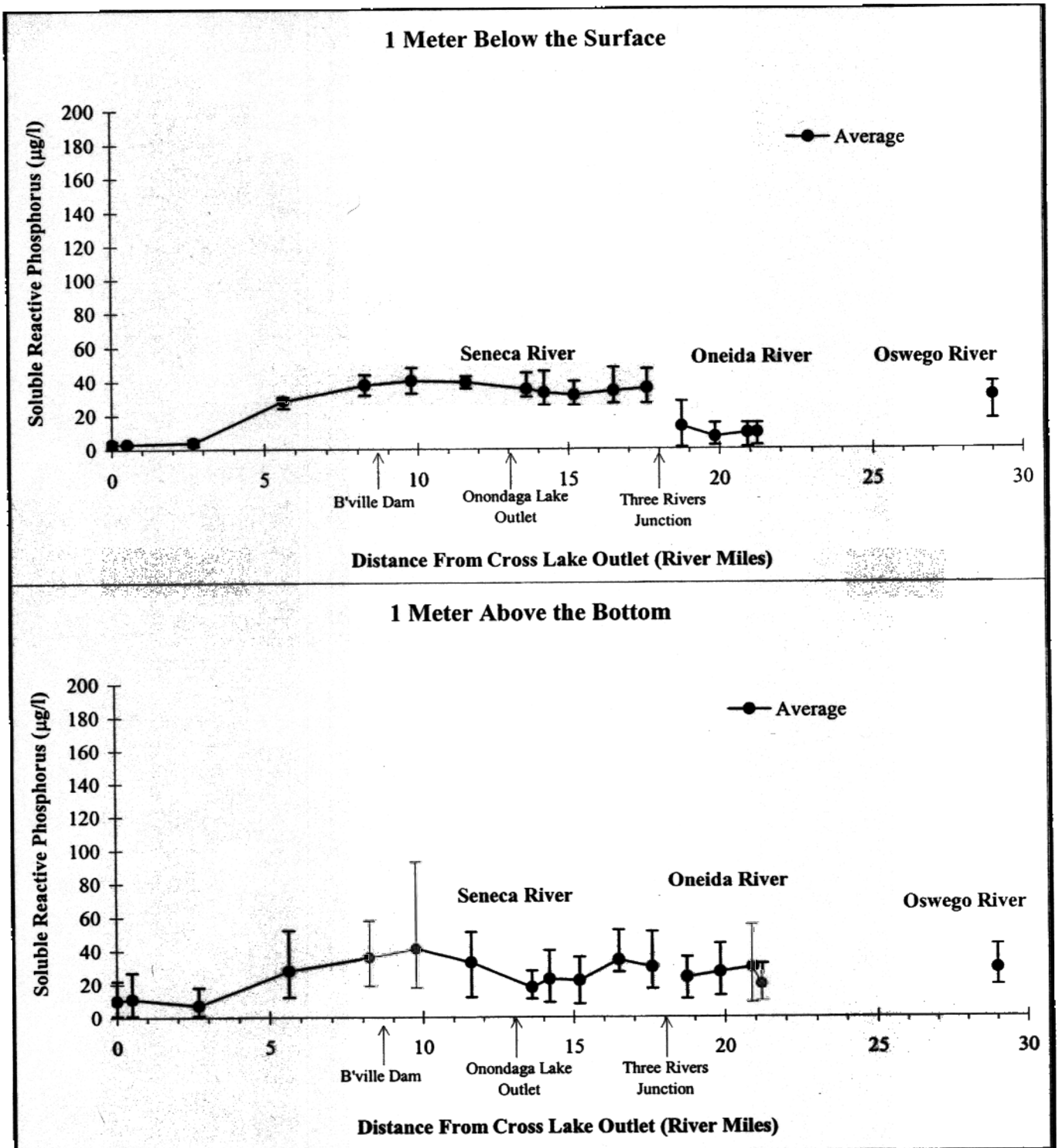
1998 Seneca, Oneida, and Oswego River data include 4 events on July 20, August 10 and 17, and September 1, 1998.

FIGURE 11-7B AVERAGE AND RANGE OF TOTAL PHOSPHORUS OBSERVED DURING THE 1998 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS



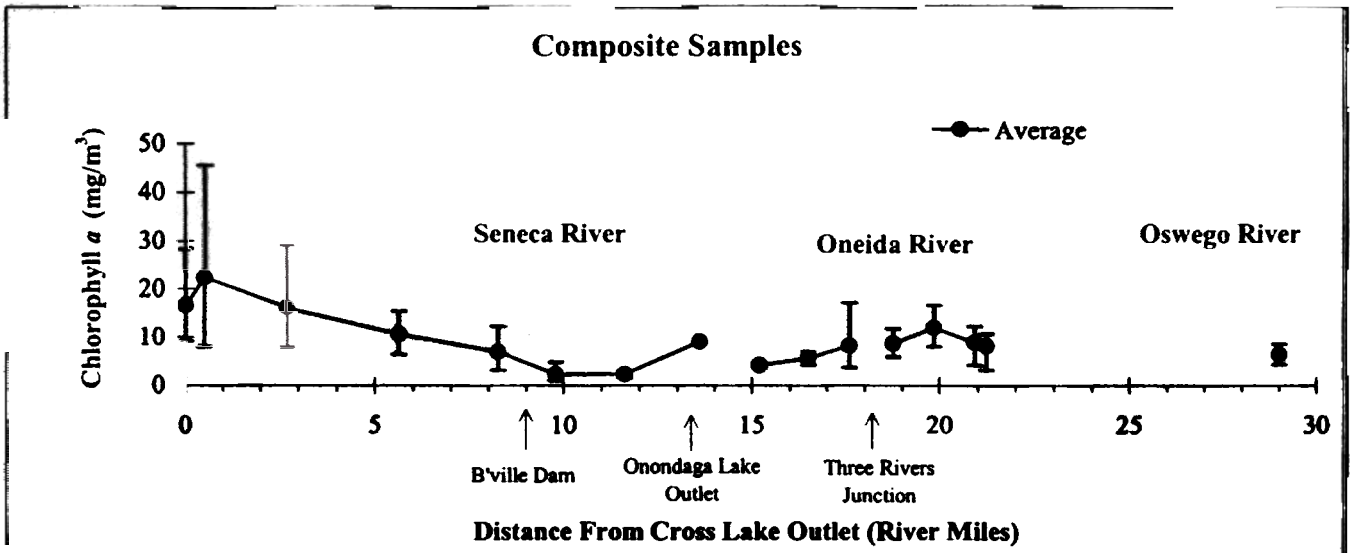
1999 Seneca , Oswego, and Oneida River data include 3 events July 22, August 17, and September 13, 1999.

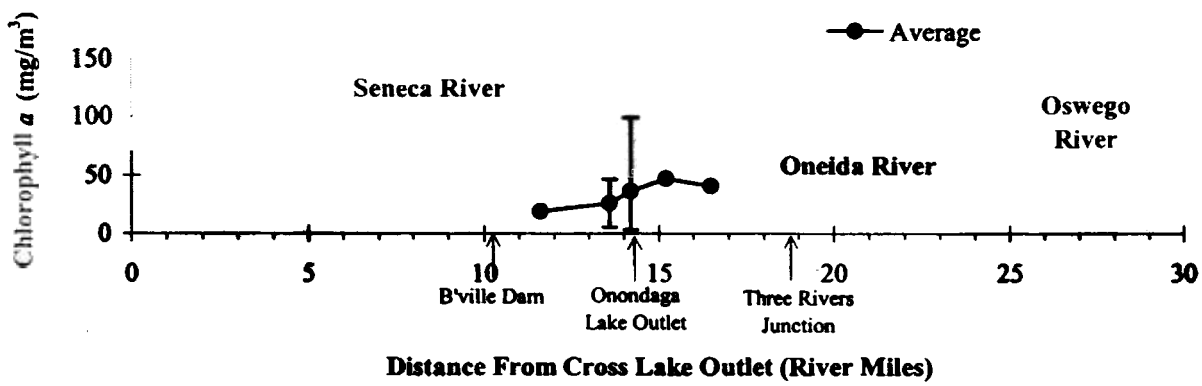
FIGURE 11-8A AVERAGE AND RANGE OF SOLUBLE REACTIVE PHOSPHORUS OBSERVED DURING THE 1999 MONITORING OF THE SENECA,OSWEGO, AND ONEIDA RIVERS

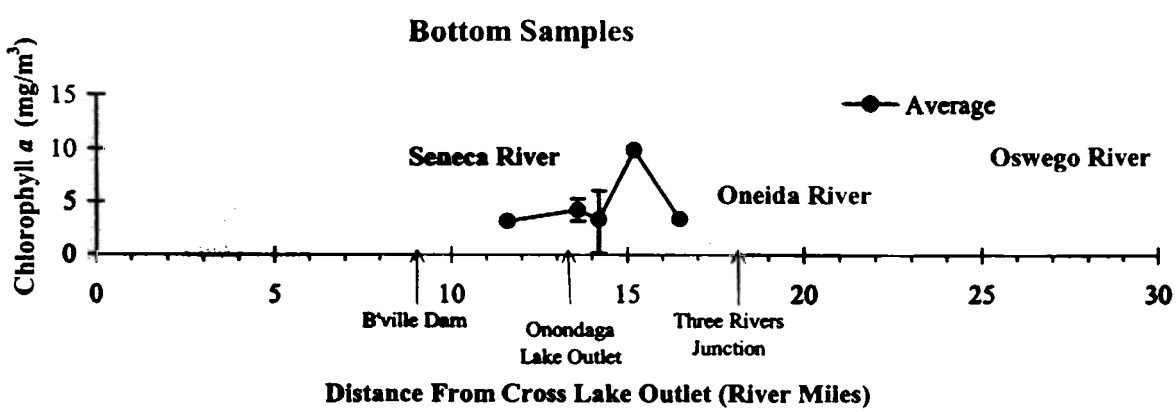


1998 Seneca , Oswego, and Oneida River data include 4 events July 20, August 10 and 17, and September 1, 1998.

FIGURE 11-8B AVERAGE AND RANGE OF SOLUBLE REACTIVE PHOSPHORUS OBSERVED DURING THE **1998** MONITORING OF THE SENECA,OSWEGO, AND ONEIDA RIVERS



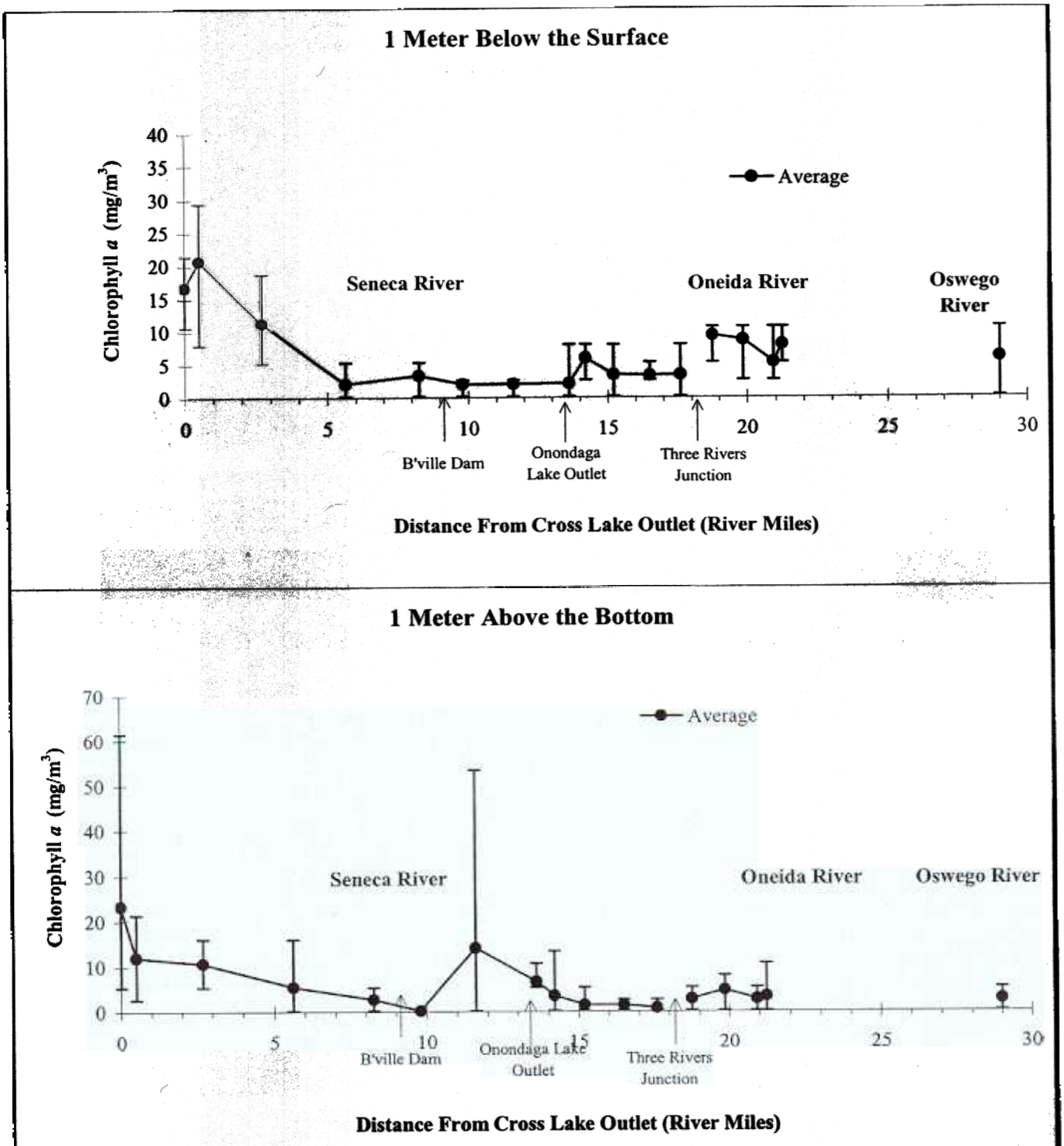




1999 Seneca, Oneida and Oswego River data include 3 events on July 22, August 17, and September 13, 1999.

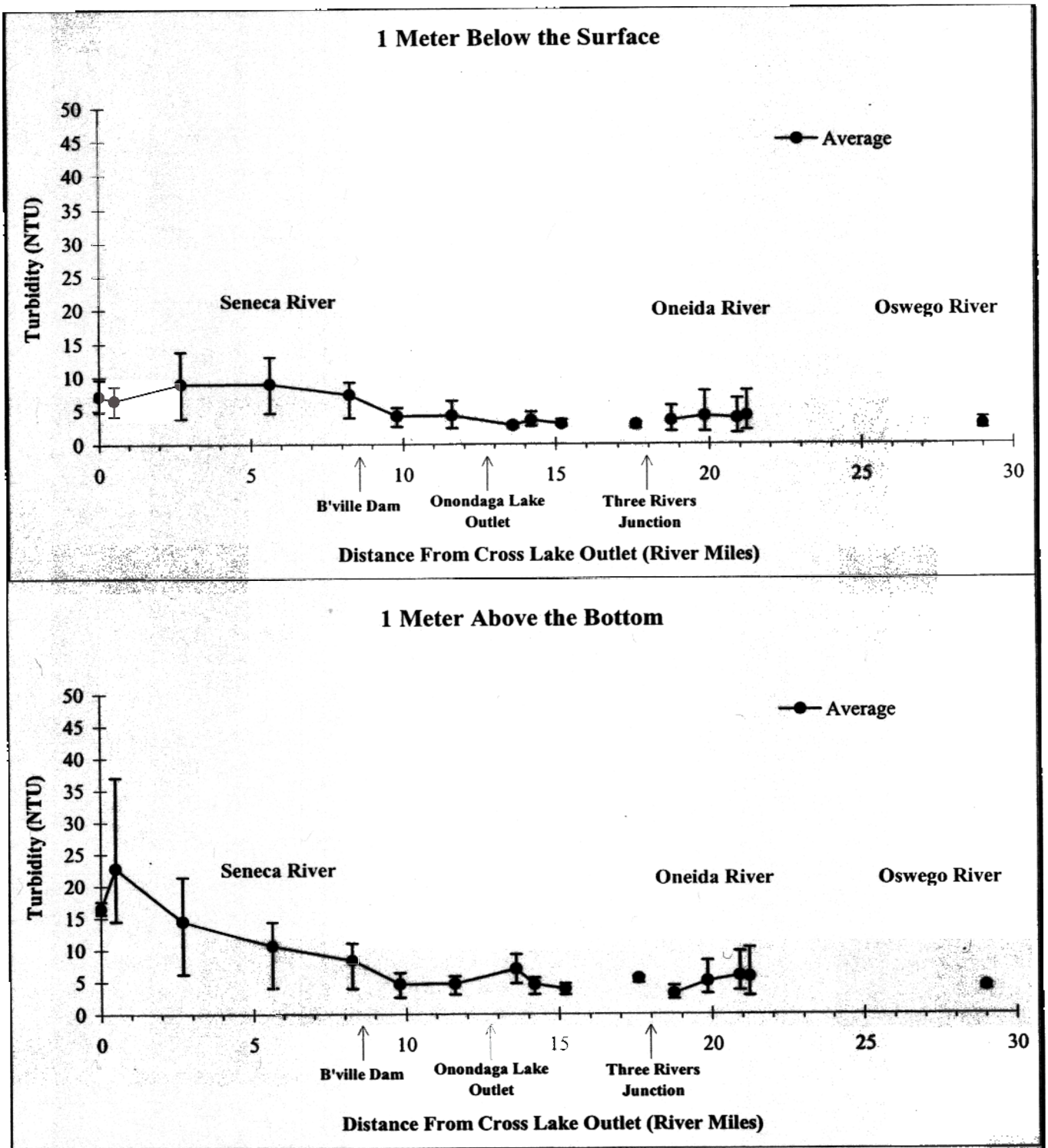
FIGURE 11-9A AVERAGE AND RANGE OF CHLOROPHYLL *a* OBSERVED DURING THE 1999 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS

9-CHLA_99/1999 plot



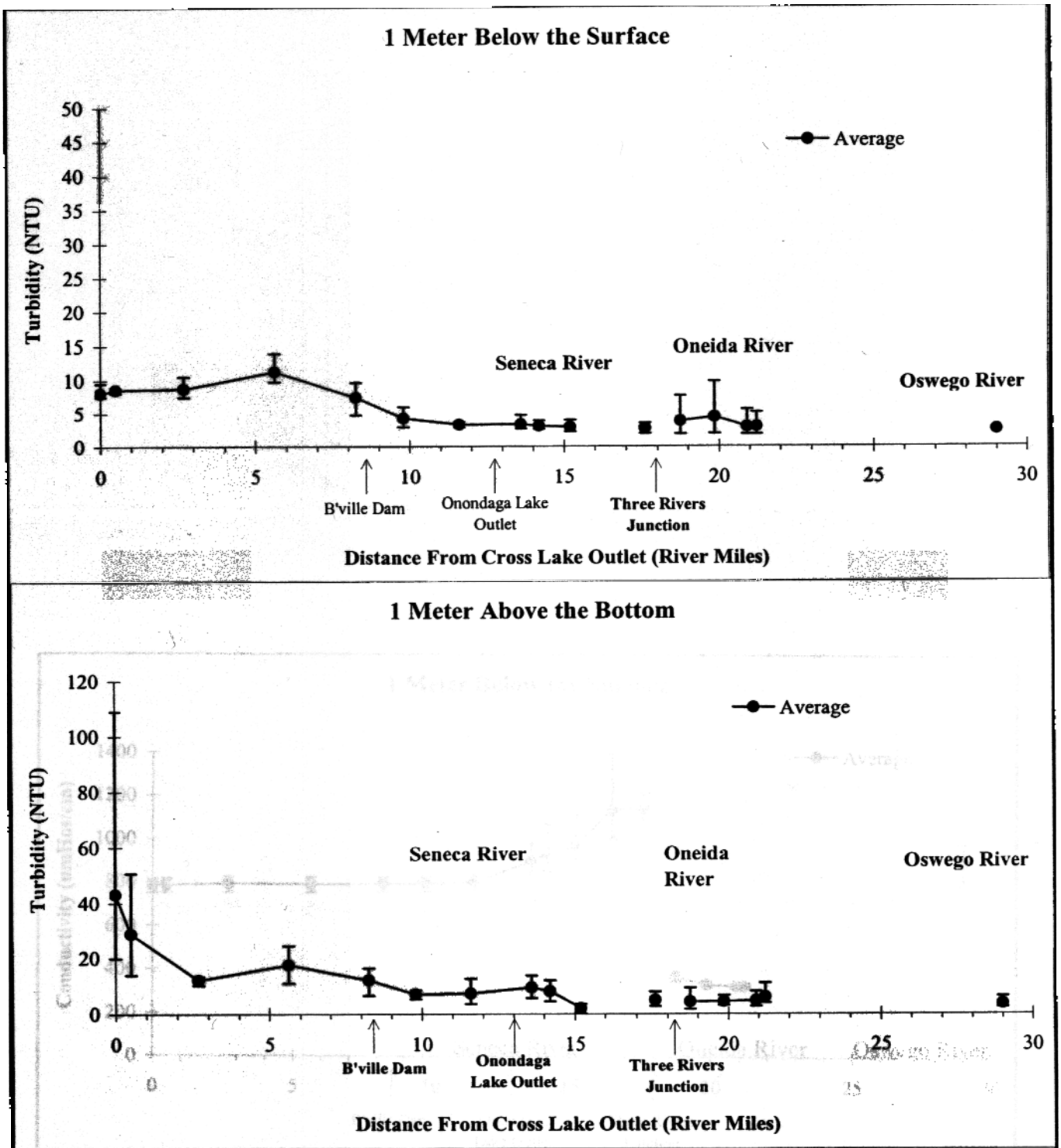
1998 Seneca, Oneida and Oswego River data include 4 events on July 20, August 10 and 17, and September 1, 1998.

FIGURE 11-9B AVERAGE AND RANGE OF CHLOROPHYLL *a* OBSERVED DURING THE 1998 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS



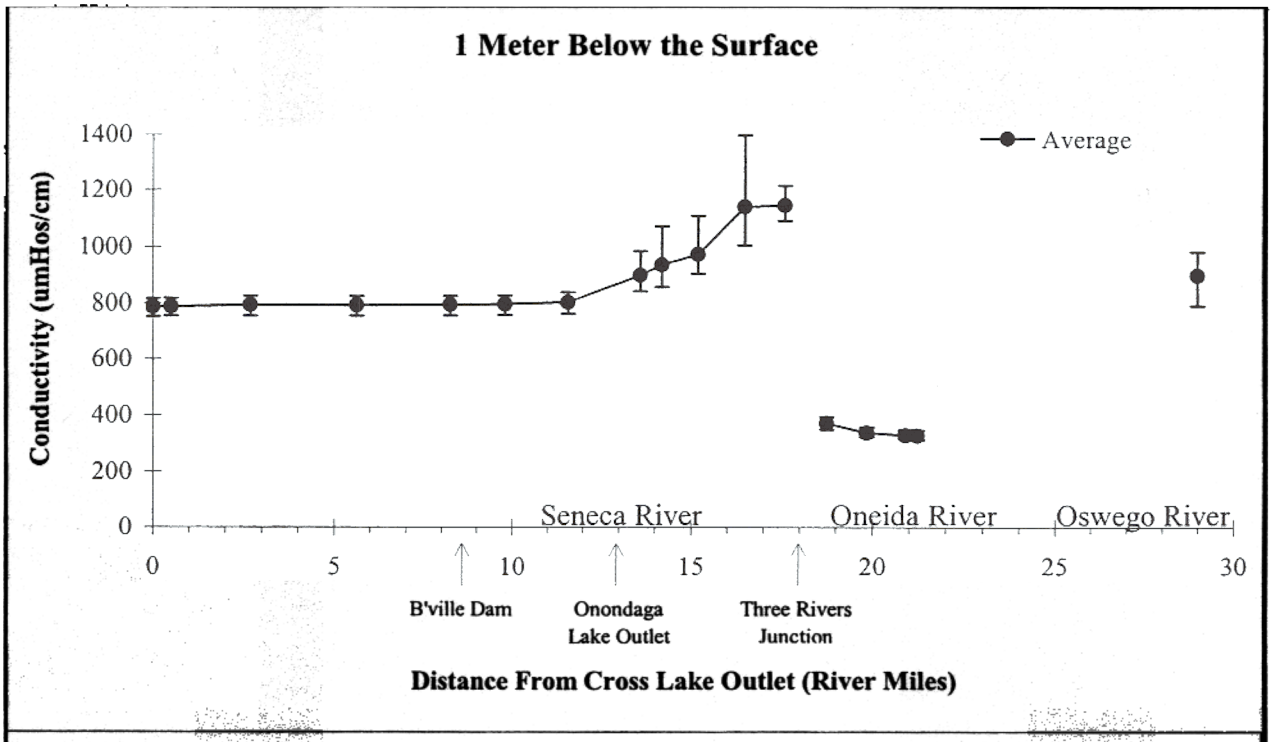
1999 Seneca, Oneida and Oswego River data include 3 events on July 22, August 17, and September 13, 1999.

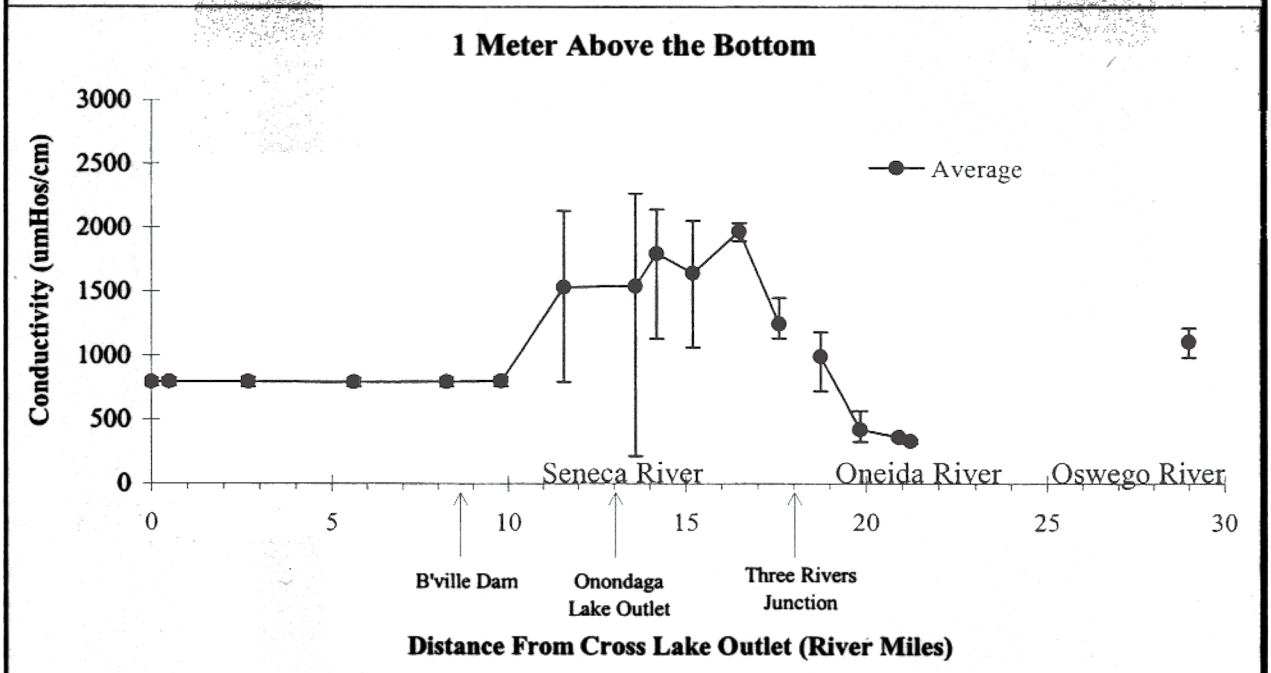
FIGURE 11-10A AVERAGE AND RANGE OF TURBIDITY OBSERVED DURING THE 1999 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS



1998 Seneca, Oneida and Oswego River data include 4 events on July 20, August 10 and 17, and September 1, 1998.

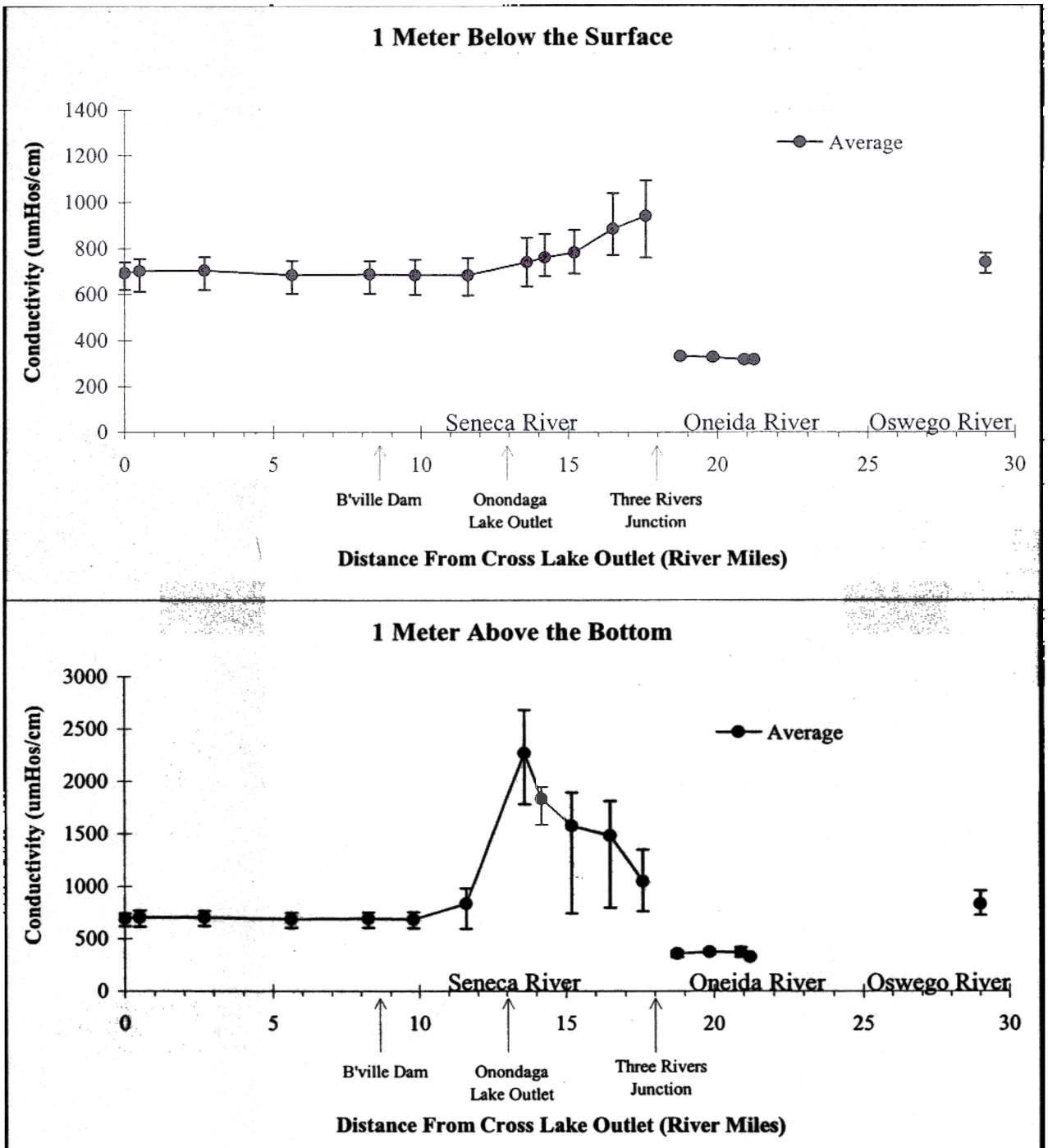
FIGURE 11-10B AVERAGE AND RANGE OF TURBIDITY OBSERVED DURING THE 1998 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS





1999 Seneca, Oneida, and Oswego River data include 3 events on July 22, August 17, and September 13, 1999.

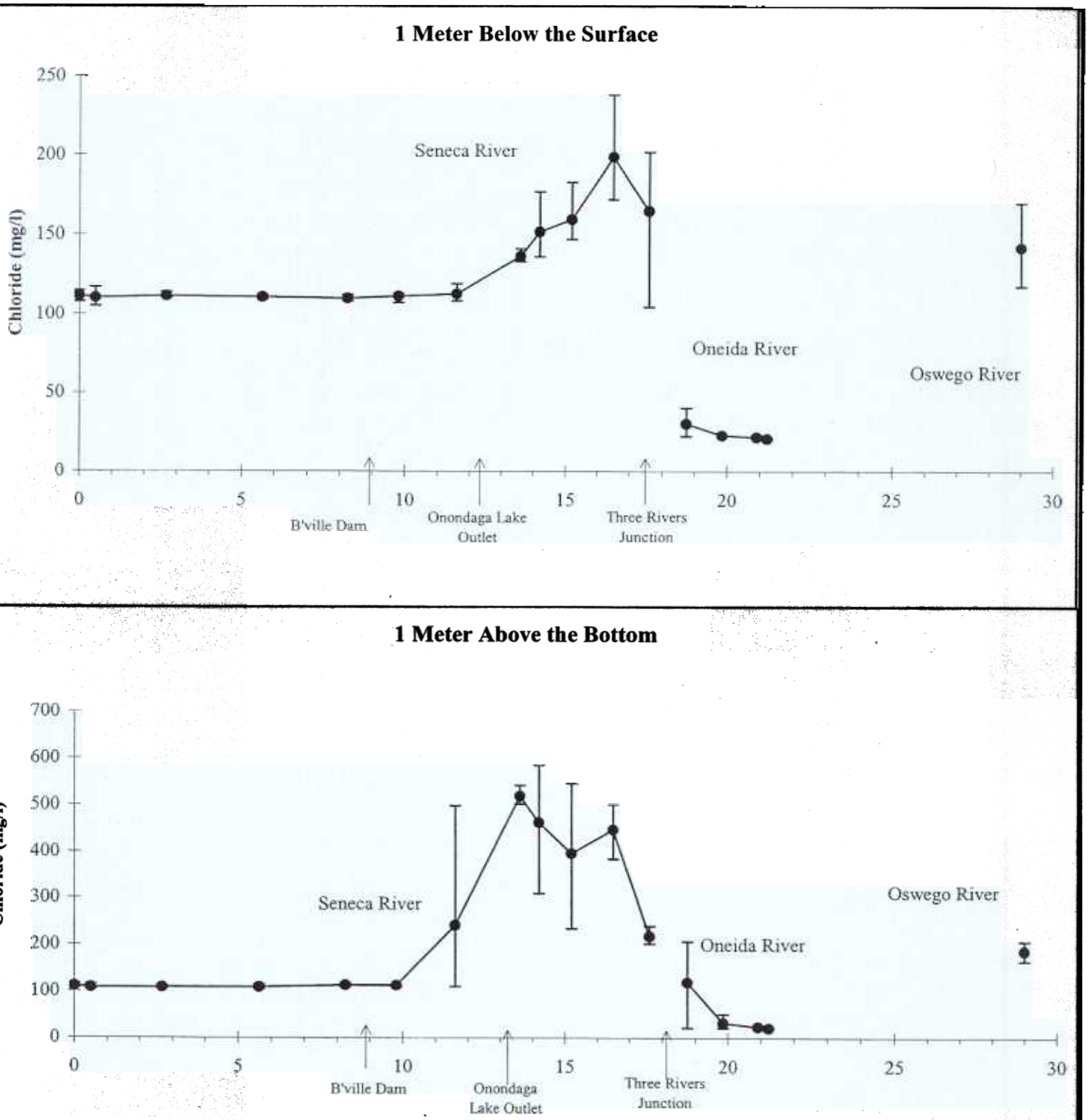
FIGURE 11-11A AVERAGE AND RANGE OF CONDUCTIVITY OBSERVED DURING THE 1999 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS



1998 Seneca, Oneida, and Oswego River data include 4 events on June 20, August 10 and 17, and September 1, 1998.

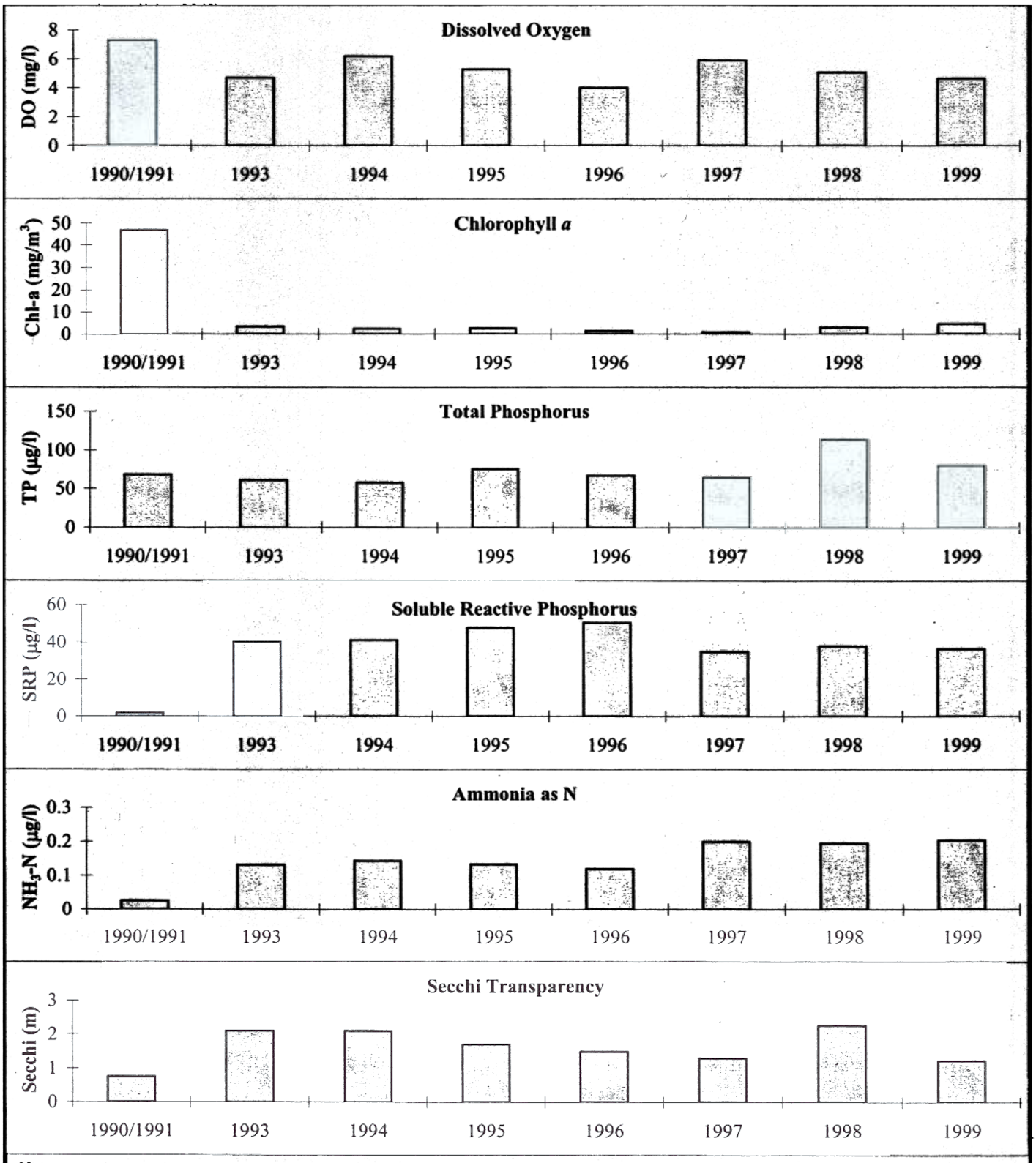
FIGURE 11-11B AVERAGE AND RANGE OF CONDUCTIVITY OBSERVED DURING THE 1998 MONITORING OF THE SENECA, ONEIDA AND OSWEGO RIVERS

11-COND_99/1998 plot



1999 Seneca, Oneida, and Oswego River data include 3 events on July 22, August 17, and September 13, 1999.

FIGURE 11-12 AVERAGE AND RANGE OF CHLORIDE OBSERVED DURING THE 1999 MONITORING OF THE SENECA AND ONEIDA RIVERS.



Note:
1990/1991, 1993 data from:
Effler et al. 1996. Impact of Zebra Mussel Invasion on River Water Quality. Water Environment Research. 68 (2): 205-214.
1994-1999 data from this study.

FIGURE 11-13 VARIOUS WATER QUALITY PARAMETERS IN THE SENECA RIVER NEAR BALDWINSVILLE, 1990/1991 THROUGH 1999.

TABLE 11-1

WATER QUALITY PARAMETERS MONITORED IN THE SENECA, ONEIDA, AND OSWEGO RIVERS STUDY, 1999
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Analytical Parameter	Limit of Detection	Justification for Inclusion in Study
5-day BOD	2.0 mg/l	Indicator of oxygen-demanding material
Chloride	1.0 mg/l	To evaluate mixing and dilution patterns in the Rivers
Chlorophyll *a*	0.2 mg/m3	Indicator of trophic status/algal productivity
Ammonia Nitrogen as N	0.1 mg/l	Compare to NYS ambient standard
Nitrite as N	0.01 mg/l	Compare to NYS ambient standard
Nitrate as N	0.01 mg/l	Indicator of nitrogen cycling
Total Kjeldahl Nitrogen	0.1 mg/l	Indicator of nitrogen cycling
Soluble Reactive P	0.001 mg/l	Indicator of trophic status/algal productivity
Total Phosphorus as P	0.001 mg/l	Indicator of trophic status/algal productivity
Total Dissolved P	0.001 mg/l	Indicator of trophic status/algal productivity
Total Organic Carbon	0.1 mg/l	Indicator of oxygen demanding material
Total Organic Carbon-Filtered	0.1 mg/l	Indicator of oxygen demanding material
Total Suspended Solids	1.0 mg/l	Indicator of water clarity
Turbidity	1.0 mg/l	Indicator of water clarity

Field Parameter	Limit of Detection	Justification for Inclusion in Study
Depth	-	To standardize measurement depths in water profile
Temperature	-	To calculate NH3 standards and DO (%Sat)
pH	-	Indicator of CO2 production/decomposition
Specific Conductance	-	Indicator of salinity/stratification
Salinity	-	Indicator of stratification
Dissolved Oxygen	-	Indicator of suitability for aquatic biota/Zebra mussel activity
Dissolved Oxygen (% Sat)	-	Indicator of suitability for aquatic biota/Zebra mussel activity
Redox	-	Indicator of oxidation status of water

TABLE 11-2

SENECA, ONEIDA AND OSWEGO RIVER MONITORING SITES AND INDICATOR OF LOCATION
Onondaga Lake 1999 Annual Report
Onondaga County, New York

Site on the Seneca River	Downstream Distance (River Miles) from Cross Lake Outlet
412 (Cross Lake Outlet)	0.0
409	0.5
397	2.7
362	5.6
334	8.3
Baldwinsville Dam	8.5
316	9.8
Baldwinsville WWTP	10.4
294	11.6
Onondaga Lake Outlet	12.9
269	13.6
260	14.2
Wetzel Road WWTP	14.6
255	15.2
240	
222	17.6
Three Rivers Junction	18.0

Site on the Oswego River	Downstream Distance (River Miles) from Three Rivers Junction
10	1.4

Site on the Oneida River	Upstream Distance (River Miles) from Three Rivers Junction
212	0.8
197	1.9
Oak Orchard WWTP	2.7
182	2.9
178	3.2

TABLE 11-3

SENECA RIVER FLOWS RECORDED ON SAMPLING DATES
Onondaga Lake 1999 Annual Report
Onondaga County, New York

River Sampling Date or Interval	Sampling Type (Regular Bi-weekly or Diurnal)	Average Flow Rate * (cfs)
May 9, 1995	Bi-weekly	e688
May 23, 1995	Bi-weekly	432
June 6, 1995	Bi-weekly	842
June 20, 1995	Bi-weekly	e350
July 5, 1995	Bi-weekly	e570
July 18, 1995	Bi-weekly	e400
August 1, 1995	Bi-weekly	e640
August 22, 1995	Diurnal	e1600
July 16-17, 1996	Diurnal	2020
August 13-14, 1996	Diurnal	2720
September 10, 1996	Diurnal	631
June 10, 1997	Bi-weekly	3760
June 17, 1997	Bi-weekly	2080
July 8, 1997	Bi-weekly	e1200
July 22, 1997	Bi-weekly	1220
August 5, 1997	Bi-weekly	600
August 19, 1997	Bi-weekly	544
September 2, 1997	Bi-weekly	431
September 9, 1997	Bi-weekly	881
September 29, 1997	Bi-weekly	796
July 20, 1998	Monthly/Diurnal	1630
August 10, 1998	Monthly/Diurnal	720
August 17, 1998	Monthly/Diurnal	714
September 1, 1998	Monthly/Diurnal	674
July 22, 1999	Monthly/Diurnal	611
August 17, 1999	Monthly/Diurnal	526
September 13, 1999	Monthly/Diurnal	664

* Finalized Seneca River flow rates recorded at Baldwinsville, NY

e = Estimated

Source: USGS, Ithaca

TABLE 11-4

VARIOUS WATER QUALITY PARAMETERS IN THE SENECA RIVER, UP-RIVER AND DOWN-RIVER THE CUT, 1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

			SENECA RIVER Buoy 409 Up-River of the CUT				SENECA RIVER Buoy 334 Down-River of the CUT			
Parameter	Units		Average	Max.	Min.	<LOD* : Total #**	Average	Max.	Min.	<LOD* : Total #**
CBOD5	mg/l	C	3	4	<2	1 : 3	<2	<2	<2	3 : 3
CHLOR-A	mg/m³	C	22	45	8	0 : 3	7	12	3	0 : 3
COND	µmHos/cm	S	787	817	754	0 : 3	794	825	756	0 : 3
		B	795	826	763	0 : 3	795	827	756	0 : 3
DO - Field	mg/l	S	8.86	9.45	8.06	0 : 3	5.46	5.88	4.74	0 : 3
		B	4.59	6.65	2.19	0 : 3	4.44	5.53	3.32	0 : 3
NH3-N	mg/l	S	0.11	0.17	<0.05	1 : 3	0.16	0.2	0.12	0 : 3
		B	0.06	0.06	0.05	0 : 3	0.15	0.21	0.12	0 : 3
NO2	mg/l	S	0.01	0.01	<0.01	2 : 3	0.02	0.02	0.01	0 : 3
		B	<0.01	<0.01	<0.01	3 : 3	0.02	0.02	0.02	0 : 3
NO3	mg/l	S	<0.01	<0.01	<0.01	3 : 3	0.027	0.04	0.01	0 : 3
		B	<0.01	<0.01	<0.01	3 : 3	0.027	0.04	0.01	0 : 3
SRP	mg/l	S	0.002	0.003	0.002	0 : 3	0.030	0.046	0.016	0 : 3
		B	0.005	0.01	0.002	0 : 3	0.030	0.047	0.016	0 : 3
Org-N	mg/l	S	0.5	0.7	0.4	0 : 3	0.5	0.5	0.4	0 : 3
		B	0.7	0.8	0.5	0 : 3	0.4	0.5	0.4	0 : 3
pH-field	std. units	S	8.34	8.45	8.23	0 : 3	7.61	7.69	7.57	0 : 3
		B	7.74	7.93	7.58	0 : 3	7.50	7.56	7.41	0 : 3
Phaeophytin-a	mg/m3	C	6.78	9.56	3.58	0 : 3	3.03	4.27	1.55	0 : 3
TEMP	°C	S	24.62	27.38	23.04	0 : 3	24.53	26.91	22.84	0 : 3
		B	23.82	26.01	22.68	0 : 3	24.39	26.62	22.78	0 : 3
TP	mg/l	S	0.065	0.079	0.055	0 : 3	0.086	0.125	0.061	0 : 3
		B	0.099	0.136	0.074	0 : 3	0.078	0.104	0.059	0 : 3
TDP	mg/l	S	0.024	0.026	0.022	0 : 3	0.047	0.053	0.040	0 : 3
		B	0.025	0.032	0.022	0 : 3	0.048	0.071	0.026	0 : 3
TKN	mg/l	S	0.6	0.8	0.5	0 : 3	0.6	0.7	0.6	0 : 3
		B	0.7	0.9	0.5	0 : 3	0.6	0.6	0.5	0 : 3
TOC	mg/l	S	3.62	4.00	3.10	0 : 3	4.06	4.50	3.80	0 : 3
		B	3.86	4.18	3.50	0 : 3	3.97	4.10	3.72	0 : 3
TOC-F	mg/l	S	3.44	3.80	3.00	0 : 3	3.90	4.30	3.60	0 : 3
		B	3.38	3.74	2.9	0 : 3	3.61	3.90	3.42	0 : 3
TSS	mg/l	S	8	11	6	0 : 3	8	10	5	0 : 3
		B	28	47	18	0 : 3	8	11	3	0 : 3
Turbidity	NTU	S	6.51	8.60	4.16	0 : 3	7.34	9.17	3.89	0 : 3
		B	22.77	37.00	14.50	0 : 3	8.39	11.10	3.98	0 : 3

See Figure 11.A-1 for buoy locations.

*LOD: the laboratory limit of detection (2.0 for BOD5; 0.20 for CHLOR-A; 0.1 for NH3-N; 0.01 for NO2; 0.001 for SRP; 0.001 for TDP). Statistics are calculated using the limit of detection when observations are below that limit.

B: Data collected at 1 meter above the bottom.

S: Data collected at 1 meter below the surface.

C: Sample collected as a composite throughout the water column.

TABLE 11-5

VARIOUS WATER QUALITY PARAMETERS IN THE SENECA RIVER, UP-RIVER AND DOWN-RIVER OF THE BALDWINSVILLE WASTEWATER TREATMENT PLANT AND THE ONONDAGA LAKE OUTLET, 1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

			SENECA RIVER [1] Buoy 316 Up-River of Onondaga Lake Outlet				SENECA RIVER [2] Buoy 269 Down-River of Onondaga Lake Outlet			
Parameter	Units		Average	Max.	Min.	<LOD* : Total #**	Average	Max.	Min.	<LOD* : Total #**
BOD5	mg/l	C	<2	<2	<2	3 : 3	3	4	2	2 : 2
CHLOR-A	mg/m³	C	2.3	4.8	1.1	0 : 3	9.1	9.1	9.1	0 : 1
		S					5.3	5.3	5.3	0 : 1
		PZC					46.5	46.5	46.5	0 1
COND	µmHos/cm	S	796	827	758	0 : 3	898	984	842	0 : 3
		B	799	832	759	0 : 3	1542	2270	215	0 : 3
DO - Field	mg/l	S	5.24	5.72	4.50	0 : 3	6.85	9.62	5.23	0 : 3
		B	3.46	5.17	1.61	0 : 3	3.74	6.10	1.35	0 : 3
NH3-N	mg/l	S	0.3	0.5	0.2	0 : 3	0.1	0.2	0.1	0 : 3
		B	0.2	0.3	0.2	0 : 3	0.5	0.8	0.1	0 : 3
NO2	mg/l	S	0.04	0.06	0.02	0 : 3	0.05	0.07	0.03	0 : 3
		B	0.04	0.07	0.02	0 : 3	0.13	0.17	0.10	0 : 3
NO3	mg/l	S	0.07	0.08	0.05	0 : 3	0.18	0.24	0.14	0 : 3
		B	0.07	0.08	0.05	0 : 3	1.28	1.45	1.02	0 : 3
SRP	mg/l	S	0.036	0.052	0.023	0 : 3	0.021	0.034	0.004	0 : 3
		B	0.050	0.090	0.024	0 : 3	0.016	0.028	0.009	0 : 3
Org-N	mg/l	S	0.3	0.4	0.1	0 : 3	0.4	0.5	0.4	0 : 3
		B	0.3	0.4	0.3	0 : 3	0.5	0.7	0.4	0 : 3
pH-field	std. units	S	7.59	7.74	7.51	0 : 3	7.73	8.08	7.55	0 : 3
		B	7.44	7.49	7.38	0 : 3	7.43	7.64	7.20	0 : 3
Phaeophytin-a	mg/m3	C	2.0	3.0	0.8	0 : 3	4.1	4.1	4.1	0 : 1
		S					1.8	1.8	1.8	0 : 1
		PZC					1.8	1.8	1.8	0 : 1
TEMP	°C	S	24.62	27.03	22.84	0 : 3	24.63	26.89	23.07	0 : 3
		B	24.14	26.09	22.75	0 : 3	22.58	23.36	21.97	0 : 3
TP	mg/l	S	0.073	0.101	0.056	0 : 3	0.088	0.123	0.067	0 : 3
		B	0.084	0.133	0.055	0 : 3	0.115	0.200	0.062	0 : 3
TDP	mg/l	S	0.052	0.064	0.034	0 : 3	0.044	0.064	0.032	0 : 3
		B	0.073	0.124	0.035	0 : 3	0.065	0.117	0.027	0 : 3
TKN	mg/l	S	0.6	0.6	0.5	0 : 3	0.5	0.6	0.5	0 : 3
		B	0.6	0.6	0.5	0 : 3	1.0	1.2	0.8	0 : 3
TOC	mg/l	S	4.16	4.70	3.87	0 : 3	4.18	4.30	4.00	0 : 3
		B	4.02	4.50	3.70	0 : 3	3.84	4.00	3.73	0 : 3
TOC-F	mg/l	S	3.70	3.80	3.59	0 : 3	3.93	4.00	3.80	0 : 3
		B	3.71	4.00	3.53	0 : 3	3.57	3.72	3.50	0 : 3
TSS	mg/l	S	3	6	2	0 : 3	4	6	2	0 : 3
		B	4	6	1	0 : 3	8	10	5	0 : 3
Turbidity	NTU	S	4.15	5.38	2.57	0 : 3	2.74	3.14	2.39	0 : 3
		B	4.67	6.40	2.58	0 : 3	7.01	9.22	4.74	0 : 3

[1] : See Figure 11.A-1 for buoy locations.

[2] : *LOD: the laboratory limit of detection (2.0 for BOD5; 0.20 for CHLOR-A; 0.1 for NH3-N; 0.01 for NO2; 0.001 for SRP; 0.001 for TDP). Statistics are calculated using the limit of detection when observations are below that limit.

B: Data collected at 1 meter above the bottom.

S: Data collected at 1 meter below the surface.

C: Water column composite sample.

PZC: Photic zone composite sample.

TABLE 11-6

VARIOUS WATER QUALITY PARAMETERS IN THE ONEIDA RIVER, UP-RIVER AND DOWN-RIVER OF OAK ORCHARD WASTEWATER TREATMENT PLANT, 1999

Onondaga Lake 1999 Annual Report
Onondaga County, New York

			ONEIDA RIVER Buoy 178 Up-River of Oak Orchard				ONEIDA RIVER Buoy 197 Down-River of Oak Orchard			
Parameter	Units		Average	Max.	Min.	<LOD* : Total #**	Average	Max.	Min.	<LOD* : Total #**
BOD5	mg/l	C	2	3	<2	1 : 3	2.0	2.0	<2	3 : 3
CHLOR-A	mg/m^3	C	11.9	16.6	8.0	0 : 3	8.2	10.7	3.2	0 : 3
COND	mmHos/cm	S	338	357	323	0 : 3	328	347	313	0 : 3
		B	420	568	326	0 : 3	331	348	315	0 : 3
DO - Field	mg/l	S	10.39	11.91	9.11	0 : 3	9.03	10.43	7.46	0 : 3
		B	5.37	8.44	2.50	0 : 3	7.25	8.20	6.26	0 : 3
NH3-N	mg/l	S	0.1	0.1	<0.05	1 : 3	0.1	0.1	<0.05	1 : 3
		B	0.2	0.3	0.1	0 : 3	0.1	0.1	<0.05	1 : 3
NO2	mg/l	S	0.02	0.03	0.02	0 : 3	0.01	0.01	<0.01	2 : 3
		B	0.05	0.09	0.03	0 : 3	0.02	0.05	<0.01	1 : 3
NO3	mg/l	S	0.06	0.10	0.02	0 : 3	0.01	0.02	<0.01	2 : 3
		B	0.16	0.25	0.10	0 : 3	0.03	0.04	<0.01	1 : 3
SRP	mg/l	S	0.013	0.017	0.010	0 : 3	0.008	0.012	0.004	0 : 3
		B	0.048	0.095	0.019	0 : 3	0.010	0.018	0.004	0 : 3
Org-N	mg/l	S	0.7	1.2	0.4	0 : 3	0.5	0.6	0.4	0 : 3
		B	0.4	0.6	0.3	0 : 3	0.4	0.4	0.3	0 : 3
pH-field	std. units	S	8.72	8.98	8.46	0 : 3	8.60	8.90	8.20	0 : 3
		B	7.95	8.62	7.34	0 : 3	8.26	8.52	7.86	0 : 3
Phaeophytin-a	mg/m3	C	1.4	1.9	0.6	0 : 3	1.9	2.4	1.7	0 : 3
TEMP	°C	S	24.60	26.68	22.80	0 : 3	24.15	25.84	22.79	0 : 3
		B	23.54	25.18	22.56	0 : 3	23.49	25.18	22.44	0 : 3
TP	mg/l	S	0.101	0.113	0.086	0 : 3	0.063	0.079	0.052	0 : 3
		B	0.098	0.118	0.079	0 : 3	0.061	0.069	0.055	0 : 3
TDP	mg/l	S	0.029	0.035	0.025	0 : 3	0.025	0.034	0.019	0 : 3
		B	0.058	0.099	0.030	0 : 3	0.031	0.037	0.023	0 : 3
TKN	mg/l	S	0.8	1.2	0.5	0 : 3	0.6	0.7	0.5	0 : 3
		B	0.6	0.7	0.6	0 : 3	0.5	0.5	0.4	0 : 3
TOC	mg/l	S	4.17	5.10	2.90	0 : 3	4.32	5.35	2.90	0 : 3
		B	4.31	5.10	3.00	0 : 3	3.84	4.53	3.00	0 : 3
TOC-F	mg/l	S	3.92	4.90	2.60	0 : 3	3.80	4.50	2.60	0 : 3
		B	3.88	4.70	2.80	0 : 3	3.65	4.25	2.70	0 : 3
TSS	mg/l	S	8	17	4	0 : 3	8	12	5	0 : 3
		B	6	11	3	0 : 3	10	16	7	0 : 3
Turbidity	NTU	S	4.10	7.81	1.82	0 : 3	4.14	7.89	2.04	0 : 3
		B	5.09	8.30	3.21	0 : 3	5.77	10.30	2.86	0 : 3

[1] : See Figure 11.A-1 for buoy locations.

[2] : *LOD: the laboratory limit of detection (2.0 for BOD5; 0.20 for CHLOR-A; 0.1 for NH3-N; 0.01 for NO2; 0.001 for SRP; 0.001 for TDP). Statistics are calculated using the limit of detection when observations are below that limit.

B: Data collected at 1 meter above the bottom.

S: Data collected at 1 meter below the surface.

C: Water column composite sample.

PZC: Photic zone composite sample.

TABLE 11-7

VARIOUS WATER QUALITY PARAMETERS IN THE SENECA RIVER, UP-RIVER AND DOWN-RIVER OF WETZEL ROAD WASTEWATER TREATMENT PLANT, 1999

Onondaga Lake 1999 Annual Report

Onondaga County, New York

			ONEIDA RIVER Buoy 260 Up-River of Wetzel Road							
Parameter	Units		Average	Max.	Min.	<LOD* : Total #**				
BOD5	mg/l	C	4	5	3	0 : 3	3	6	2	2 : 3
CHLOR-A	mg/m³	PZC	98.3	98.3	98.3	0 : 1	47.0	47.0	47.0	0 : 1
		B	3.3	6.1	0.2	1 : 3	9.9	9.9	9.9	0 : 1
		C	5.1	6.9	3.2	0 : 2	4.3	4.8	3.7	0 : 2
COND	µmHos/cm	S	935	1071	856	0 : 3	972	1108	903	0 : 3
		B	1793	2140	1131	0 : 3	1640	2050	1065	0 : 3
DO - Field	mg/l	S	7.64	11.26	5.64	0 : 3	8.69	14.63	5.56	0 : 3
		B	2.26	4.77	1.00	2 : 3	3.96	4.58	2.91	0 : 3
NH3-N	mg/l	S	0.2	0.3	0.2	0 : 3	0.1	0.3	0.1	1 : 3
		B	1.3	2.2	0.3	0 : 3	0.3	0.4	0.1	0 : 3
NO2	mg/l	S	0.05	0.06	0.03	0 : 3	0.05	0.06	0.04	0 : 3
		B	0.05	0.10	0.02	0 : 3	0.13	0.21	0.08	0 : 3
NO3	mg/l	S	0.19	0.27	0.14	0 : 3	0.28	0.35	0.22	0 : 3
		B	0.29	0.82	0.01	1 : 3	1.03	1.27	0.62	0 : 3
SRP	mg/l	S	0.018	0.026	0.003	0 : 3	0.020	0.032	0.001	0 : 3
		B	0.394	0.827	0.003	0 : 3	0.022	0.034	0.014	0 : 3
Org-N	mg/l	S	0.5	1.0	0.2	0 : 3	0.6	0.9	0.4	0 : 3
		B	0.7	1.1	0.2	0 : 3	0.6	0.7	0.4	0 : 3
pH-field	std. units	S	7.85	8.39	7.58	0 : 3	7.92	8.66	7.55	0 : 3
		B	7.28	7.50	7.15	0 : 3	7.41	7.50	7.29	0 : 3
[illegible]	mg/m3	PZC	3.0	3.0	3.0	0 : 1	3.5	3.5	3.5	0 : 1
		B	4.9	7.3	3.2	0 : 3	3.4	3.4	3.4	0 : 1
		C	2.4	2.8	2.0	0 : 2	2.1	3.0	1.1	0 : 2
TEMP	°C	S	24.61	26.77	23.10	0 : 3	25.02	27.76	23.21	0 : 3
		B	21.84	23.69	20.61	0 : 3	23.15	24.28	22.58	0 : 3
TP	mg/l	S	0.095	0.159	0.058	0 : 3	0.079	0.108	0.063	0 : 3
		B	0.668	0.981	0.058	0 : 3	0.085	0.089	0.080	0 : 3
TDP	mg/l	S	0.047	0.057	0.040	0 : 3	0.046	0.064	0.021	0 : 3
		B	0.577	0.873	0.026	0 : 3	0.062	0.085	0.042	0 : 3
TKN	mg/l	S	0.7	1.2	0.5	0 : 3	0.7	1.0	0.4	0 : 3
		B	2.0	2.5	1.0	0 : 3	0.8	1.1	0.7	0 : 3
TOC	mg/l	S	4.35	4.40	4.25	0 : 3	4.23	4.50	4.10	0 : 3
		B	4.36	4.80	3.60	0 : 3	4.14	4.30	3.90	0 : 3
TOC-F	mg/l	S	3.72	4.10	3.50	0 : 3	3.98	4.20	3.80	0 : 3
		B	4.05	4.50	3.30	0 : 3	3.95	4.06	3.80	0 : 3
TSS	mg/l	S	5	12	1	0 : 3	5	7	2	0 : 3
		B	4	5	2	0 : 3	4	5	4	0 : 3
Turbidity	NTU	S	3.48	4.73	2.60	0 : 3	2.95	3.61	2.61	0 : 3
		B	4.61	5.62	3.04	0 : 3	3.90	4.70	3.00	0 : 3

[1] : See Figure 11.A-1 for buoy locations.

[2] : *LOD: the laboratory limit of detection (2.0 for BOD5; 0.20 for CHLOR-A; 0.1 for NH3-N; 0.01 for NO2; 0.001 for SRP; 0.001 for TDP). Statistics are calculated using the limit of detection when observations are below that limit.

B: Data collected at 1 meter above the bottom.

S: Data collected at 1 meter below the surface.

C: Water column composite sample.

PZC: Photic zone composite sample.

CHAPTER 12

MASS-BALANCE MODELING

(By Dr. William Walker, Jr.)

12.1 INTRODUCTION

The development and structure of a mass-balance modeling framework for Onondaga Lake is described in the 1998 lake monitoring report (Ecologic, et al, 1999). Interactive software facilitates computation and analysis of mass balances for nutrients and other water-quality components using hydrologic and water quality data collected in the lake and its tributaries (Figure 12-1). Predictive models for annual outflow and summer lake total phosphorus and total nitrogen concentrations use simple first-order rate expressions to represent nutrient retention within the Lake.

This chapter updates the mass-balance framework to include 1986-1999 data. Total phosphorus and total nitrogen models are refined and recalibrated. The phosphorus balance is linked to a network of empirical models for predicting trophic state indicators including chlorophyll-a, transparency, and hypolimnetic oxygen depletion rate (Figure 12-2). These models provide a basis for predicting seasonally averaged lake responses to reductions in external phosphorus loads resulting from future implementation of point-source and nonpoint-source control measures.

12.2 DATABASE UPDATES

Mass-balance tables have been updated to include 1999 data using methods and assumptions described in the 1998 annual report. Ten-year trends in concentration and load for each source and water quality component are summarized in Tables 12-1 and12-2, respectively. Five-year-average mass-balances for chloride, total phosphorus, and total nitrogen are listed in Tables 12-3, 4, & 5, respectively. Accuracies of the water balance and load computation framework are supported by the fact that chloride inputs and output differ by ~1% over the 1995-1999 period.

In the previous report, total phosphorus loads for the 1985-1989 period (when TP was not measured) were estimated by applying TP/TIP ratios to the measured TIP loads for each tributary. The ratios were calibrated to data from subsequent years when both TP and TIP were measured. These estimates have been refined by developing a TP vs. TIP regression model for each tributary and the lake epilimnion. The model includes both a slope and an intercept, whereas the previous procedure assumed an intercept of zero. In addition, each model has been calibrated to paired TP and TIP measurements (vs. annual loads).

Figure 12-3 shows yearly variations in total precipitation, lake inflow volumes and loads of total phosphorus and total nitrogen over the 1986-1999 period. Inflow volumes and nutrient loads were relatively low in 1999, primarily because of low precipitation (31 inches vs. average of 37 inches for 1986-1998). Total phosphorus loads generally declined over the 1986-1999 period. Trend analysis results for 1990-1999 (Tables 12-1 & 12-2) indicate significant decreasing trends in phosphorus load and concentration for Onondaga Creek and Metro. When adjusted for variations in flow, however, only the Metro trend (-5% per year) is significant. For this particular time period, the adjustment procedure may over-compensate for flow effects because the time series starts with a wet year (1990) and ends in a dry year (1999). When this occurs, it is difficult to distinguish effects of flow from a long-term trend. For this reason, the declining trend in Onondaga Creek may in fact be significant, even though the regression indicates otherwise. Total nitrogen loads decreased steadily over the 1996-1999 period. This is attributed primarily to reductions in ammonia nitrogen load resulting from increased nitrification at Metro.

Yearly phosphorus and nitrogen balances are listed in Tables 12-6 and 12-7, respectively. Other data used for calibration and testing of the eutrophication model network are summarized in Table 12-8. These data have been derived from the mass-balance framework and historical lake water quality files.

12.3 TOTAL PHOSPHORUS MODEL

The structure of the phosphorus balance model is identical to that described in the 1998 annual report (Figure 12-2, Table 12-9). Flows and phosphorus loads used for model calibration and testing are listed in Table 12-6. The annual flow-weighted-mean outflow concentration is predicted from outflow volume and inflow load using a first-order settling velocity to predict net sedimentation within the Lake (Vollenweider, 1969; Chapra, 1975). Because the mass-balance is used to predict both annual outflow concentration and summer epilimnetic P concentration, it is formulated on a water-year basis (October thru September). A calendar-year basis would be less appropriate because loads between October and December could not influence lake conditions in summer of the same calendar year.

The settling velocity (22.9 m/yr) is calibrated to data from the last 5 water years (1995-1999). Hindcasts of 1986-1994 data provide a basis for model testing. Observed and predicted outflow P concentrations are plotted in Figure 12-4. Within the calibration period, the model explains 73 % of the variance in the observed outflow concentration with a residual standard error of 11%. There is a tendency for the model to over-predict outflow concentrations in earlier years (1986, 1989, 1991, 1992). This may reflect:

positive correlation between net settling rate and concentration or load, as embodied in other empirical phosphorus models developed from lake or reservoir data sets (Canfield & Bachman 1981; Walker, 1985; Sas,1989);

2 non-steady-state conditions in the Lake owing to feedback of sediment phosphorus during this period of declining external phosphorus loads; and/or

anomalies in sampling of the lake outlet owing to backflows from the Seneca River.

Development of a dynamic P balance model that accounts for sediment P storage and recycling may help to determine whether the second mechanism is important. Because the reasons cannot be specifically identified and because predictions of summer epilimnetic P concentrations do not show the same pattern (see below), modification of the model to simulate outflow concentrations in these early years does not seem appropriate. Future mass-balance results will determine whether the apparent pattern of a declining net settling rate computed from lake outflow concentrations continues.

Summer epilimnetic total phosphorus concentrations at the Lake South station drive predictions of other trophic state indicators (Figure 12-5). For reasons described below, summer epilimnetic concentrations are computed from samples collected between July and September at the Lake South station at depths ranging from 0 to 3 meters. Summer P values are predicted by applying a constant ratio to the annual flow-weighted-mean outflow concentration predicted by the mass-balance model (Sas, 1989). This ratio (0.55, calibrated to 1995-1999 data) accounts for seasonal and, to a lesser extent, spatial variations. Within the calibration period, the model explains 29% of the variance in the observed lake P concentration with a residual standard error of 9%. The low r^2 value reflects low variability in the observed concentration during this period; the validity of the model is supported by the low residual standard error, well below the ~20% level typical of empirical phosphorus balance models (Walker, 1985,1996). Model performance statistics for the entire 1986-1999 period are r^2 = 88% and CV =13%.

Summer epilimnetic P concentrations respond quickly to year-to-year variations in external load (Figure 12-5). This suggests that feedback of sediment phosphorus deposited historically is not significantly delaying the recovery of the lake during this period of declining phosphorus loads, at least within the concentration ranges achieved to date. Long-term trends in average inflow and outflow concentrations and loads (Figure 12-6) are also consistent with a rapid lake response to reductions in external load.

12.4 TOTAL NITROGEN MODEL

The structure of the nitrogen balance model is identical to that described in the 1998 annual report (Table 12-9, Figure 12-2). The annual flow-weighted-mean outflow concentration is predicted from inflow volume and load using a first-order settling velocity to predict net sedimentation within the Lake. Flows and nitrogen loads used for model calibration and testing are listed in Table 12-7. As for phosphorus, the nitrogen model is calibrated to water-year time series.

The nitrogen settling velocity (24 m/yr) is calibrated to data from the last 5 water years (1995-1999). Hindcasts of 1986-1994 data are used for model testing. Observed and predicted outflow N concentrations are plotted in Figure 12-7. Within the calibration period, the model explains 75% of the variance in the observed outflow concentration with a residual standard error of 8 %. Corresponding values for the entire 1986-1999 period are 61% and 7%, respectively.

Summer epilimnetic total nitrogen concentrations at the Lake South station (Figure 12-8) are predicted by applying a constant ratio to the annual flow-weighted-mean outflow concentration predicted by the mass-balance model. This ratio (1.15, calibrated to 1995-1999 data) accounts for seasonal and, to a lesser extent, spatial variations. Apparently because of the importance of point-source nitrogen loadings, summer nitrogen levels in the lake epilimnion are 15% greater than annual, flow-weighted-mean outflow concentrations. Within the calibration period, the model explains 71% of the variance in the observed lake total N concentration with a residual standard error of 10%. Corresponding statistics for the entire 1986-1999 period are 53% and 11%, respectively.

12.5 TROPHIC RESPONSE MODELS

A network of empirical models has been assembled from the literature to provide a basis for predicting variations in the following trophic state indicators from summer epilimnetic Total P concentrations:

Mean Chlorophyll-a
Algal Bloom Frequencies (percent of time Chl-a exceeds 10, 20, 30, and 40 ppb)
Mean Secchi Depth
Secchi Frequencies (percent of time Secchi is less than 1.2 meters [4 feet bathing standard] and 2 meters)
Hypolimnetic Oxygen Depletion Rate & Duration of Anoxic Conditions

The linkage of variables in the model network is shown in Figure 12-2 Calibration data are listed in Table 12-8. Model equations and calibration results are listed in Table 12-9.

Generally, these models were originally developed and calibrated to data from phosphorus-limited lakes (lakes in which algal productivity is limited by phosphorus concentrations). Historically, phosphorus concentrations in Onondaga Lake have been well in excess of growth-limiting levels. It is likely that factors such as light and zooplankton grazing have been controlling. Figure 12-9 shows total and ortho (~soluble reactive) phosphorus concentrations in the epilimnion (July-September means, 0-6 m, Lake South) between 1986-1999. Excess Ortho P is present in the Lake when Total P concentrations exceed ~50-60 ppb. The plots show that the Lake has approached a phosphorus-limited condition in recent years as the concentration of total phosphorus has reached 50-60 ppb. Given the increasingly P-limited conditions, it is likely that trophic state indicators (chlorophyll-a, transparency) will respond to future P reductions more dramatically than they have to historical P reductions.

As borne out by the data presented below, phosphorus-based models would be expected to over-predict historical concentrations of chlorophyll-a and other trophic state indicators. As phosphorus concentrations have declined and approached growth-limiting levels in recent years, observations and model predictions have converged. Attempting to adapt the models to simulate historical conditions may be futile and is not necessary to forecast responses to future reductions in phosphorus load. Accordingly, the calibration strategy is to focus in recent years (1995-1999). High R^2 values are not expected within this period, given the limited number of years and range of data. In some situations, the models are adopted without re-

calibration because observed concentrations are not significantly different from model predictions. If necessary, the models can be recalibrated to match observed responses as phosphorus levels decrease future years. The key assumption in using the models in a forecast mode is that phosphorus will remain limiting and that the Lake will respond to reductions in phosphorus in a manner that is reflected in the cross-sectional data sets derived from other phosphorus-limited lakes.

For each year, trophic state indicators are computed from samples collected between July and September at the Lake South station at depths ranging from 0 to 3 meters. Figure 12-10 shows average seasonal variations in total phosphorus, chlorophyll-a, and transparency based upon 0-3 meter samples at the Lake South station. Chlorophyll-a concentrations tend to be significantly lower in June and transparencies, significantly higher, as compared with the rest of the summer. This probably reflects clearing events driven by zooplankton activity. The precise timing of these events varies from year to year and introduces considerable variability in the summer means computed from June-September or June-August data. Summarizing the data on a July-September basis excludes the highly variable conditions in June and provides greater precision in the modeled response variables. These months represent "worst-case" conditions for chlorophyll-a and transparency.

12.5.1 Chlorophyll-a

Summer mean chlorophyll-a concentrations are modeled as a log-linear function of summer phosphorus concentration (Figure 12-11). The regression model developed by Jones & Bachman (1976) has been calibrated to 1996-1999 data by adjusting the intercept from 0.081 to 0.076. The model is similar to others developed from other lake data sets (Dillon & Rigler, 1994; Carlson, 1977; Walker, 1979).

Figure 12-11 shows 80% prediction intervals (10th, 50th, and 90th percentiles) in relation to observed mean chlorophyll-a concentrations between 1986 and 1999. Prediction intervals are computed from the residual standard error for the 1996-1999 period (CV = 24%). A variety of chlorophyll-a sampling methods were used over the 1986-1999 (discrete depths, epilimnetic composite, photic zone composite). These results have been pooled and averaged by date before computing summer means. Figure 12-11 shows observed mean values plus or minus one standard error. Standard errors are computed from the number of sampling dates and the standard deviation of the mean concentration across dates. The residual CV in 1996-1999 (24%) is similar to the standard error of the observed mean values (averaging 23%). This suggests that sampling variability alone could account for a significant fraction of the difference between observed and predicted concentrations.

As expected, the model significantly over-predicts chlorophyll-a concentrations in the years prior to 1995 when phosphorus was not limiting. Predictions and observations converge as phosphorus concentration decrease in later years.

12.5.2 Algal Bloom Frequencies

Summer algal bloom frequencies (percent of the time that chlorophyll-a exceeds bloom criteria of 10, 20, 30, or 40 ppb) are predicted as a function of mean chlorophyll-a concentrations by modeling temporal variation in chlorophyll-a with a lognormal distribution (Walker, 1984). The temporal coefficient of variation (CV = 0.60) has been calibrated to 1986-1999 data. Chlorophyll-a levels of 10, 20, and 30 ppb correspond to "visible", "nuisance", and "severe nuisance" algal blooms, according to results of user surveys reported by Walmsley (1984). Figure 12-12 plots observed and predicted bloom frequencies against observed mean chlorophyll-a levels. These relationships typically show a threshold response that is useful for setting goals (Heiskary & Walker, 1988).

In a forecast mode, bloom frequencies would be estimated from predicted mean chlorophyll-a levels, in turn predicted from phosphorus levels. Observed and predicted algal bloom frequencies are plotted against predicted lake total phosphorus in Figure 12-13 and against year in Figure 12-14. Prediction intervals are computed directly from the prediction intervals for mean chlorophyll-a. As expected, the models tend to over-estimate bloom frequencies in earlier years when phosphorus concentrations were not limiting.

Results suggest that the apparent reductions in severe bloom frequencies (30 or 40 ppb) in recent years can be at least partially attributed to reductions in phosphorus levels.

12.5.3 Secchi Depth

Secchi depths are predicted with a model that partitions light extinction into two components: an algal component (assumed to be proportional to chlorophyll-a concentration) and a non-algal component (attributed to color, inorganic particles, and non-algal organic particles) (Walker, 1985; 1996; Effler, 1994). The light extinction coefficient is assumed to be inversely proportional to the Secchi depth. Model coefficients are calibrated to Secchi and chlorophyll-a concentrations observed between 1990 and 1999 (Figure 12-15). There is a strong indication that non-algal turbidity was higher in years prior to 1990 (range 0.4-1.3 m^{-1} vs. average 0.3 m^{-1} in 1990-1999). This may reflect reductions in calcium, suspended solids, or other substances contributing to light extinction but independent of chlorophyll-a concentration. If further reductions in non-algal turbidity occur following implementation of additional source controls, it will be necessary to recalibrate the model by adjusting the non-algal turbidity term.

In a forecast mode, Secchi depths would be estimated from predicted mean chlorophyll-a levels, in turn predicted from phosphorus loads. Figure 12-16 plots observed mean Secchi depths against predicted lake phosphorus concentration and year. Prediction intervals are computed from the residual standard error over the 1995-1999 period (CV = 19%). As expected, transparency is under-predicted in earlier years when phosphorus concentrations were not limiting algal growth. Because of potential future reductions in non-algal turbidity unrelated to phosphorus controls, response of transparency to reductions in phosphorus load may be more dramatic than those predicted by the model as it is currently calibrated.

12.5.4. Secchi Frequencies

To recreational users, the average water transparency over a summer may have little meaning because of high variability experienced within the summer. The frequency of transparencies less than 1.2 meters (4-foot bathing standard) is of interest from a management perspective. Secchi interval frequencies (percent of time < 1.2 meters and < 2 meters) are predicted using a model analogous to that described above for algal bloom frequencies. Temporal variations in transparency are simulated with a lognormal distribution and CV=0.32, calibrated to 1986-1999 data. Figure 12-17 plots observed and predicted Secchi interval frequencies against observed mean Secchi depths.

In a forecast mode, bloom frequencies would be estimated from predicted mean transparency, in turn predicted from chlorophyll-a and phosphorus loads. Observed and predicted Secchi frequencies are plotted against predicted total lake phosphorus and year in Figure 12-18 (<1.2 meters) and Figure 12-19 (< 2 meters). Prediction intervals are computed from the prediction intervals for mean transparency. Again, the models tend to over-predict frequencies in earlier years when phosphorus concentrations were not limiting. One exception is 1986, when non-algal turbidity levels in the Lake were apparently much higher than those present in subsequent years.

12.5.5 Hypolimnetic Oxygen Depletion Rate

The rate of oxygen depletion below the thermocline in the spring and early summer has been promoted as a useful index of trophic state (Mortimer, 1941). This rate reflects the combined effects of respiration and decomposition processes ultimately fueled by external and internal sources of nutrients and organic matter. This rate also has a strong influence on summer hypolimnetic oxygen levels that, in turn, can limit fish habitat and control nutrient cycling.

The HOD rate is typically expressed on an aerial basis (mg/m^2-day) and computed from temperature and dissolved oxygen profiles collected on dates when the water column is thermally stratified and before oxygen is depleted. The calculation assumes that HOD values are independent of dissolved oxygen concentration when the above conditions are met. In Onondaga and other productive lakes, depletion occurs rapidly and closely- spaced profiles (~weekly) are needed for accurate computation of HOD rates.

Table 12-8 lists computed HOD rates for Onondaga Lake based upon data collected at the Lake South station between 1986 and 1999. Computations are based upon temperature and dissolved oxygen measurements collected at 3-meter increments between 6 and 18 meters. Measurements collected at finer depth increments with HYDROLAB units may provide an improved basis for HOD calculations in recent years The 3-meter data have been used because they were reported consistently over the 1986 to 1999 period. Results indicate that the accuracy of HOD calculations is more likely to be controlled by temporal sampling frequency (biweekly) than by vertical spacing of the observations. While thermocline depths may vary somewhat from year to year, HOD rates are computed for each year based upon the change in volume-weighted-mean oxygen concentrations below 6 meters, a typical spring thermocline level for the Lake. The areal HOD rate is computed as the product of the volumetric depletion rate (mg/m^3-day) and the mean depth below the thermocline (8.3 meters for a thermocline depth of 6 meters).

As indicated in Table 12-8, computed HOD rates in 7 out of 14 years under-estimate actual values because of incomplete spring turnover and/or depletion of oxygen in a least part of the hypolimnion between the first and second stratified dates. HOD rates are positively correlated with hypolimnetic mean dissolved oxygen concentration at the end of the calculation period in years when that concentration is less than ~ 4 mg/liter. In other years with reasonably reliable HOD estimates, rates ranged from 1500 to 2400 mg/m^2-day, as compared with a range of 1100 to 1900 mg/m^2-day reported by Effler (1994). These values are well within the "eutrophic" range proposed by Mortimer (1941) (> 550 mg/m^2-day).

Walker (1979) developed relationships between HOD rates and other trophic state indices (phosphorus, chlorophyll-a, transparency) in northern temperate lakes. When apparent morphometric effects (represented by mean depth) were also considered, the model explained 91% of the variance in reported HOD values for 30 lakes with a residual standard error of 23%. For a lake with a fixed mean depth (in this case, 10.9 meters), the model equations can be condensed to a log-linear function of summer epilimnetic P concentration (Table 12-9, HOD = $42.3\ P^{0.94}$).

Observed and predicted HOD rates are plotted against predicted total phosphorus and year in Figure 12-20. Prediction intervals are computed from the residual standard error for the 1995-1999 period (CV = 21%). This standard error is similar to that computed from the model development data set (CV = 23%, Walker,1979). As for other trophic state indicators, the model tends to over-predict HOD rates in earlier years when phosphorus concentrations exceeded ~100 ppb and were not limiting algal growth.

As indicated in Table 12-9, HOD rates can be translated into other useful measures of oxygen status. The "Days of Oxygen Supply" (T_{DO}, Walker, 1979) is computed from the HOD rate, oxygen concentration at the onset of stratification (typically 12 ppm) and the mean hypolimnetic depth (in this case, 8.3 meters for a 6-meter thermocline depth). The T_{DO} value represents the theoretical number of days between the onset of stratification and depletion of all oxygen stored in the hypolimnion. Oxygen levels at the bottom of the hypolimnion are usually depleted before this occurs. The duration of the anoxic period (T_{ANOXIC}) is estimated by the difference between TDO and the duration of the stratified period (T_{STRAT} ~ 183 days, April 15 – October 15).

12.6 MODEL IMPLEMENTATION

The model network has been programmed on an Excel™ worksheet (Table 12-10). Variable categories include parameter values (constant across simulated cases), input values, and output values. Trophic state predictions are driven by lake outflow volume and inflow total phosphorus load, each referenced to a specified hydrologic period of record. Nitrogen models could added to the worksheet, but are not included in this version because they do not influence predictions of chlorophyll-a and related trophic state indicators.

The predicted response of each trophic state indicator to variations in phosphorus load are shown in Figure 12-21. Results are for average 1995-1999 hydrologic conditions (outflow volume = 399 hm^3/yr). The 80% prediction interval (10th, 50th,90th percentiles) is shown for each response variable. These intervals reflect the combined influences of sampling variations (uncertainty in loads and measured responses) and model error.

The following table lists projected lake phosphorus concentrations for various management scenarios involving combinations of Metro effluent P levels & nonpoint source load reductions:

	Total P Concentrations (ppb)				
	Assumed Inflow Concs.		Predicted Lake Conc.		
Scenario	Metro	NonPoint	Mean	10 %	90 %
Existing (1995-1999)	470	83	57	49	65
April 2006	120	83	30	26	35
April 2006 + 20% NPS	120	66	26	23	30
Dec 2012	20	83	23	20	26
Dec 2012 + 20% NPS	20	66	18	16	21
Metro Diversion	0	83	24	21	28
Diversion + 20% NPS	0	66	20	17	23

Lake P levels approach the 20 ppb criterion for management scenarios involving control of Metro load (either by diversion or by achieving the 2012 effluent P level of 20 ppb) and ~20% reduction in nonpoint load. The accuracy of these forecasts should improve with further refinement of the model framework, in particular, calibration to additional years under phosphorus-limited conditions.

12.7 CONCLUSIONS & RECOMMENDATIONS

1. Lake phosphorus concentrations have responded quickly to historical reductions in external phosphorus load. This suggests that lake P levels are controlled more by current loads and hydrologic regimes than by recycling of historical loads from lake bottom sediments. The latter may become more important with further reductions in external load, however.

2. Despite the observed phosphorus reductions, the trophic response of the lake to has been minimal because algal growth has been limited by factors other than phosphorus. As a consequence of cumulative reductions in phosphorus load, phosphorus limitation has become increasingly important as a factor controlling algal growth. Supporting evidence includes: (a) epilimnetic soluble reactive phosphorus concentrations were nearly depleted approached depletion during the summers of 1996-1999 and (b) chlorophyll-a, transparency, & hypolimnetic oxygen depletion rates approached levels that are consistent with predictions of empirical models calibrated to data from other phosphorus-limited lakes. With increased P limitation, it is expected that trophic state indicators will be more responsive to future reductions in lake P concentrations.

3. The empirical model network developed above can be used to forecast responses to future load reductions, assuming that relationships among lake phosphorus concentration, chlorophyll-a, and other trophic state indicators are similar to those characteristic of other phosphorus-limited lakes. Depending upon the magnitude of lake water quality improvements, periodic recalibration of the model may be necessary to track responses.

4. Model residual errors are similar to or below those expected based upon statistical analysis of other lake and reservoir datasets.

Recommendations for future enhancement of the model include:

An error analysis to partition lake time series and model residuals into measurement error, model error, and background year-to-year variability.

2. Extension of the model scope to include organic nutrient species (phosphorus, nitrogen, carbon), which have been shown to be correlated with phosphorus and chlorophyll-a concentrations in phosphorus-limited lakes and reservoirs (Walker, 1985;1996).

3. Extension of the model scope to include near-shore transparencies based upon observed correlations with Secchi depths at the Lake South station. This would enable direct evaluation of conditions at recreational areas relative to New York's 4-foot transparency criterion for bathing beaches.

4. Investigation of the potential effects of differences in the forms and timing of P inputs from the various sources on model performance. A kilogram of particulate phosphorus discharged from a tributary during the winter has the same impact on predicted summer chlorophyll-a levels as a kilogram of dissolved phosphorus discharged to the epilimnion during the summer. Because of phosphorus storage, transformations, and recycling within the lake, the actual responses would not necessarily be significantly different. Differences in P forms and timing may be important to forecasting the effects of reductions in Metro P load. These effects can be investigated statistically (by examining model residuals) and experimentally (by performing laboratory studies of bioavailability / Algal Growth Potential on representative samples from major phosphorus sources). Periodic recalibration of the model network as reductions in external loads are accomplished will improve forecast accuracy and provide a basis for identifying differential responses to the forms and timing of phosphorus inputs.

5. Integration of data from other regional lakes. This would provide additional information for model calibration and a local frame of reference for interpreting current and projected lake conditions.

6. Coupling of the phosphorus balance model with a simplified watershed model that allows prediction of lake phosphorus loads as a function of land use and non-point source control measures.

   Development of software to facilitate evaluation of management scenarios involving implementation of alternative point-source and non-point-source control measures under a range of hydrologic conditions.

8. Modification of the mass-balance framework to allow generation of daily flow & load data sets. This information would be useful for diagnostic purposes and for supporting the development and application of a mechanistic lake model. The latter would provide alternative projections of lake responses to reductions in phosphorus loads and potentially address a broader range of management questions.

12.7 REFERENCES

Canfield, D.E. and R.W. Bachman, "Prediction of Total Phosphorus Concentrations, Chlorophyll-a, and Secchi Depths in Natural and Artificial Lakes", Canadian Journal of Fisheries and Aquatic Sciences, Vol. 30, No. 4, pp. 414-423, 1981.

Carlson, R.E., "A Trophic State Index for Lakes", Limnology and Oceanography, Vol. 22, No. 2, pp. 361-369, 1977.

Chapra, S.C., "Comment on an Empirical Method of Estimating the Retention of Phosphorus in Lakes, by W. B. Kirchner & P.J. Dillon", Water Resources Bulletin, Vol. 11, No. 6, pp. 1033-1034, 1975.

Dillon, P.J. and F.H. Rigler, "The Phosphorus-Chlorophyll Relationship in Lakes", Limnology & Oceanography, Vol. 19, No. 5, pp. 767-773, 1974.

Ecologic, LLC et al., "Onondaga Lake Monitoring Program, 1998 Annual Report", prepared for Onondaga County, New York, February 2000.

Effler, S.W., Limnological and Engineering Analysis of a Polluted Urban Lake, Springer, New York, 832 pp., 1994.

Heiskary, S.A. & W.W. Walker, "Developing Phosphorus Criteria for Minnesota Lakes". Lake & Reservoir Management, Vol. 4, No. 1, pp. 1-9, 1988.

Jones, J.R. & R.W. Bachman, "Prediction of Phosphorus and Chlorophyll Levels in Lakes", Journal of the Water Pollution Control Federation, Vol. 48, No. 9, pp. 2176-2182, 1976.

Mortimer, C.H., "The Exchange of Dissolved Substances Between Mud and Water in Lakes, Parts II and II", Journal of Ecology, Vol. 29, pp. 280-329, 1941.

Sas, H., Lake Restoration by Reduction of Nutrient Loading: Expectations, Experiences, Extrapolations, Academia Verlag, ISBN 3-88345-379-X, 1989.

Vollenweider, R.A., "Possibilities and Limits of Elementary Models Concerning the Budget of Substances in Lakes", Arch. Hydrobiol., Vol. 66, No. 1, pp. 1-36, April 1969.

Walker, W.W., "Use of Hypolimnetic Oxygen Depletion Rate as a Trophic State Index for Lakes", Water Resources Research, Vol. 15, No. 6, pp. 1463-1470, December 1979.

Walker, W.W., "A Sensitivity and Error Analysis Framework for Lake Eutrophication Modeling' Water Resources Bulletin, Volume 19, No. 1, pp. 53-59, February 1982.

Walker, W.W., "Statistical Bases for Mean Chlorophyll-a Criteria", in "Lake and Reservoir Management - Practical Applications", Proc. 4th Annual Conference, North American Lake Management Society, McAfee, New Jersey, pp. 57-62, October 1984.

Walker, W.W., "Empirical Methods for Predicting Eutrophication in Impoundments - Report 3: Model Refinements", prepared for Office, Chief of Engineers, U.S. Army, Washington, D.C., Technical Report E 81-9, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, Draft 1983, published March 1985.

Walker, W.W., "AUTOFLUX ", Load Computation Software & Documentation, prepared for Onondaga County Department of Drainage & Sanitation and Stearns & Wheler, LLC, 1995.

Walker, W.W., "Simplified Procedures for Eutrophication Assessment and Prediction", U.S. Army Corps of Engineers, Waterways Experiment Station, Instruction Report W-96-2, September 1996.

Walmsley, R.D., "A Chlorophyll-a Trophic Status Classification System for South African Impoundments", Journal of Environmental Quality, Vol. 13, No. 1, pp. 97-104, 1984.

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12-6 Yearly Total Phosphorus Balances

12-7 Yearly Total Nitrogen Balances

12-8 Model Calibration Data

12-9 Model Equations

12-8 Model Inputs & Outputs

Figure 12-1

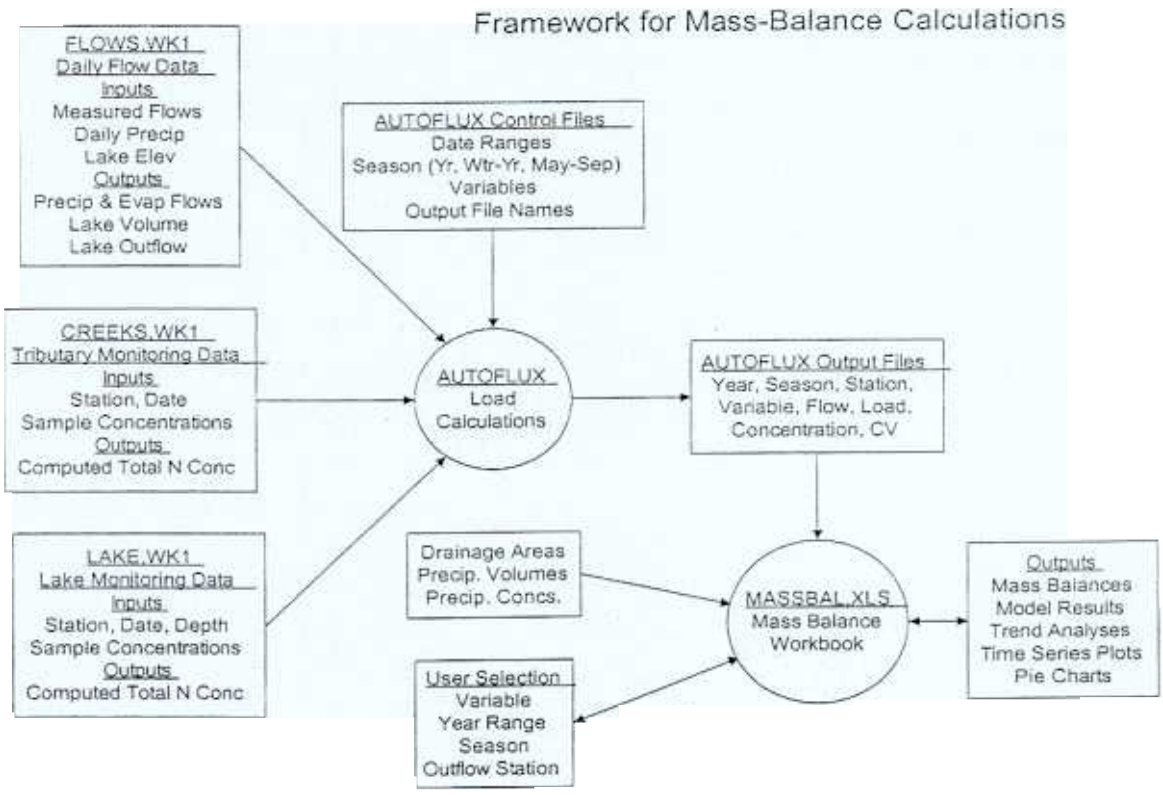

Framework for Mass-Balance Calculations
FLOWS.WK1
Daily Flow Data
Inputs
Measured Flows
Daily Precip
Lake Elev
Outputs
Precip & Evap Flows
Lake Volume
Lake Outflow
AUTOFLUX Control Files
Date Ranges
Season (Yr, Wtr-Yr, May-Sep)
Variables
Output File Names
CREEKS.WK1
Tributary Monitoring Data
Inputs
Station, Date
Sample Concentrations
Outputs
Computed Total N Conc
AUTOFLUX
Load
Calculations
AUTOFLUX Output Files
Year, Season, Station,
Variable, Flow, Load,
Concentration, CV
LAKE.WK1
Lake Monitoring Data
Inputs
Station, Date, Depth
Sample Concentrations
Outputs
Computed Total N Conc
Drainage Areas
Precip. Volumes
Precip. Concs.
MASSBAL.XLS
Mass Balance
Workbook
Outputs
Mass Balances
Model Results
Trend Analyses
Time Series Plots
Pie Charts
User Selection
Variable
Year Range
Season
Outflow Station

Figure 12-2

Eutrophication Model Network for Onondaga Lake

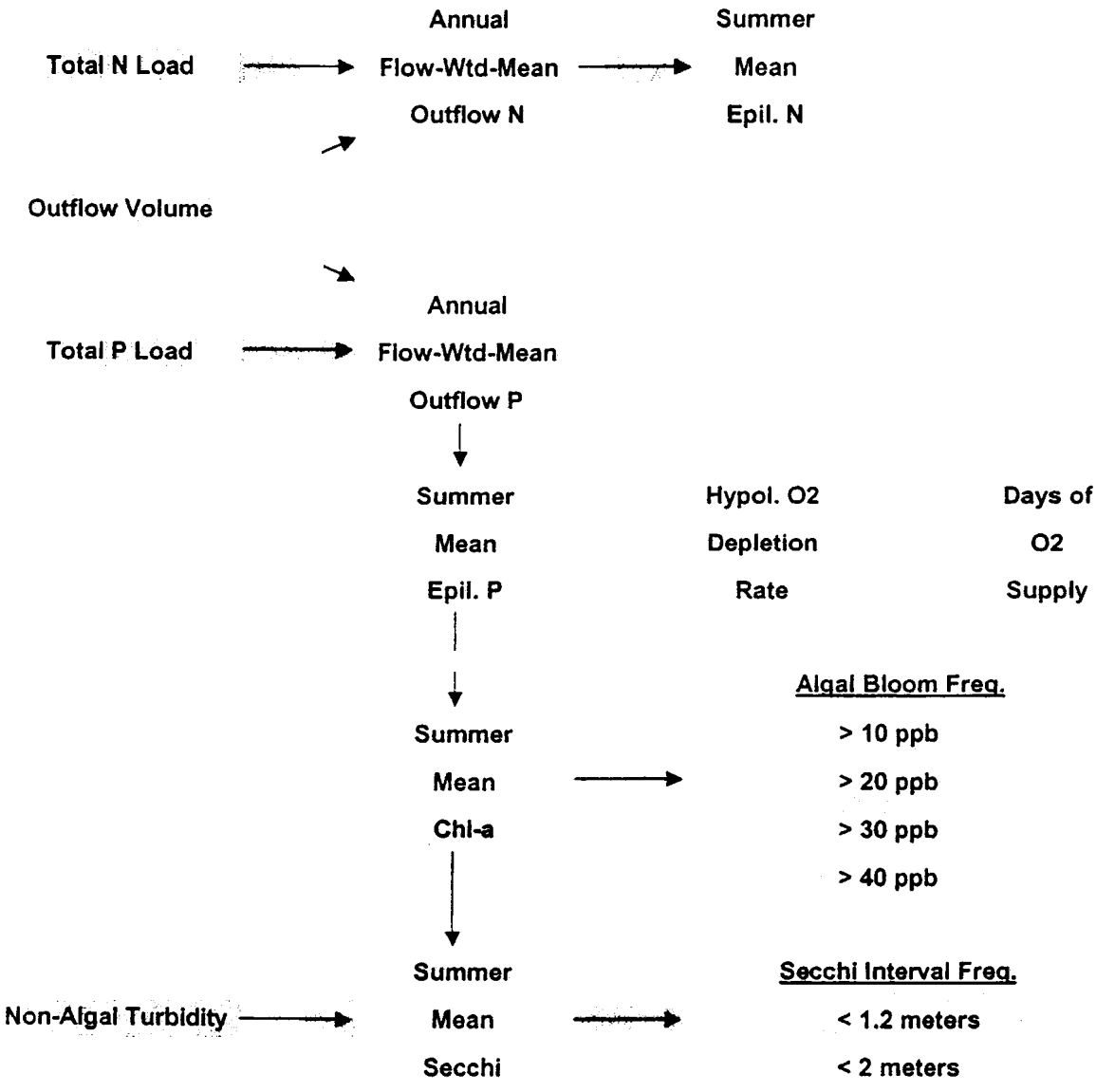


Figure 12-3
Lake Inflow Time Series

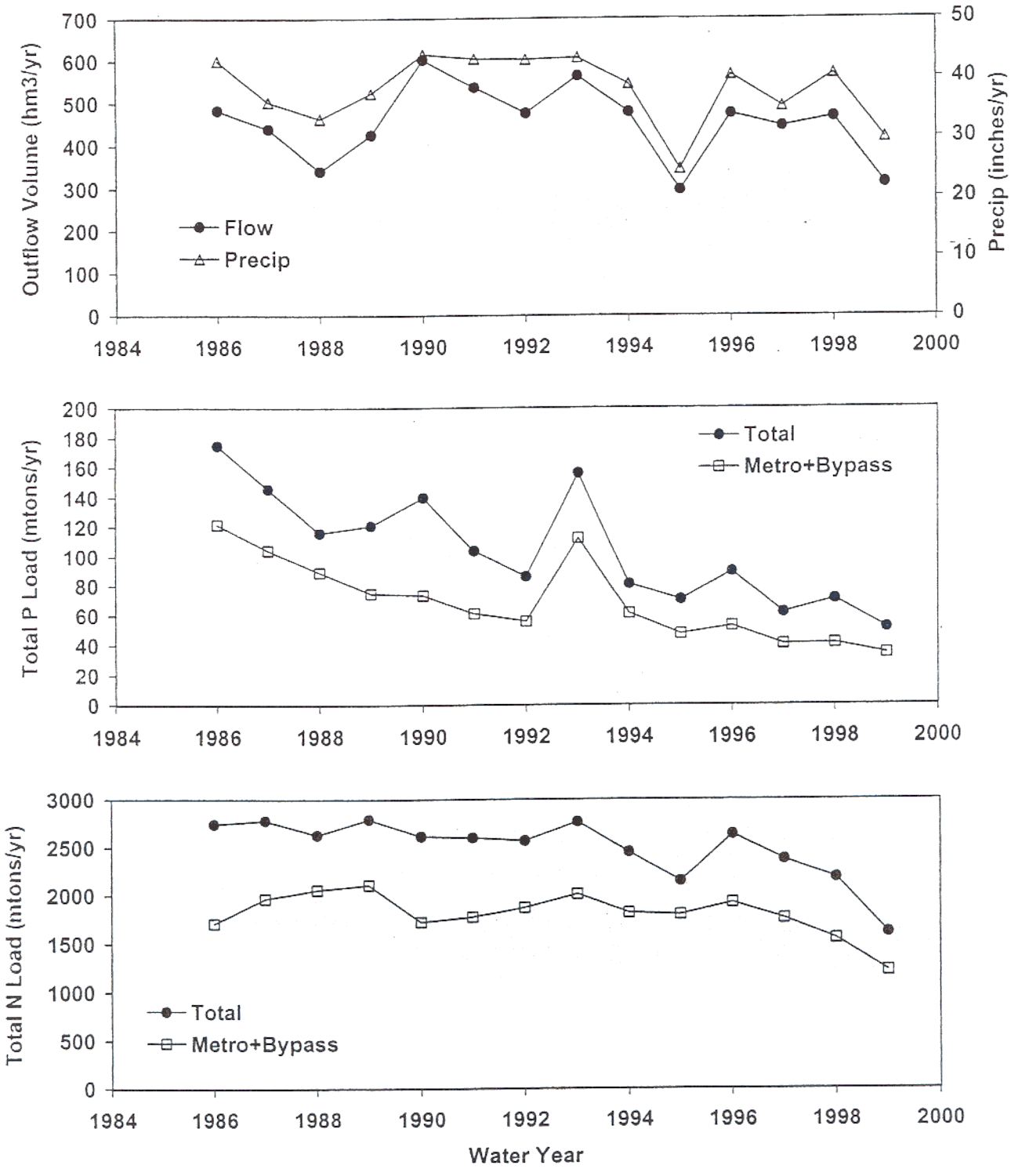


Figure 12-4
Observed & Predicted Annual Outflow P Concentrations

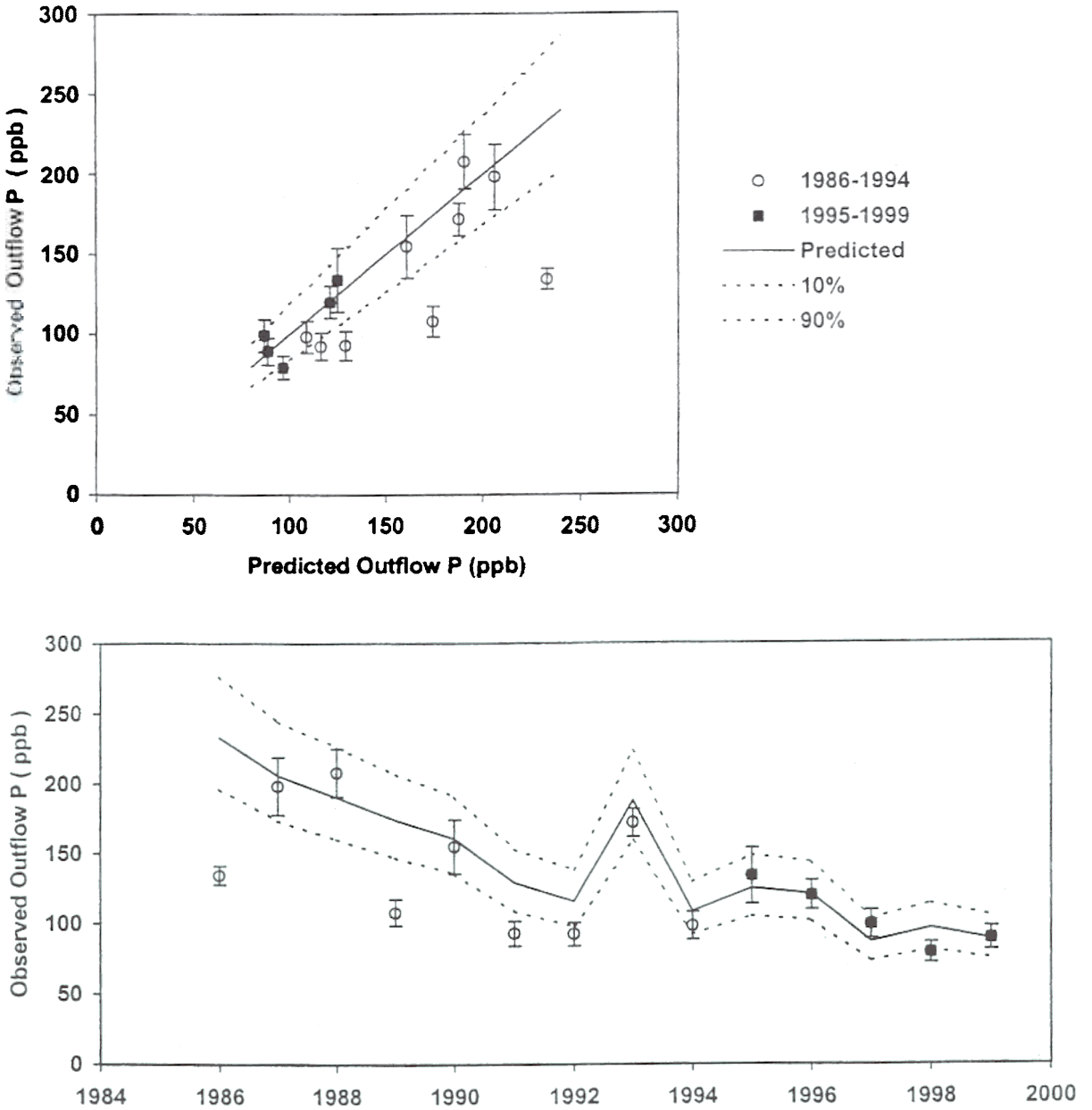


Figure 12-5
Observed & Predicted Summer Epilimnetic P Concentrations

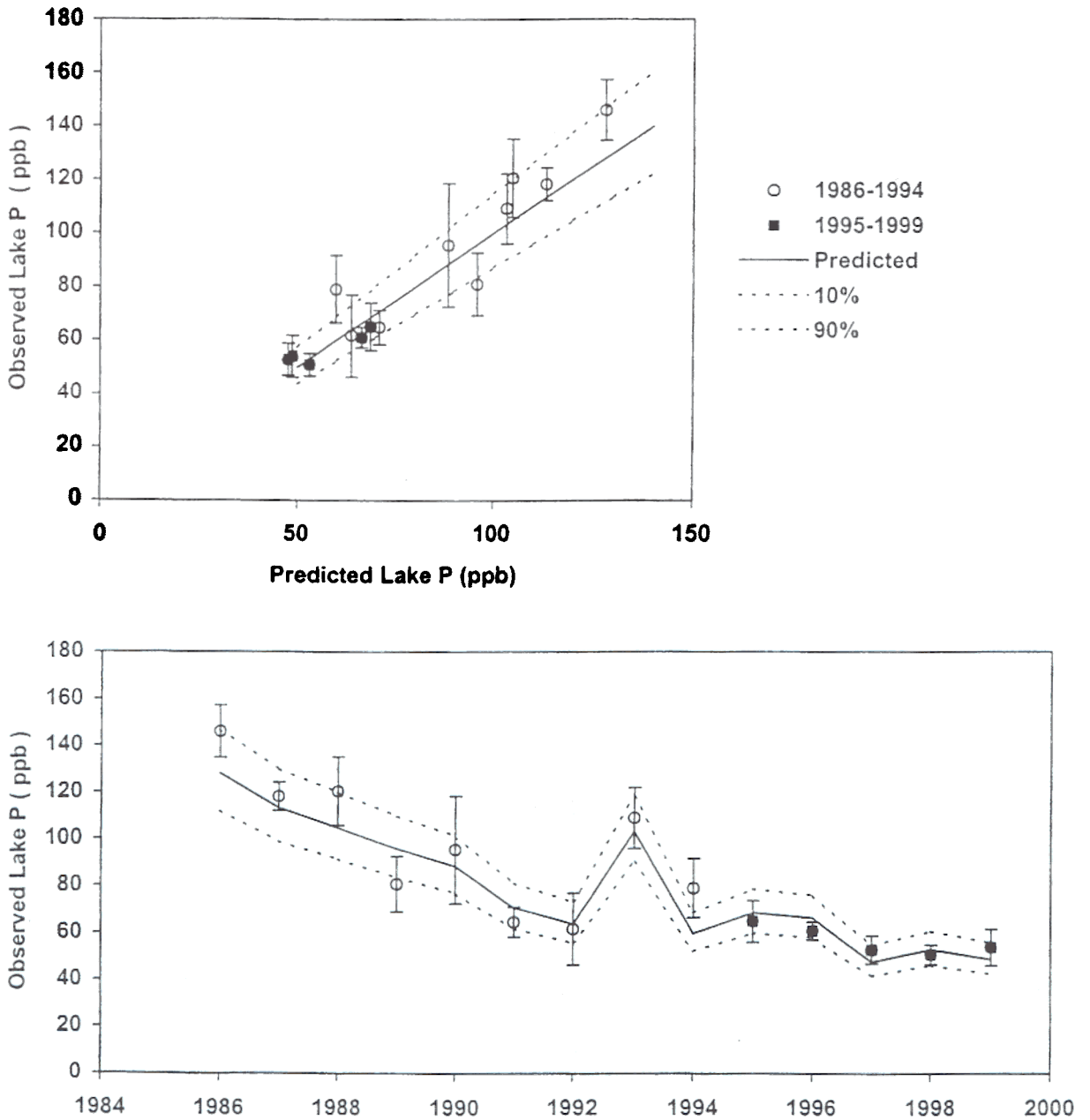
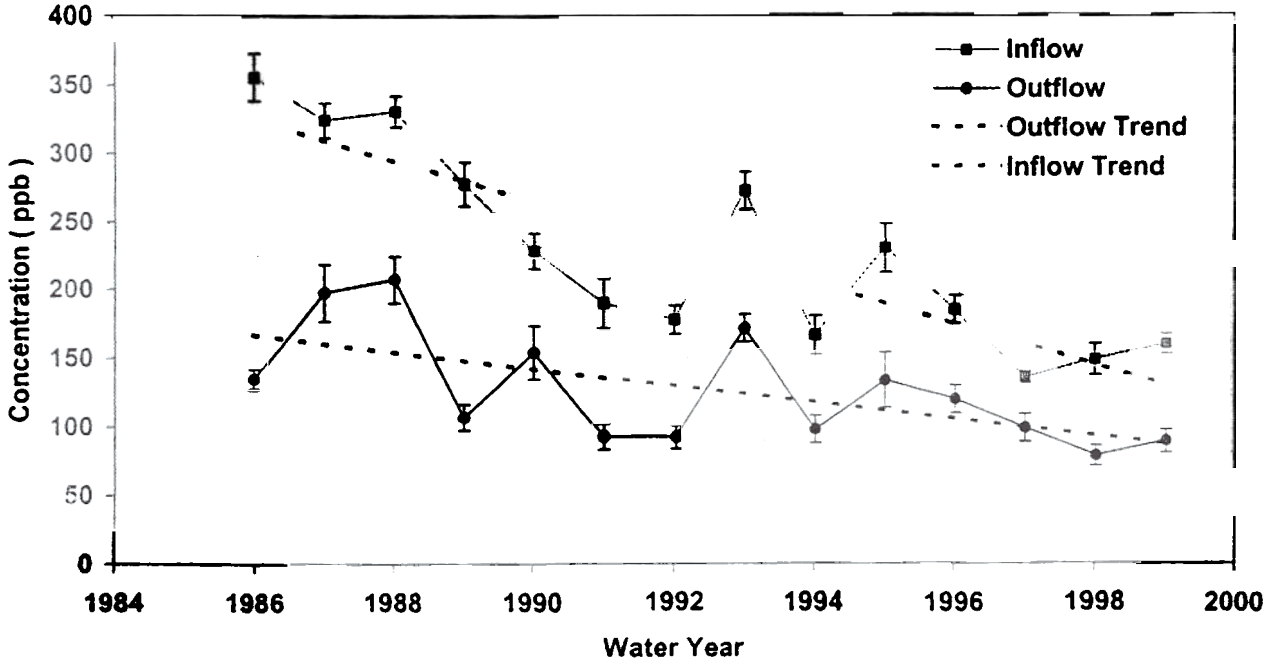


Figure 12-6
Long-Term Trends in Phosphorus Concentration & Load



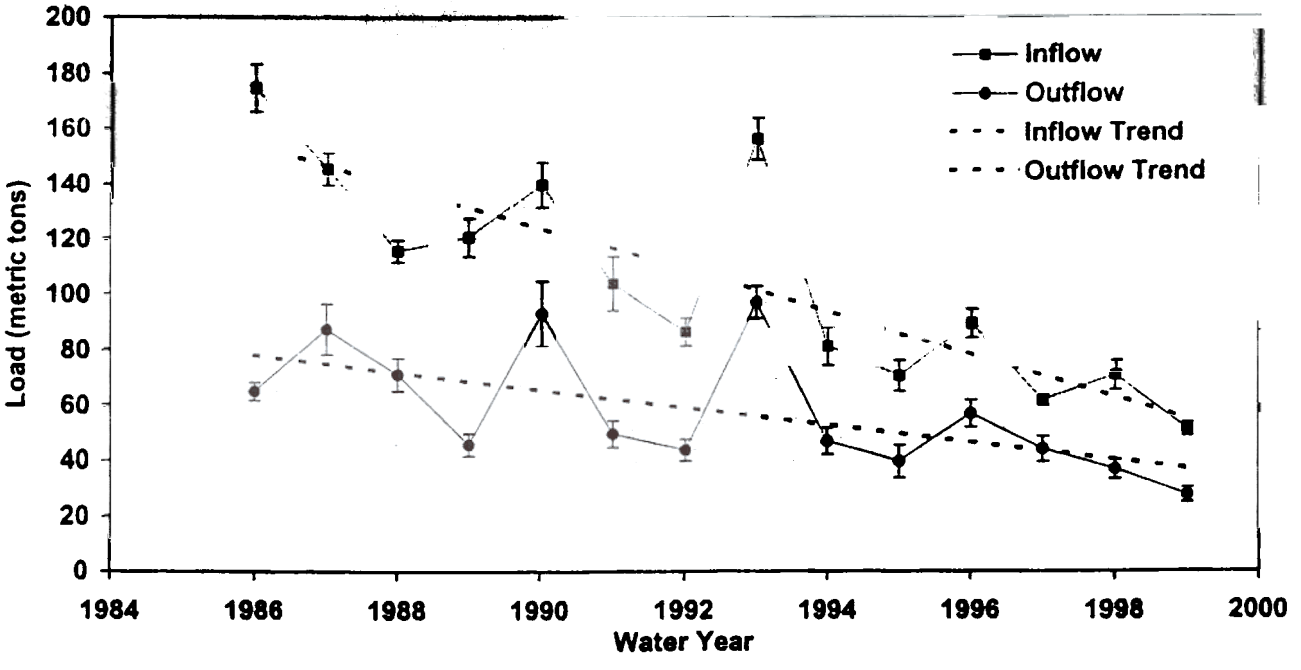


Figure 12-7
Observed & Predicted Annual Outflow N Concentrations

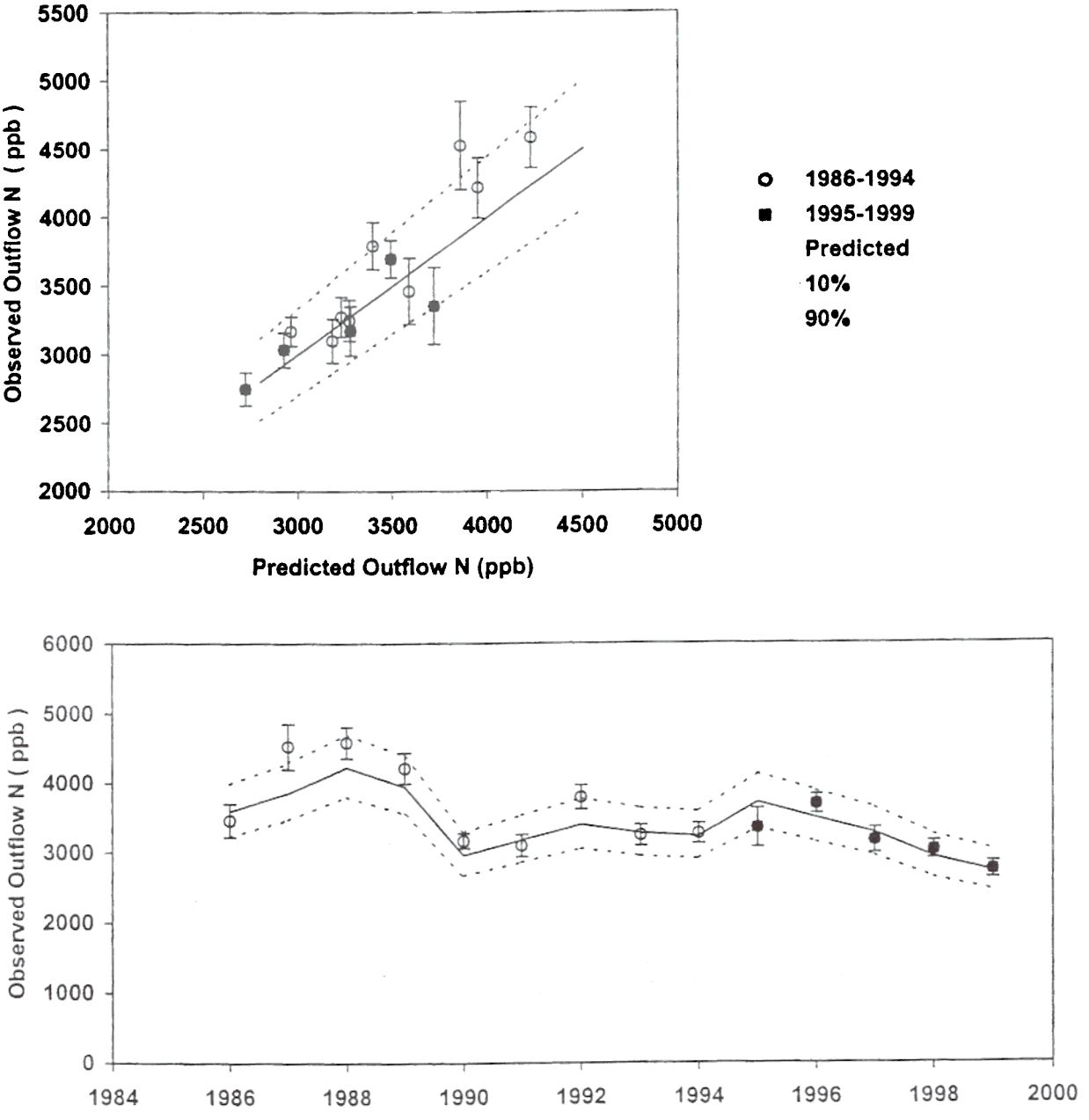
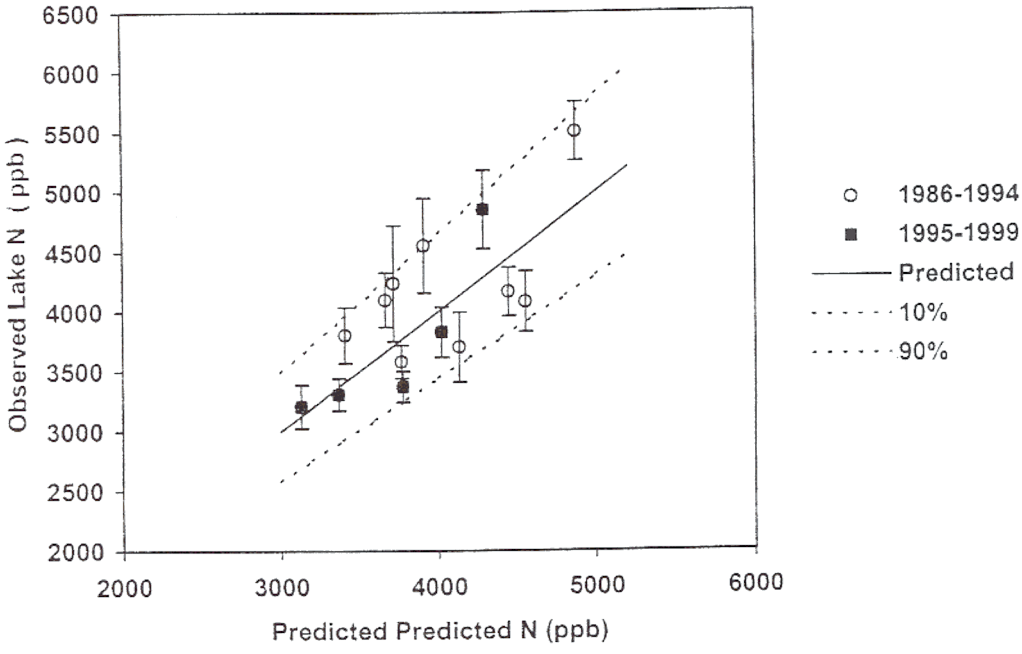


Figure 12-8
Observed & Predicted Summer Total N Concentrations



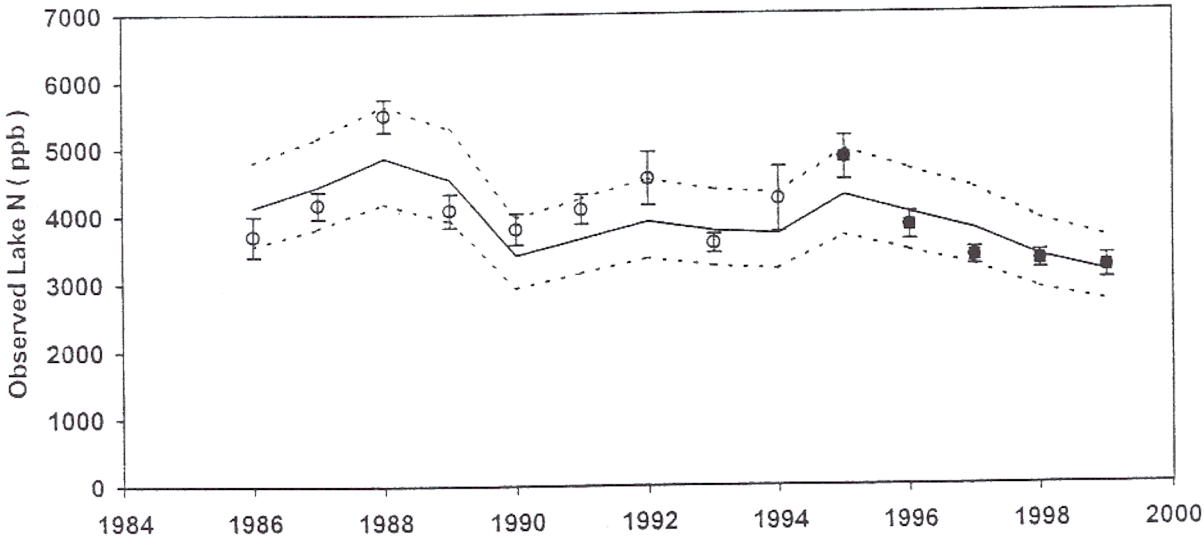
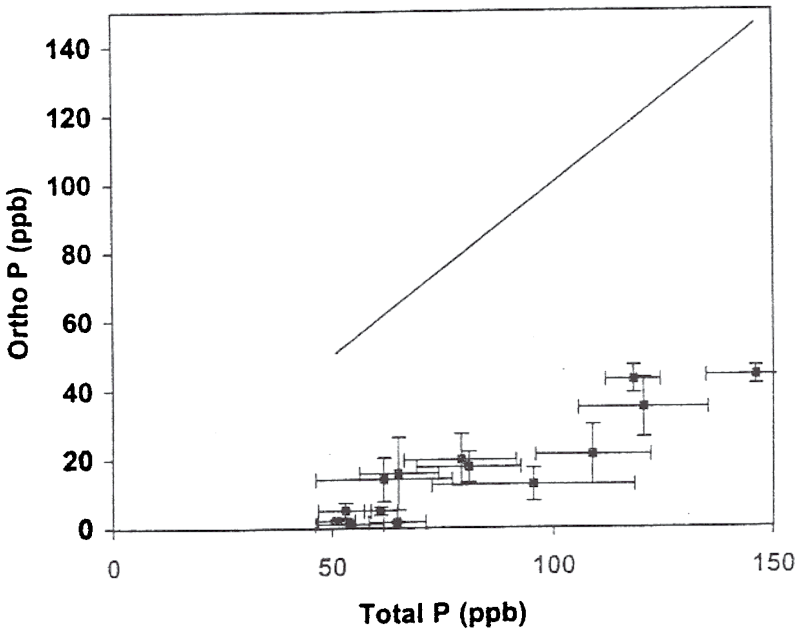
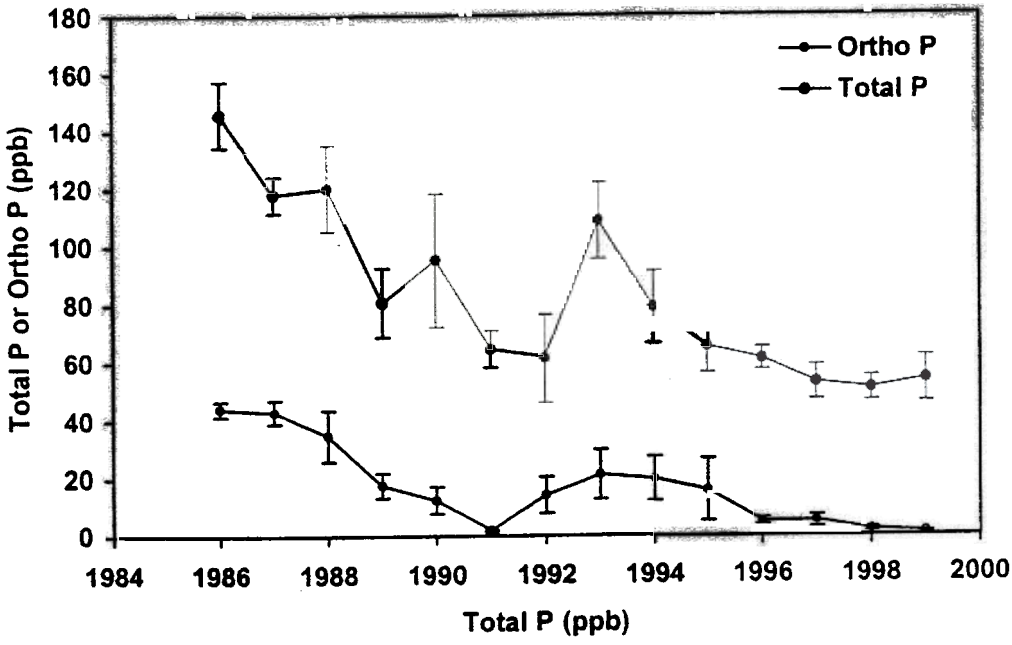


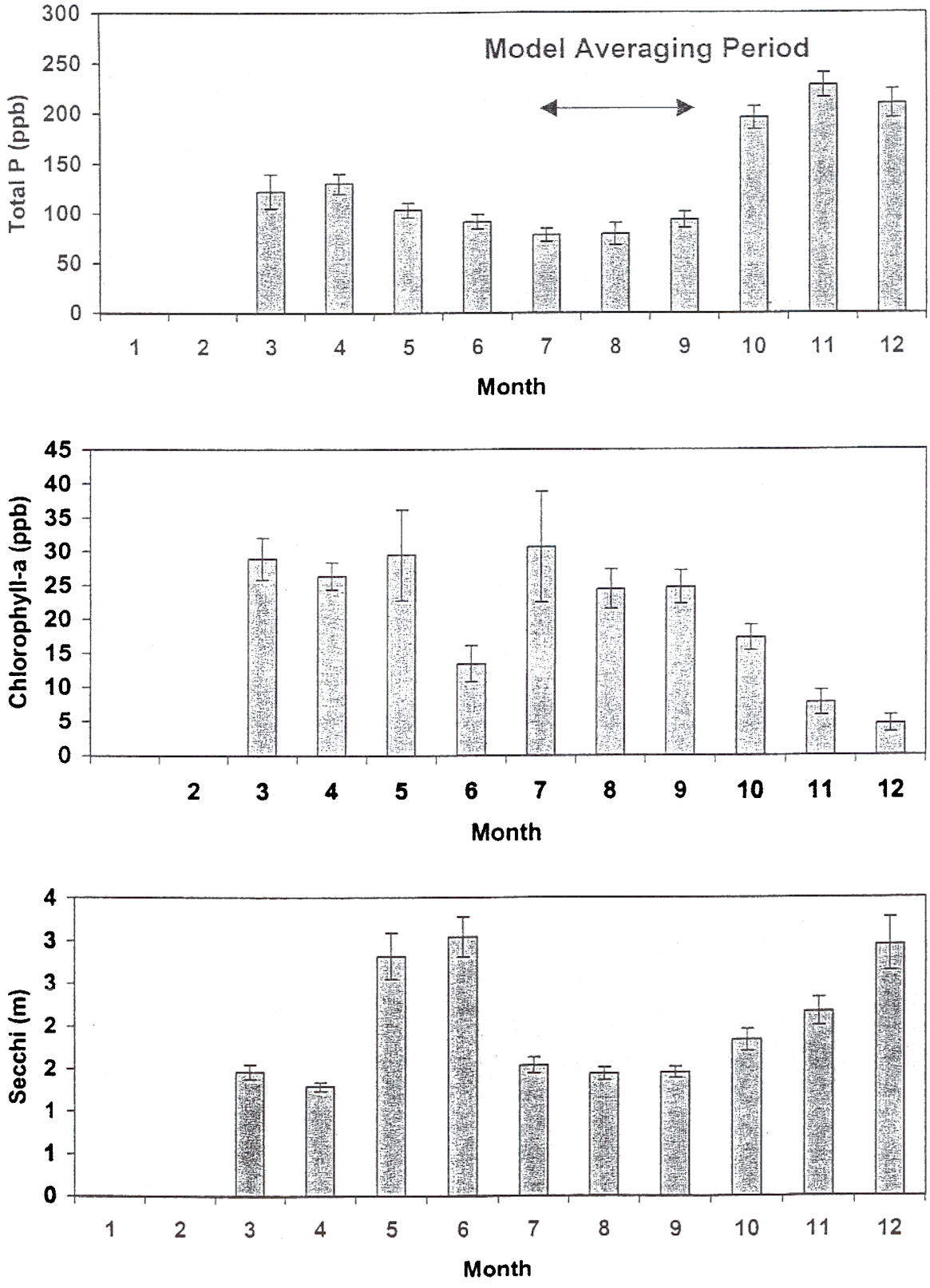
Figure 12-9
Ortho P vs. Total P Concentrations
July-September Means, 0-3 meters, Lake South Station





Error bars show mean +/- 1 standard error

Figure 12-10
Season Variations in Trophic State Indicators



Means +/- 1 Standard Error, 1986-1999, 0-3 meters, Lake South

Figure 12-11
Observed & Predicted Mean Chlorophyll-a

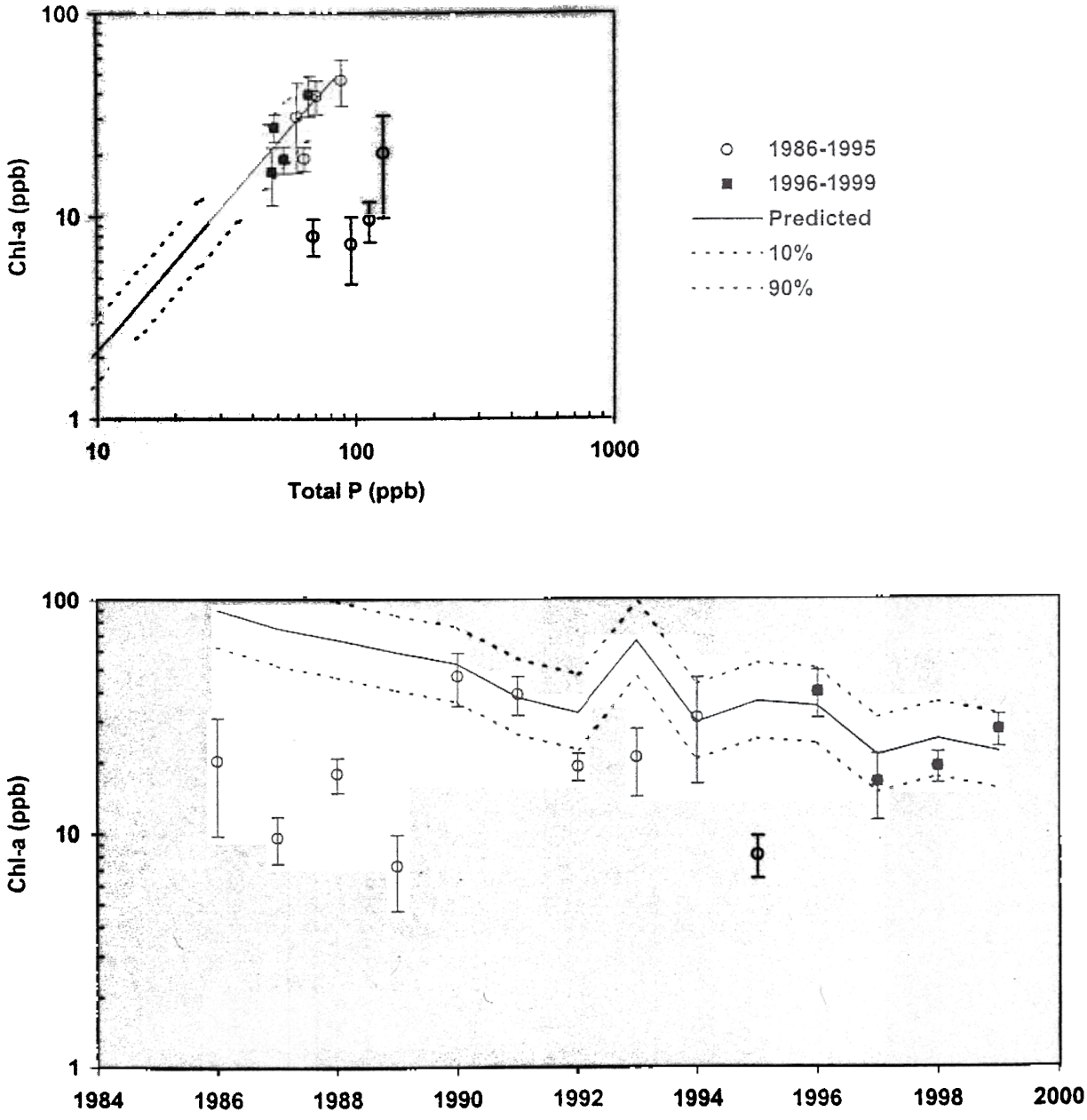


Figure 12-12

Algal Bloom Frequencies vs. Observed Mean Chlorophyll-a

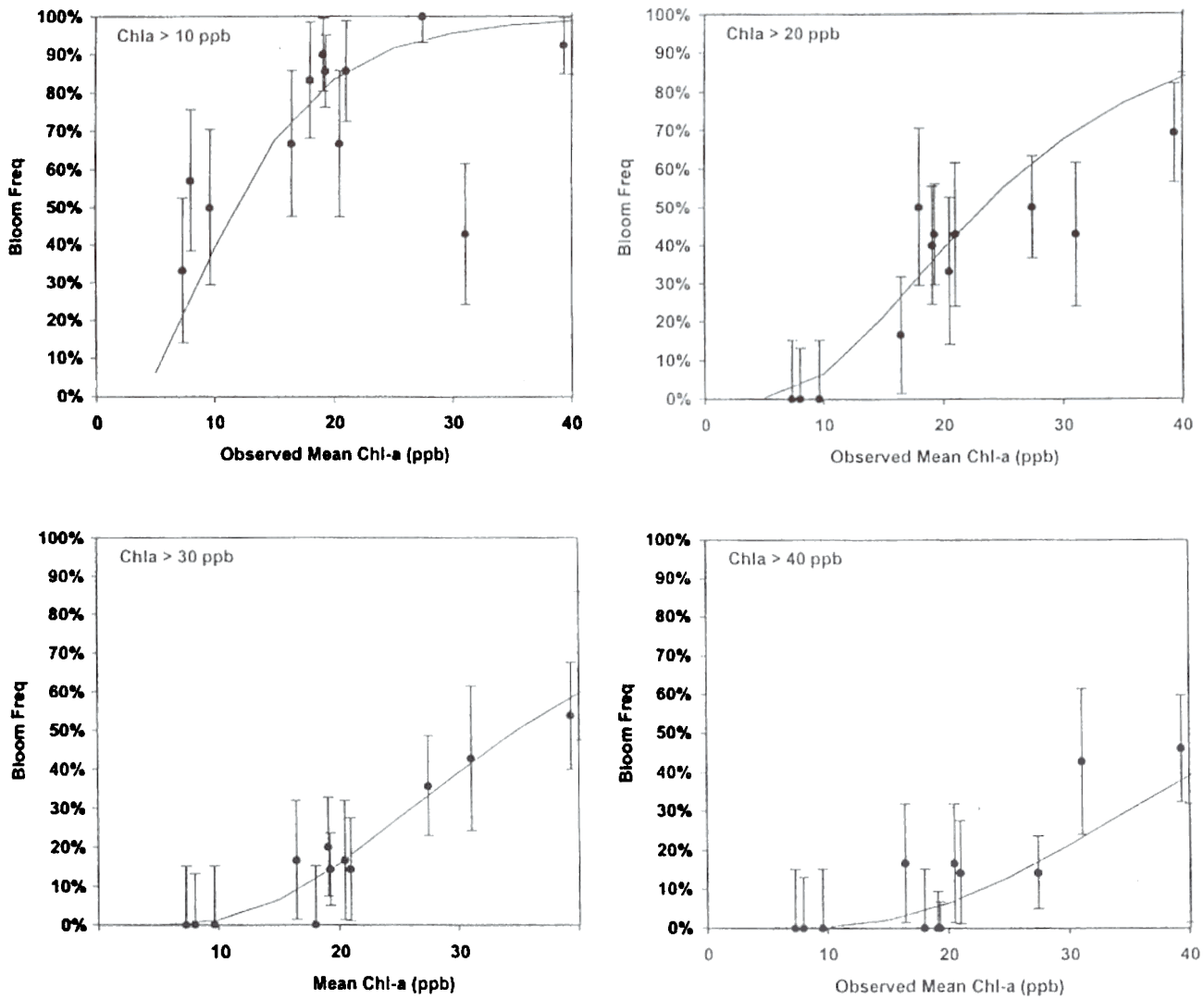


Figure 12-13
Algal Bloom Frequencies vs. Predicted Total Phosphorus

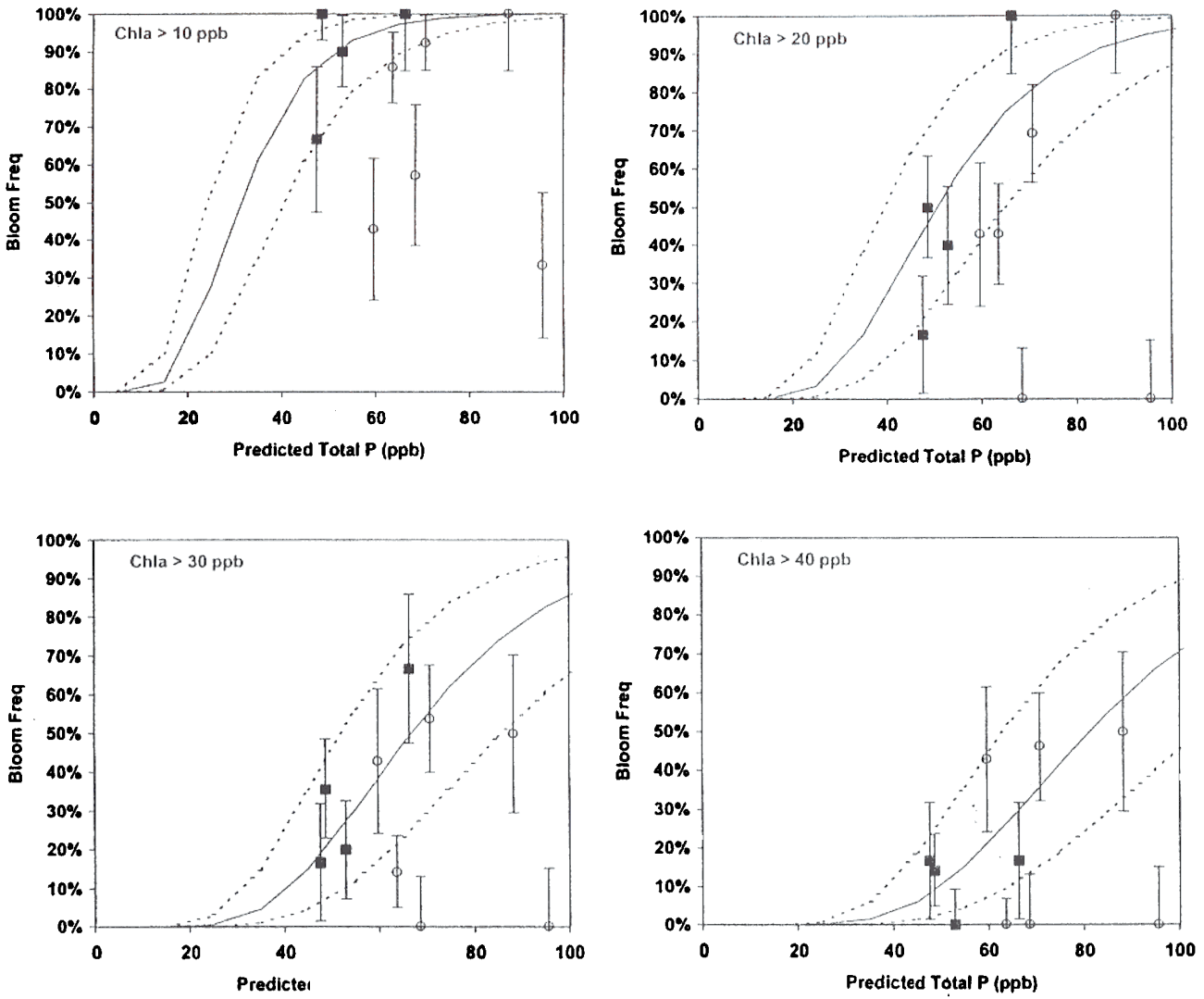


Figure 12-14
Algal Bloom Frequencies vs. Year

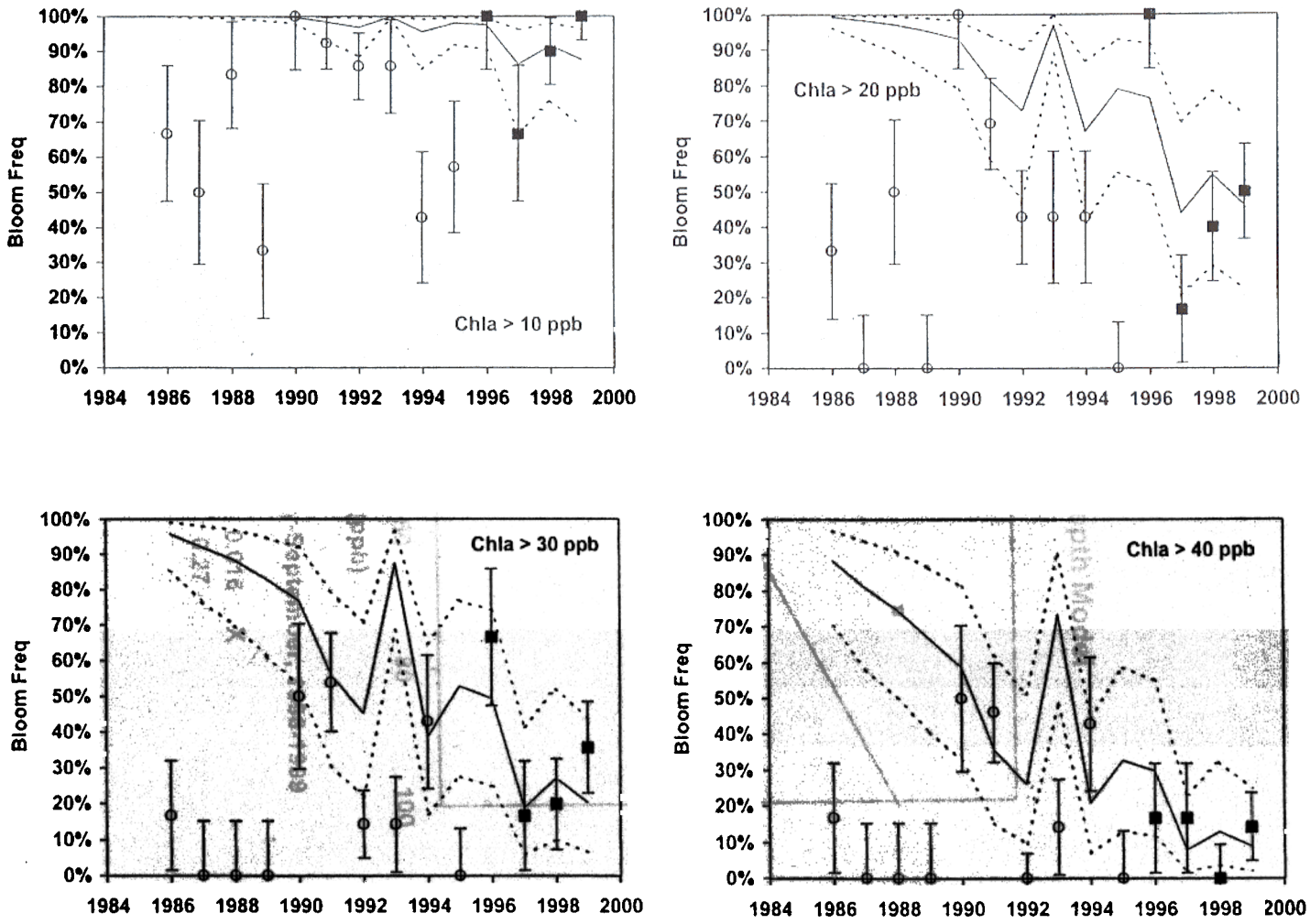
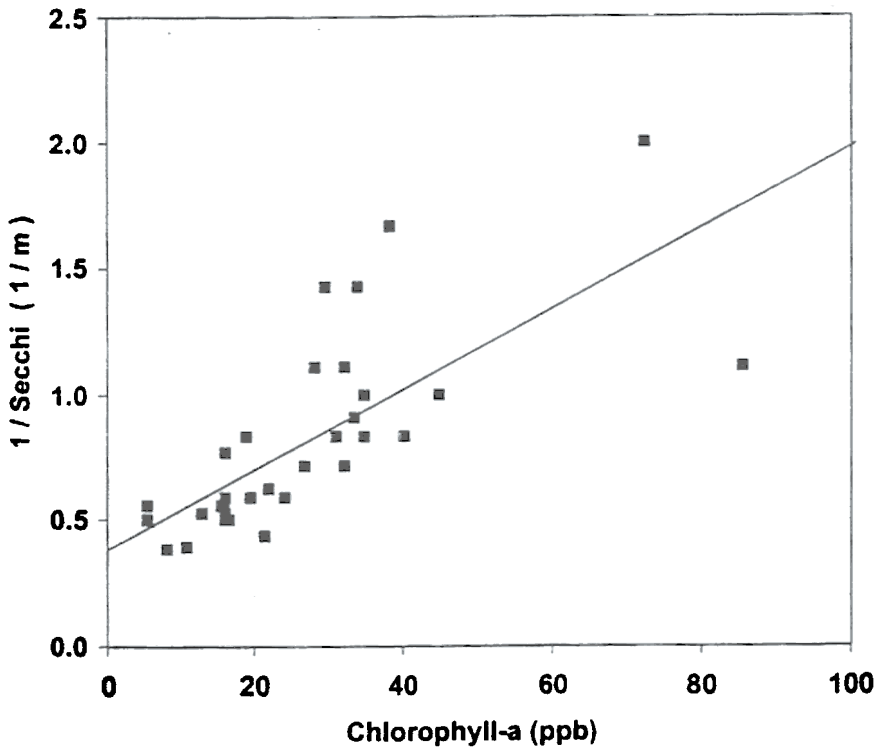


Figure 12-15
Calibration of Secchi Depth Model

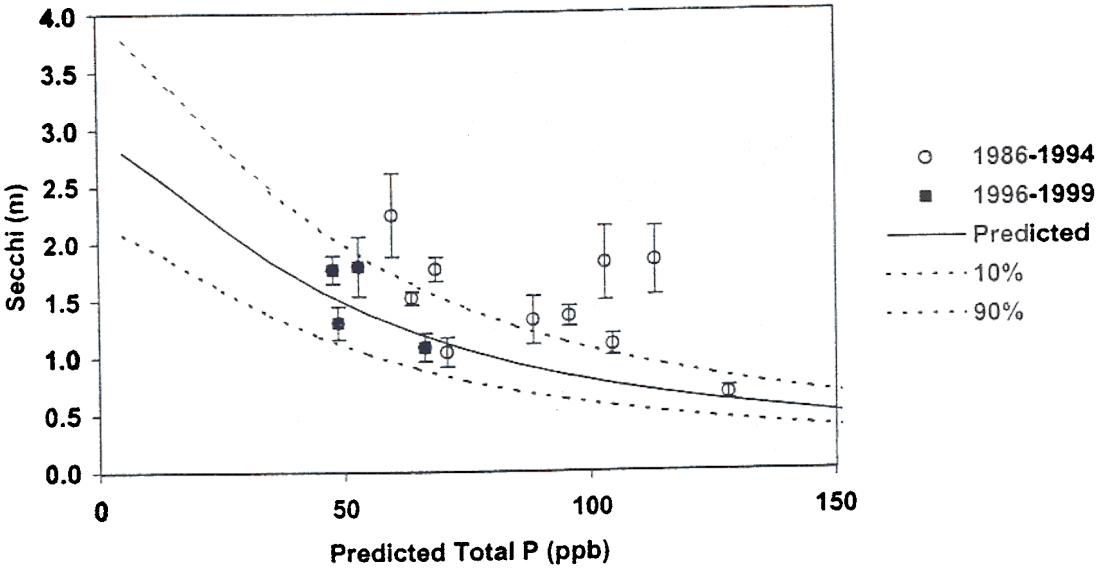


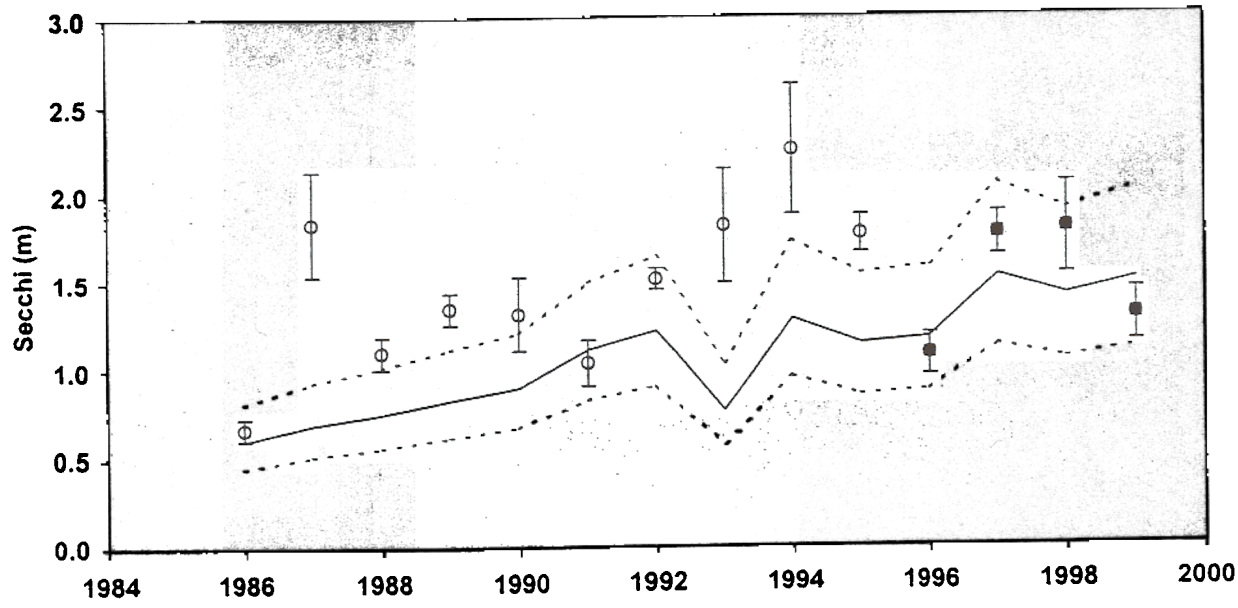
Lake South Epilimnion Samples, 0-3 m, July-September, 1996-1999
Regression:

$Y = 0.381 + 0.016 X$

$R^2 = 0.53$ SE = 0.27

Figure 12-16
Observed & Predicted Secchi Depth





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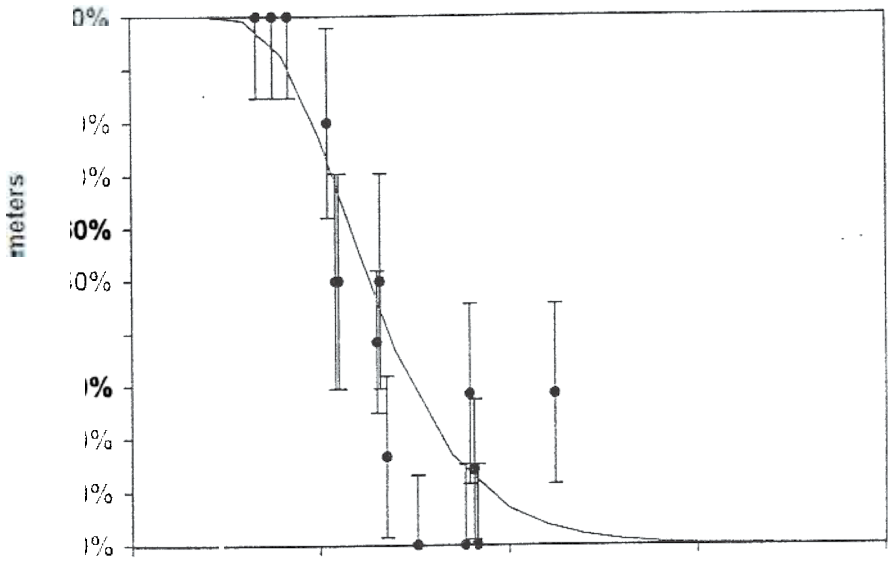

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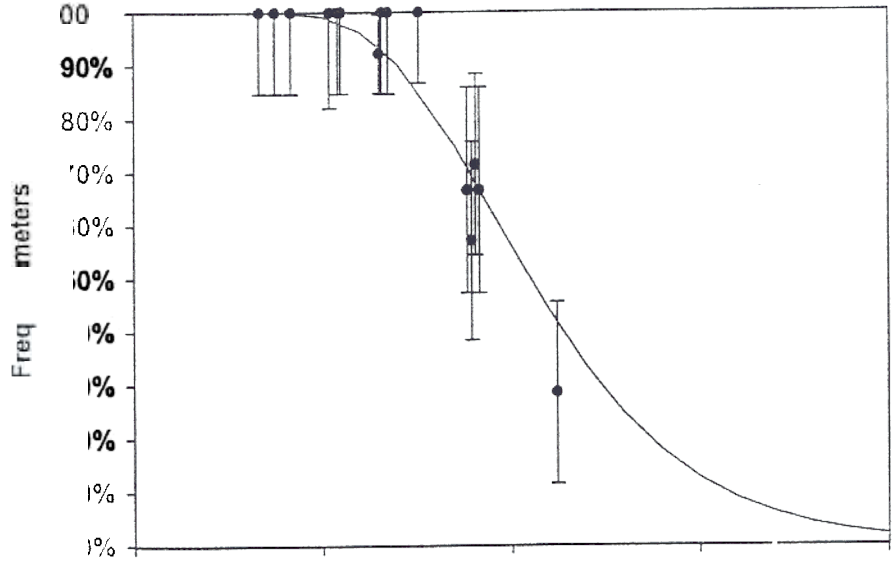

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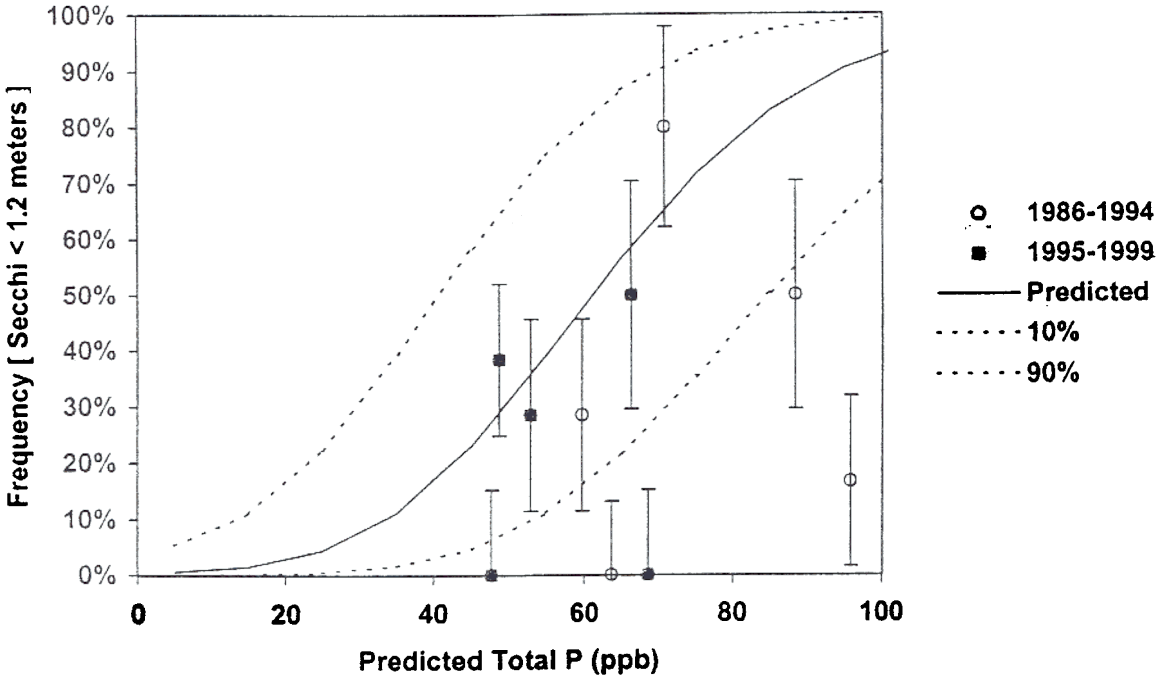
Figure 12-18
Observed & Predicted Frequency of Secchi < 1.2 meters



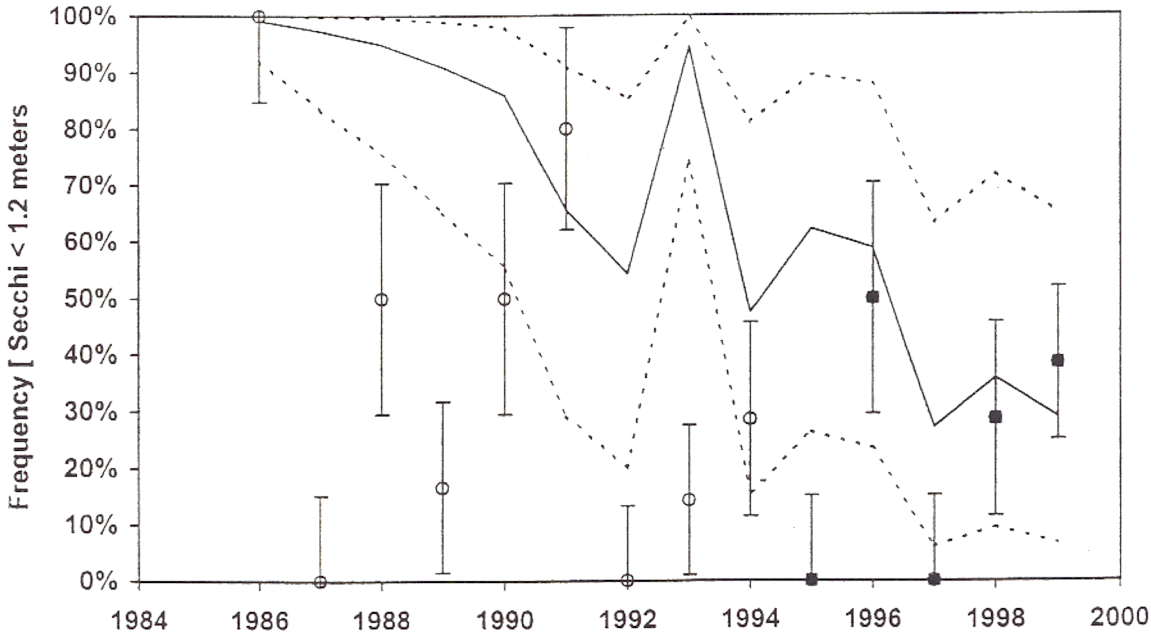
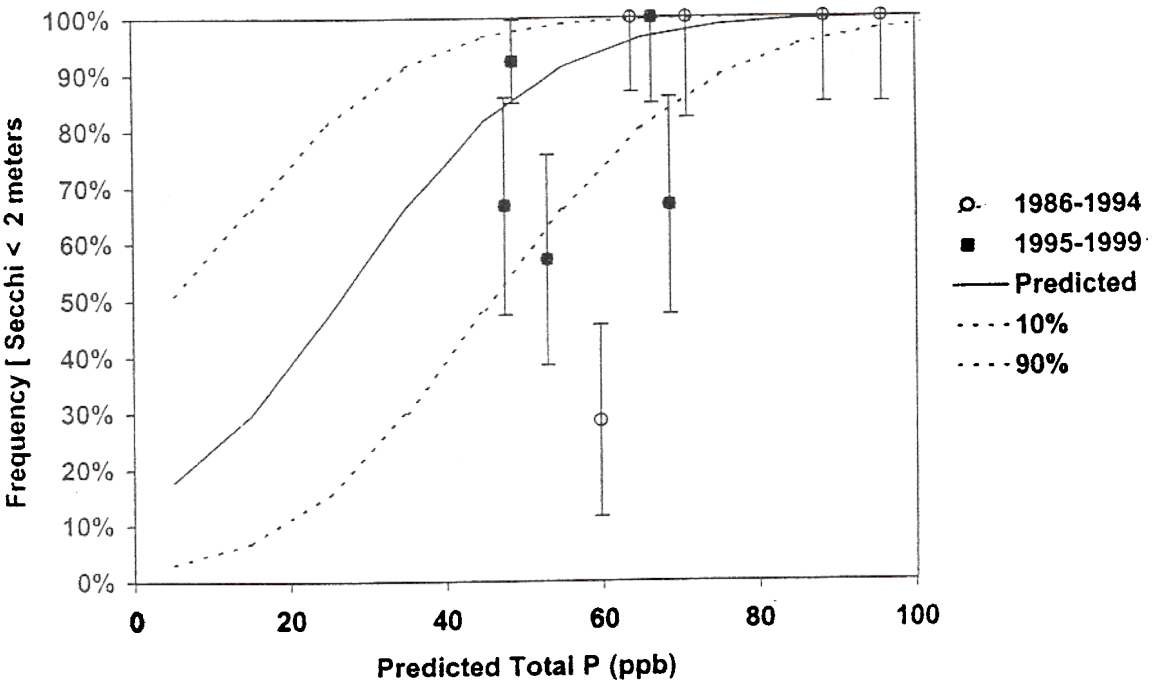


Figure 12-19
Observed & Predicted Frequency of Secchi < 2 meters



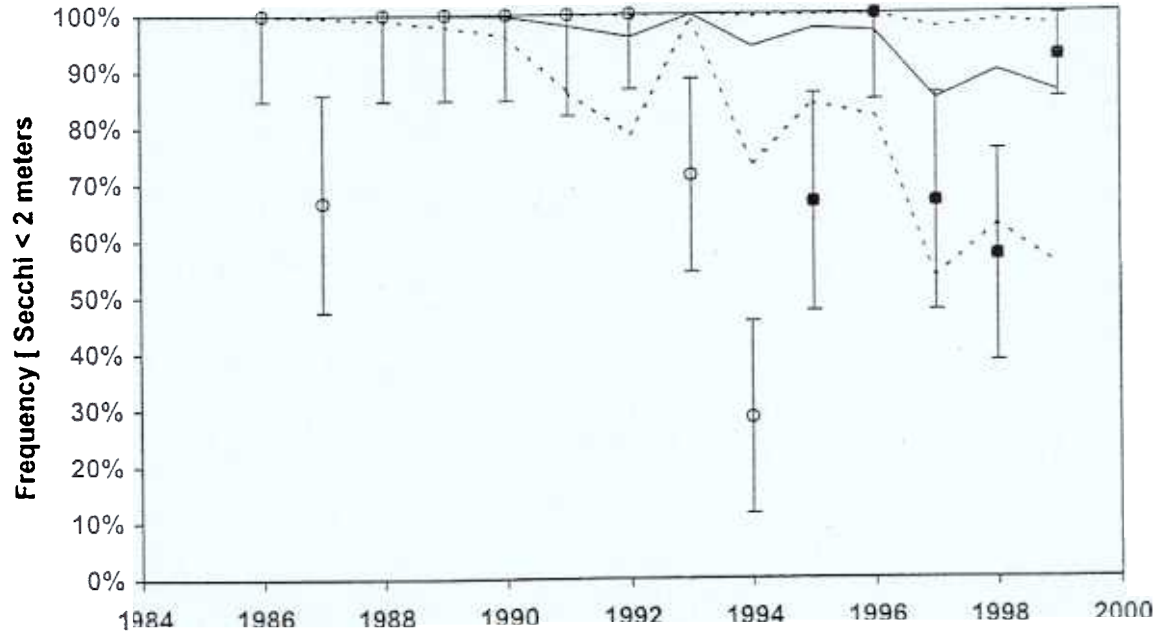
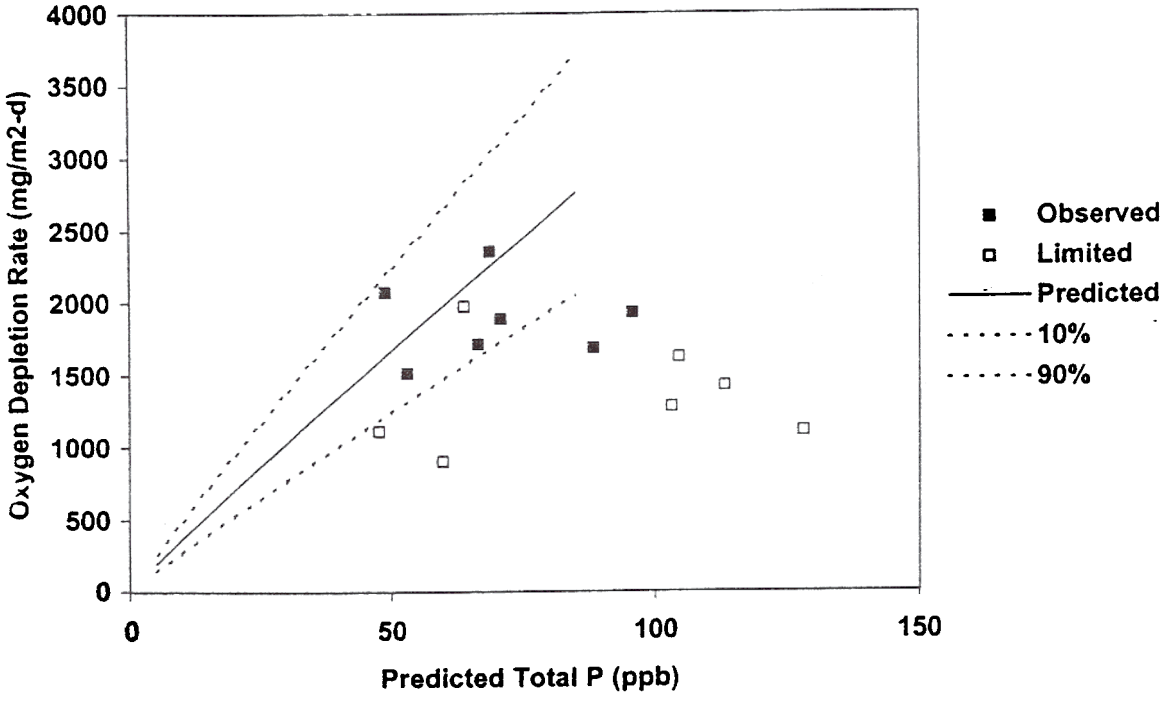
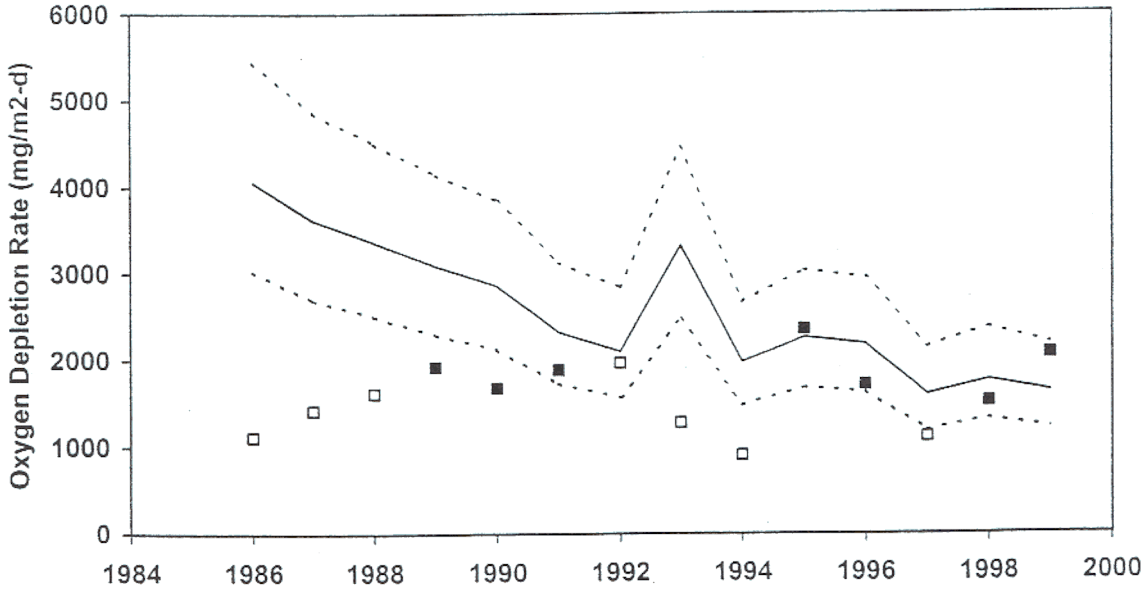


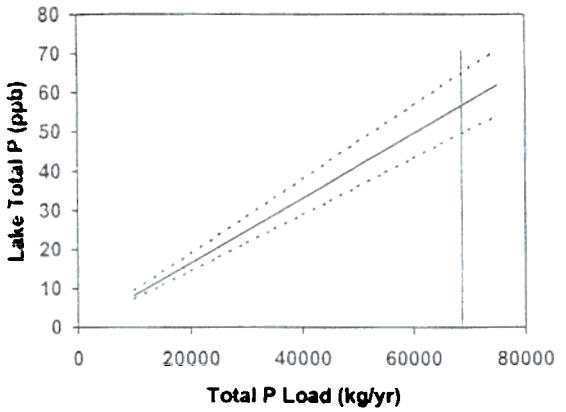
Figure 12-20
Observed & Predicted Hypolimnetic Oxygen Depletion Rates





Limited = observed value limited by incomplete spring turnover or partial depletion of oxygen; lower limit of actual value

Figure 12-21



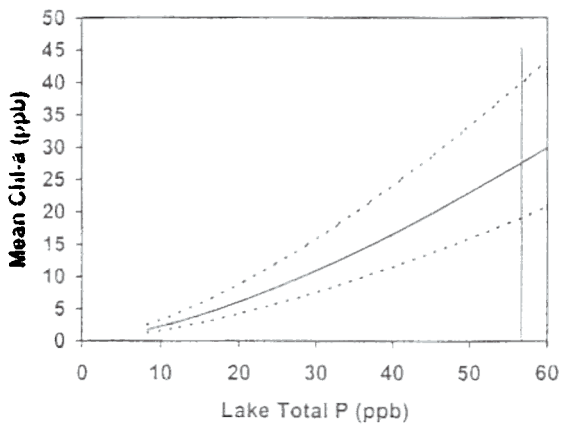
Predicted Lake Responses to Reductions in Phosphorus Load

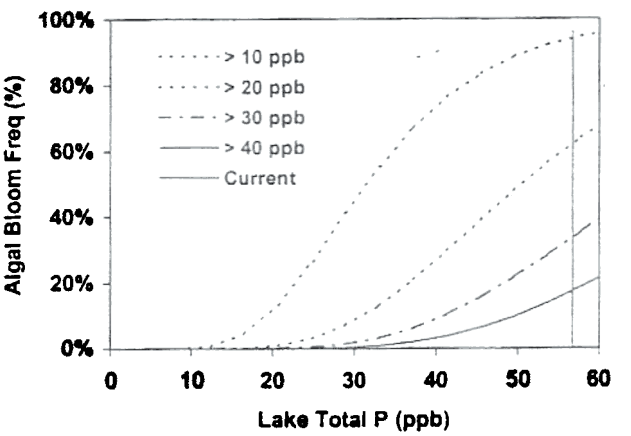
Base Conditions (1995-1999)

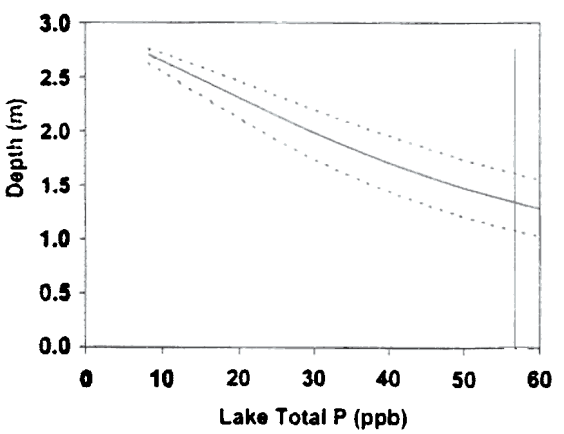
Average Outflow = 399 hm^3/yr

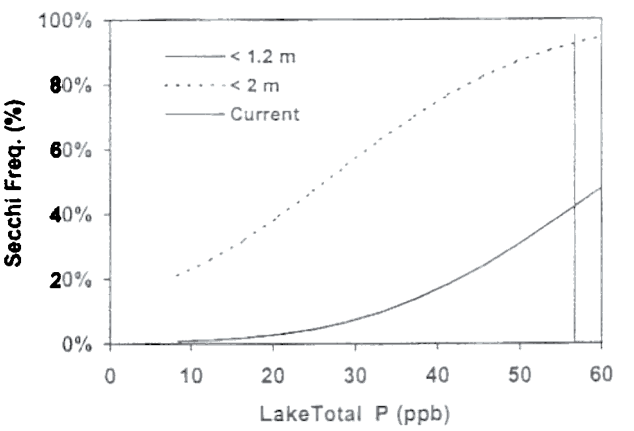
Total P Load = 68752 kg/yr

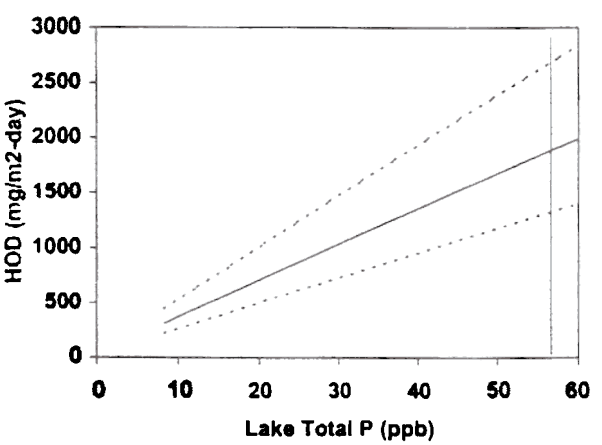
Dashed lines show 80% prediction intervals
Vertical Line = 1995-1999 Average Load











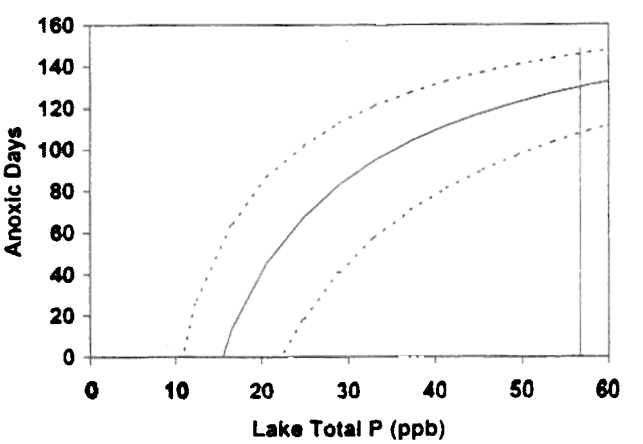


Table 12-1: 10-Year Trends in Concentration

Concentration Trends (% / yr) Period: 1990 to 1999 Period: Year

Term	ALK	BOD5	CA	CL	FCOLI	NA	NH3N	NO2N	NO3N	ORTHOP	TIC	TKN	TN	TOC	TP	
Metro			-2%			3%			16%	-11%				-4%	-6%	
Bypass		-5%														
Allied	-3%				21%	2%	10%	14%	-6%	7%	2%	-9%	10%		3%	
Crucible			2%			3%		-9%	-5%	20%			-6%			
Harbor/Hiawatha	1%	6%				3%								-6%		
Ley/Park																
Ninemile/Rt48	-1%	6%														
Onond./Kirkpatrick	-1%	8%				6%					-1%	3%			6%	
Harbor/Velasko	-6%							-65%		24%	-6%					
Onondaga/Dorwin	-2%					4%	10%		2%		-2%		3%		-8%	
Total Gauged	-1%		1%			3%			7%	-8%	-1%				-4%	
NonPoint Gauged	-1%										-1%				-6%	
Ungauged	-1%										-1%				-6%	
Total NonPoint	-1%										-1%				-6%	
Total Industrial	-3%	-9%			26%		20%	-25%	-8%		-3%	17%	15%	-4%		
Total Municipal			-2%			3%			16%	12%					-6%	
Total External	-1%		-1%			3%			7%	-8%	1%				-4%	
Total Inflow	-1%		1%			3%			7%	-8%	1%				-4%	
Total Outflow	-2%		2%								-1%			-3%		6%
Outlet2	-2%		-2%								1%			-3%		6%
Outlet12	-1%		-1%			3%					1%			-3%		
Outlet Avg	-1%		-1%								1%			-3%		6%
South Epil	-1%					3%					1%			-2%		

Flow-Adjusted Concentration Trends (% / yr)

Term	ALK	BOD5	CA	CL	FCOLI	NA	NH3N	NO2N	NO3N	ORTHOP	TIC	TKN	TN	TOC	TP	TSS
Metro									16%	-8%				-4%	-6%	
Bypass																
Allied																
Crucible																
Harbor/Hiawatha		5%														
Ley/Park																
Ninemile/Rt48	-1%		-2%								-1%					
Onond./Kirkpatrick	-1%	7%									-1%					
Harbor/Velasko	-6%							-69%		-24%	-6%					
Onondaga/Dorwin	-2%						10%		3%		-2%		3%			
Total Gauged			-1%													
NonPoint Gauged	1%		-2%								1%					
Ungauged	1%		-2%								1%					
Total NonPoint	1%		-2%								1%					
Total Industrial																
Total Municipal																
Total External			1%													
Total Inflow			-1%													
Total Outflow	1%		-2%													
Outlet2	-1%		-2%													
Outlet12	-1%		-1%													
Outlet Avg	-1%		-1%													
South Epil			-1%													

Table 12-2: 10-Year Trends in Load

Load Trends (% / yr) Period: 1990 to 1999 Period: Year

Term	ALK		CA	CL	FCOLI	NA	NH3N	NO2N	NO3N	RTHOP_F		TKN	TN	TOC	TP	TSS
Metro	-3%		-4%				-5%		15%	-12%		-5%		-6%	7%	-5%
Bypass																
Allied	-36%	-35%	-33%	-34%	-39%	-32%	39%	-42%	-39%	23%	-35%	-38%	-39%	33%	-30%	-37%
Crucible	-12%	-11%	-9%	-10%	-17%	-7%	10%	-19%	-17%		-12%	10%	-17%	13%		
Harbor/Hiawatha	-7%		-5%						-7%		-7%		-6%	-7%		
Ley/Park	-7%		-5%	-6%				10%	-7%	11%	-6%	-7%	-7%	10%		
Ninemile/Rt48	-8%		-8%	-8%		-6%	-6%				-7%	-7%	-6%	-9%	12%	
Onond./Kirkpatrick	-6%		-4%								-6%				11%	
Harbor/Velasko																
Onondaga/Dorwin															12%	10%
Total Gauged	-6%		-6%	-5%			5%	-7%		12%	-6%	-5%	-4%	-7%	-9%	
NonPoint Gauged	-7%		-6%	-5%				-7%			-6%	-5%	-5%	-7%	10%	
Ungauged	-7%		-6%	-5%				-7%			-6%	-5%	-5%	-7%	10%	
Total NonPoint	-7%		-6%	-5%				-7%			-6%	-5%	-5%	-7%	10%	
Total Industrial	-27%	-27%	-24%	-26%	-36%	24%	-38%	-42%	-32%	19%	27%	36%	-36%	-26%	25%	26%
Total Municipal	-3%		-4%	-3%			-5%		14%	13%	-3%	-5%	-3%		-6%	
Total External	-6%		-6%	-5%			-5%	7%		12%	-6%	-5%	-4%	-7%	-9%	
Total Inflow	-6%		-6%	-5%			-5%	-6%		11%	-6%	5%	-4%	-7%	-9%	
Total Outflow	-6%	-7%	-7%	-5%					-6%		-6%		-6%	-6%	-6%	12%
Retention								14%	47%	-340%	-6%	6%			-9%	
Outlet2	-6%	-7%	-7%	5%					-6%		-6%		-6%	-6%	-6%	12%
Outlet12	-6%	-6%	-6%								-6%		-4%	-7%	-6%	
Outlet Avg	-6%	-6%	-6%	-4%							-6%		-5%	-6%	-6%	10%
South Epil.	-6%	-6%	-6%	-3%					-5%		-6%		-6%	-7%		-9%

Flow-Adjusted Load Trends (% / yr)

Term	ALK	BOD5	CA	CL	FCOLI	NA	NH3N	NO2N	NO3N	RTHOP_F	TIC	TKN	TN	TOC	TP	TSS
Metro									16%	-8%				-4%	-5%	
Bypass																
Allied																
Crucible																
Harbor/Hiawatha																
Ley/Park														-3%		
Ninemile/Rt48	1%		-3%								1%					
Onond./Kirkpatrick	1%	8%									1%					
Harbor/Velasko																
Onondaga/Dorwin	-2%					3%	10%		3%		-2%		3%			
Total Gauged			-1%					-4%								
NonPoint Gauged	-1%		-1%								1%					
Ungauged	-1%		-1%								1%					
Total NonPoint	-1%		-1%								1%					
Total Industrial																
Total Municipal																
Total External			-1%					-4%								
Total Inflow			-1%					-4%								
Total Outflow	1%		-2%													
Outlet2	1%		-2%													
Outlet12	1%		-1%													
Outlet Avg	1%		-1%													
South Epil.			-1%													

Table 12-3: Chloride Balance for 1995-1999

Variable: Chloride Average for Years: 1995 thru 1999 Season: Year

Term	Flow 10^6 m3	Load mtons	Std Error mtons	Conc ppm	RSE %	Samp. Count	Percent of Total Inflow Flow %	Load %	Error %		Runoff cm	Expc mton kn
Metro Effluent	89.77	27780	1411	309	5%	26	22%	19%	19%			
Metro Bypass	1.70	811	193	476	24%	6	0%	1%	0%			
East Flume	0.29	130	5	443	4%	27	0%	0%	0%			
Crucible	0.61	190	3	310	2%	27	0%	0%	0%			
Harbor Brook	7.74	1762	82	228	5%	28	2%	1%	0%	29.3	26.4	60.2
Ley Creek	32.03	9461	569	295	6%	27	8%	6%	3%	77.5	41.3	122.1
Ninemile Creek	115.99	55486	1814	478	3%	27	29%	38%	32%	298.1	38.9	186.1
Onondaga Creek	130.56	45810	2000	351	4%	28	32%	31%	39%	285.1	45.8	160.7
Nonpoint Gauged	286.32	112519	2761	393	2%	110	71%	76%	74%	690.0	41.5	163.1
Nonpoint Ungauged	15.37	6039	831	393	14%	0	4%	4%	7%	37.0	41.5	163.1
NonPoint Total	301.69	118557	2883	393	2%	110	75%	80%	80%	727.0	41.5	163.1
Industrial	0.90	320	6	354	2%	53	0%	0%	0%			
Municipal	91.47	28592	1424	313	5%	32	23%	19%	20%			
Total External	394.07	147468	3216	374	2%	195	97%	100%	100%	727.0	54.2	202.8
Precipitation	10.52	11	1	1	9%	0	3%	0%	0%	11.7	89.9	0.9
Total Inflow	404.59	147479	3216	365	2%	195	100%	100%	100%	738.7	54.8	199.6
Evaporation	8.86						2%			11.7	75.7	
Outflow	395.73	145838	3485	369	2%		98%	99%	117%	738.7	53.6	197.4
Retention	0.00	1641	4742		289%		0%	1%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	395.73	176957	2445	447	1%	24	98%	120%	58%	738.7	53.6	239.5
Outlet 2 Feet	395.73	145838	3485	369	2%	24	98%	99%	117%	738.7	53.6	197.4
Outlet Average	395.73	161397	3010	408	2%	24	98%	109%	88%	738.7	53.6	218.5
Lake Epil	395.73	176545	1907	446	1%	20	98%	120%	35%	738.7	53.6	239.0
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	25.9	#N/A	#N/A
Downstream - Hiawatha	7.74	1762	82	228	5%	28	2%	1%	0%	29.3	26.4	60.2
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.4	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	100.85	12677	403	126	3%	29	25%	9%	2%	229.4	44.0	55.3
Downstream - Kirkpatrick	130.56	45810	2000	351	4%	28	32%	31%	39%	285.1	45.8	160.7
Local Inflow	29.72	33133	2040	1115	6%		7%	22%	40%	55.7	53.3	594.5

Lake Overflow Rate 33.82 m/yr Calib. Settling Rate 0.4 m/yr RSE % = Relative Std. Error of Load & Inflow Conc. Estimates

Lake Residence Time 0.32 years Calib. Retention Coef. 1% Error % = Percent of Variance in Total Inflow Load Estimate

Table 12-4: Total Phosphorus Balance for 1995-1999

Variable: Total Phosphorus **Average for Years:** 1995 thru 1999 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Samp. Count	Percent of Total Inflow Flow %	Load %	Error %	Drain. Area km2	Runoff cm	Export kg / km2
Metro Effluent	89.77	39685	464	442	1%	365	22%	60%	8%			
Metro Bypass	1.70	2515	102	1477	4%	42	0%	4%	0%			
East Flume	0.29	64	2	218	3%	26	0%	0%	0%			
Crucible	0.61	43	2	70	5%	27	0%	0%	0%			
Harbor Brook	7.74	631	173	82	27%	28	2%	1%	1%	29.3	26.4	21.5
Ley Creek	32.03	4119	649	129	16%	27	8%	6%	15%	77.5	41.3	53.2
Ninemile Creek	115.99	7174	959	62	13%	26	29%	11%	33%	298.1	38.9	24.1
Onondaga Creek	130.56	10860	1065	83	10%	28	32%	16%	41%	285.1	45.8	38.1
Nonpoint Gauged	286.32	22785	1583	80	7%	110	71%	34%	90%	690.0	41.5	33.0
Nonpoint Ungauged	15.37	1223	199	80	16%	0	4%	2%	1%	37.0	41.5	33.0
NonPoint Total	301.69	24008	1595	80	7%	110	75%	36%	92%	727.0	41.5	33.0
Industrial	0.90	107	3	118	3%	53	0%	0%	0%			
Municipal	91.47	42201	475	461	1%	407	23%	63%	8%			
Total External	394.07	66315	1664	168	3%	570	97%	100%	100%	727.0	54.2	91.2
Precipitation	10.52	316	28	30	9%	0	3%	0%	0%	11.7	89.9	27.0
Total Inflow	404.59	66630	1664	165	2%	570	100%	100%	100%	738.7	54.8	90.2
Evaporation	8.86						2%			11.7	75.7	
Outflow	395.73	40310	1582	102	4%		98%	60%	90%	738.7	53.6	54.6
Retention	0.00	26320	2296		9%		0%	40%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	395.73	44717	1599	113	4%	24	98%	67%	92%	738.7	53.6	60.5
Outlet 2 Feet	395.73	40310	1582	102	4%	24	98%	60%	90%	738.7	53.6	54.6
Outlet Average	395.73	42514	1590	107	4%	24	98%	64%	91%	738.7	53.6	57.5
Lake Epil	395.73	43011	1827	109	4%	21	98%	65%	120%	738.7	53.6	58.2
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	25.9	#N/A	#N/A
Downstream - Hiawatha	7.74	631	173	82	27%	28	2%	1%	1%	29.3	26.4	21.5
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.4	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	100.85	6138	708	61	12%	29	25%	9%	18%	229.4	44.0	26.8
Downstream - Kirkpatrick	130.56	10860	1065	83	10%		32%	16%	41%	285.1	45.8	38.1
Local Inflow	29.72	4723	1279	159	27%		7%	7%	59%	55.7	53.3	84.7

Lake Overflow Rate 3.82 m/yr Calib. Settling Rate 22.1 m/yr RSE % = Relative Std. Error of Load & Inflow Conc. Estimates

Lake Residence Time 0.32 years Calib. Retention Coef. 40% Error % = Percent of Variance in Total Inflow Load Estimate

Table 12-5: Total Nitrogen Balance for 1995-1999

Variable: Total Nitrogen **Average for Years:** 1995 thru 1999 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Samp. Count	Percent of Total Inflow Flow %	Load %	Error %	Drain. Area km2	Runoff cm	Export kg/ km2
Metro Effluent	89.77	1580852	27322	17610	2%	26	22%	74%	57%			
Metro Bypass	1.70	27107	17070	15915	63%	6	0%	1%	22%			
East Flume	0.29	2330	82	7948	4%	26	0%	0%	0%			
Crucible	0.61	1620	92	2653	6%	27	0%	0%	0%			
Harbor Brook	7.74	15442	403	1996	3%	26	2%	1%	0%	29.3	26.4	527.2
Ley Creek	32.03	57352	5549	1791	10%	24	8%	3%	2%	77.5	41.3	740.0
Ninemile Creek	115.99	213886	12322	1844	6%	26	29%	10%	12%	298.1	38.9	717.5
Onondaga Creek	130.56	205516	8005	1574	4%	27	32%	10%	5%	285.1	45.8	720.8
Nonpoint Gauged	286.32	492196	15711	1719	3%	104	71%	23%	19%	690.0	41.5	713.3
Nonpoint Ungauged	15.37	26415	3812	1719	14%	0	4%	1%	1%	37.0	41.5	713.3
NonPoint Total	301.69	518611	16167	1719	3%	104	75%	24%	20%	727.0	41.5	713.3
Industrial	0.90	3951	123	4370	3%	53	0%	0%	0%			
Municipal	91.47	1607959	32216	17578	2%	32	23%	75%	80%			
Total External	394.07	2130521	36045	5406	2%	188	97%	99%	100%	727.0	54.2	2930.4
Precipitation	10.52	19993	1795	1900	9%	0	3%	1%	0%	11.7	89.9	1708.8
Total Inflow	404.59	2150514	36090	5315	2%	188	100%	100%	100%	738.7	54.8	2911.0
Evaporation	8.86						2%			11.7	75.7	
Outflow	395.73	1274847	28020	3221	2%		98%	59%	60%	738.7	53.6	1725.7
Retention	0.00	875667	45690		5%		0%	41%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	395.73	1489835	23345	3765	2%	24	98%	69%	42%	738.7	53.6	2016.7
Outlet 2 Feet	395.73	1274847	28020	3221	2%	24	98%	59%	60%	738.7	53.6	1725.7
Outlet Average	395.73	1382341	25789	3493	2%	24	98%	64%	51%	738.7	53.6	1871.2
Lake Epil	395.73	1537519	20489	3885	1%	20	98%	71%	32%	738.7	53.6	2081.2
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	/A	#N/A	#N/A	#N/A	25.9	#N/A	#N/A
Downstream - Hiawatha	7.74	15442	403	1996	3%	26	2%	1%	0%	29.3	26.4	527.2
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.4	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	100.85	152976	6095	1517	4%	26	25%	7%	3%	229.4	44.0	666.9
Downstream - Kirkpatrick	130.56	205516	8005	1574	4%	27	32%	10%	5%	285.1	45.8	720.8
Local Inflow	29.72	52540	10061	1768	19%		7%	2%	8%	55.7	53.3	942.8

Lake Overflow Rate	33.82 m/yr	Calib. Settling Rate	23.2 m/yr	RSE % = Relative Std. Error of Load & Inflow Conc. Estimates
Lake Residence Time	0.32 years	Calib. Retention Coef.	41%	Error % = Percent of Variance in Total Inflow Load Estimate

Table 12-6
Yearly Total Phosphorus Balances
Water Years 1986-1999

Water Year	Outflow 10^6 m3	Total Load kg	Total Load RSE%	Metro+Bypass Load kg	Metro+Bypass Load RSE%	Inflow Conc ppb	Outflow Conc @ 2 ft ppb	Outflow Conc @ 2 ft RSE%	Lake South Epil. July-Sept, 0-3 m Concentration ppb	Lake South Epil. July-Sept, 0-3 m Concentration RSE%
1986	483.5	174968	5%	121740	6%	362	134	5%	136	5%
1987	440.5	145808	4%	104222	4%	331	198	10%	120	4%
1988	341.8	116002	3%	89279	4%	339	208	8%	127	5%
1989	426.7	120874	6%	74729	5%	283	108	9%	96	11%
1990	602.3	139838	6%	73460	9%	232	155	13%	88	14%
1991	536.7	103589	9%	61088	12%	193	93	10%	61	9%
1992	476.1	86216	6%	55830	7%	181	92	9%	62	18%
1993	563.7	156070	5%	112279	6%	277	172	6%	132	12%
1994	478.2	81034	8%	61232	10%	169	98	10%	87	11%
1995	296.7	70431	8%	47372	3%	237	134	15%	72	13%
1996	474.2	89570	5%	52661	3%	189	120	9%	68	10%
1997	444.9	61725	3%	40422	2%	139	99	10%	60	10%
1998	466.2	70668	7%	41068	2%	152	79	9%	55	8%
1999	312.5	51366	5%	34174	2%	164	89	9%	54	10%
95-99	398.9	68752	6%	43140	3%	172	103	11%	62	0%

RSE = relative standard error = standard error / mean

Table 12-7
Yearly Total Nitrogen Balances
Water Years 1986-1999

Water Year	Outflow 106 m3	Total Load kg	Total Load RSE%	Metro+Bypass Load kg	Metro+Bypass Load RSE%	nflow Conc ppb	Outflow Conc @ 2 ft ppb	Outflow Conc @ 2 ft RSE%	Lake South Epil. July-Sept, 0-3 m Concentration ppb	Lake South Epil. July-Sept, 0-3 m Concentration RSE%
1986	483.5	2740662	3%	1709557	3%	5668	3461	7%	3640	6%
1987	440.5	2781108	3%	1970213	4%	6314	4526	7%	4379	6%
1988	341.8	2631519	3%	2058390	4%	7698	4583	5%	5479	3%
1989	426.7	2793577	3%	2111344	4%	6546	4216	5%	4274	5%
1990	602.3	2614438	3%	1725019	4%	4340	3168	3%	3661	4%
1991	536.7	2598964	3%	1777828	4%	4843	3098	5%	4197	3%
1992	476.1	2568401	3%	1873839	3%	5395	3793	5%	4493	7%
1993	563.7	2762308	3%	2011697	3%	4900	3248	5%	3673	3%
1994	478.2	2448586	3%	1818246	4%	5121	3274	4%	4080	5%
1995	296.7	2146274	3%	1800917	4%	7233	3354	8%	5055	6%
1996	474.2	2634024	3%	1924330	3%	5555	3696	4%	3834	5%
1997	444.9	2377383	2%	1762833	2%	5343	3172	6%	3631	5%
1998	466.2	2183767	4%	1550049	5%	4684	3032	4%	3604	6%
1999	312.5	1613254	3%	1219387	4%	5162	2747	4%	3330	5%
95-99	398.9	2190940	3%	1651503	4%	5492	3224	;%	3891	5%

RSE = relative standard error = standard error / mean

Table 12-8
Model Calibration Data

Phosphorus Balance

Water Year	Net Inflow hm3	Total Load kg	SE kg	Outflow Load kg	SE kg	Inflow P P Conc ppb	SE ppb	Outflow P Conc ppb	SE ppb	July-Sept 0-3 m P Conc ppb	SE ppb
1986	483.5	174968	8339	64961	3216	361.9	17.2	134.4	6.7	146.0	11.3
1987	440.5	145808	5619	87270	9112	331.0	12.8	198.1	20.7	118.2	6.2
1988	341.8	116002	3906	71035	5864	339.4	11.4	207.8	17.2	120.5	14.7
1989	426.7	120874	6817	46070	4035	283.3	16.0	108.0	9.5	80.9	11.8
1990	602.3	139838	8048	93253	11692	232.2	13.4	154.8	19.4	95.5	23.0
1991	536.7	103589	9702	49826	4808	193.0	18.1	92.8	9.0	64.7	6.5
1992	476.1	86216	4939	43974	3947	181.1	10.4	92.4	8.3	61.7	15.4
1993	563.7	156070	7536	96799	5640	276.8	13.4	171.7	10.0	109.0	13.1
1994	478.2	81034	6850	47006	4778	169.5	14.3	98.3	10.0	79.1	12.6
1995	296.7	70431	5456	39743	5889	237.4	18.4	133.9	19.8	65.0	9.0
1996	474.2	89570	4898	56980	4869	188.9	10.3	120.2	10.3	60.9	3.8
1997	444.9	61725	1922	44172	4517	138.7	4.3	99.3	10.2	52.8	5.9
1998	466.2	70668	5204	36933	3387	151.6	11.2	79.2	7.3	50.9	4.2
1999	312.5	51366	2339	27909	2608	164.4	7.5	89.3	8.3	53.9	7.8

Chlorophyll-a — July - September, Lake South Station, 0 to 3 meters

Water Year	Sample Dates	Mean ppb	Std Dev ppb	SE ppb	Freq > 10 -	Freq > 20 -	Freq > 30 -	Freq > 40 -	Freq > 60 -
1986	6	20.5	26.2	10.7	0.667	0.333	0.167	0.167	0.167
1987	6	9.7	5.3	2.2	0.500	0.000	0.000	0.000	0.000
1988	6	18.0	7.5	3.1	0.833	0.500	0.000	0.000	0.000
1989	6	7.3	6.4	2.6	0.333	0.000	0.000	0.000	0.000
1990	6	47.2	29.4	12.0	1.000	1.000	0.500	0.500	0.167
1991	13	39.4	27.0	7.5	0.923	0.692	0.538	0.462	0.154
1992	14	19.3	9.6	2.6	0.857	0.429	0.143	0.000	0.000
1993	7	21.0	17.8	6.7	0.857	0.429	0.143	0.143	0.000
1994	7	31.1	39.3	14.9	0.429	0.429	0.429	0.429	0.143
1995	7	8.0	4.4	1.6	0.571	0.000	0.000	0.000	0.000
1996	6	40.1	22.4	9.1	1.000	1.000	0.667	0.167	0.167
1997	6	16.5	12.7	5.2	0.667	0.167	0.167	0.167	0.000
1998	10	19.1	9.2	2.9	0.900	0.400	0.200	0.000	0.000
1999	14	27.5	16.2	4.3	1.000	0.500	0.357	0.143	0.071

Secchi Depth — July - September, Lake South Station

Water Year	Sample Dates	Mean m	Std Dev m	SE m	Freq < 1.2 -	Freq < 2.0 -
1986	6	0.667	0.151	0.061	1.000	1.000
1987	6	1.833	0.731	0.299	0.000	0.667
1988	6	1.100	0.228	0.093	0.500	1.000
1989	6	1.350	0.217	0.089	0.167	1.000
1990	6	1.317	0.512	0.209	0.500	1.000
1991	5	1.040	0.288	0.129	0.800	1.000
1992	7	1.514	0.157	0.059	0.000	1.000
1993	7	1.814	0.857	0.324	0.143	0.714
1994	7	2.243	0.971	0.367	0.286	0.286
1995	6	1.767	0.258	0.105	0.000	0.667
1996	6	1.083	0.293	0.119	0.500	1.000
1997	6	1.767	0.301	0.123	0.000	0.667
1998	7	1.793	0.688	0.260	0.286	0.571
1999	13	1.300	0.529	0.147	0.385	0.923

Hypol. Oxygen Depletion Rate below 6 meters

Water Year	HOD mg/m2-day
1986	1111 *
1987	1425 *
1988	1623 *
1989	1927
1990	1687
1991	1889
1992	1974 *
1993	1278 *
1994	904 *
1995	2358
1996	1714
1997	1116 *
1998	1519
1999	2077

SE = Standard Error of Mean

* Lower limit of actual HOD because of incomplete spring turnover or loss of oxygen during calculation interval

Table 12-9 – Model Equations

Predicted Trophic Response Variables:

P_O = Water Year Flow-Wtd-Mean Outflow Total P (ppb)

P = July-Sept Surface (0-3 m) Mean Total P (ppb)

N_O = Water Year Flow-Wtd-Mean Outflow Total N (ppb)

N = July-Sept Surface (0-3 m) Mean Total N (ppb)

B = June-Sept Epilimnetic Mean Chlorophyll-a (ppb)

S = June-Sept Mean Secchi Depth (m)

HOD = Hypolimnetic Oxygen Depletion Rate (mg/m^2-day)

Lake Outflow Total P:

Reference: Vollenweider (1969) , Chapra (1975), Sas (1989)

$P_O = W_P / (Q_O + U_P A)$

W_P = Inflow P Load (kg/yr)

Q_O = Outflow = External Inflow + Precip - ET (hm^3/yr)

A = Lake Surface Area = 11.7 km^2

U_P = P Settling Rate = 22.9 m/yr

Calibrated to 1995-1999

Period	95-99	86-99
Residual CV	0.11	0.28
R^2	0.73	0.25

Lake South Epilimnetic Total P:

Reference: Walker (1978), Sas (1989)

$P = F_P P_O$

F_P = 0.55 Calibrated to 1995-1999

Period	95-99	86-99
Residual CV	0.09	0.13
R^2	0.29	0.88

Lake Outflow Total N:

$N_O = W_N / (Q_O + U_N A)$

W_N = Inflow N Load (kg/yr)

U_N = N Settling Rate = 24.0 m/yr

Calibrated to 1995-1999

Period	95-99	86-99
Residual CV	0.07	0.08
R^2	0.61	0.75

Lake South Epilimnetic Total N:

$N = F_N N_O$

F_N = 1.15 Calibrated to 1995-1999

Period	95-99	86-99
Residual CV	0.10	0.11
R^2	0.71	0.53

Table 12-9: Model Equations (ct.)

Lake South Chlorophyll-a:

Reference: Jones & Bachman (1976)

$B = k P^{1.46}$

k =	0.076	calibrated to 1996-1999 Data

DataSet	J& B	96-99
Residual CV	-	0.24
R^2	0.90	0.66

Algal Bloom Frequencies:

Reference: Walker (1984)

F_X =	$1 - \text{Normal}[(\ln(X) - \ln(B) - 0.5 S_B^2) / S_B]$
S_B =	$[\ln (1 + C_B^2)]^{1/2}$
X =	Bloom Criterion (10, 20, 30 or 40 ppb)
F_X =	Frequency of Chl-a > X
Normal	Cumulative Normal Frequency Distribution
S_B =	Standard Deviation of ln (Chl-a)
C_B =	Within-Year Temporal CV = 0.600
	Calibrated to 1986-1999 Data

Lake South Secchi Depth:

Reference: Walker (1985,1996)

$S = \exp (S_S^2) / (a + b B)$

Calibrated to Sample Dates, 1996-1999

a =	0.381	1/m
b =	0.016	m^2/mg

	From Predicted Chla	
Period	96-99	86-99
Residual CV	0.19	0.40
R^2	0.39	0.00

Table 12-9: Model Equations (ct.)

Secchi Interval Frequencies:

Reference: Walker (1984)

F_Y = Normal [(ln(Y) - ln(S) - 0.5 S_S^2) / S_S]

S_S = [ln (1 + C_S^2)] $^{1/2}$ = 0.31

C_S = 0.32 Calibrated to 1986-1999 Data

Y = Secchi Criterion (1.2 or 2 m)

F_Y = Frequency of Secchi < Y

S_S = Standard Deviation of ln (Secchi) =

C_S = Within-Year Temporal CV of Secchi Depth

Hypolimnetic Oxygen Depletion Rate:

Reference: Walker (1979)

Log HOD = -0.58 + 0.0204 I + 4.55 log Z -2.04 $(\text{Log Z})^2$

I = Phosphorus Trophic Index = -15.6 + 46.1 log P

Z = Mean Depth = 10.90 m

HOD = 42.3 $P^{0.94}$ not recalibrated

DataSet	Walker(1979)	96-99
Residual CV	0.23	0.21
R^2	0.91	0.00

Days of Oxygen Supply in Hypolimnion:

Reference: Walker (1979)

T_{DO} = 1000 DO_S Z_H / HOD

T_{ANOXIC} = T_{STRAT} - T_{DO}

T_{DO} = Oxygen Supply at Spring Turnover (days)

T_{ANOXIC} = Duration of Anoxic Period (days)

DO_S = Oxygen at Spring Turnover = 12 ppm

Z_H = Mean Hypolimnetic Depth = 8.34 meters
for 6-meter Thermocline Depth

T_{STRAT} = Duration of Stratified Period = 183 days
April 15 - October 15

Table 12-10
Model Inputs & Outputs

Model Parameters	Units	Value		
Lake Area	km2	11.7		
P Settling Rate	m/yr	22.873		
Epil P / Outflow P	-	0.550		
Outflow P Error CV	-	0.112		
Lake P Error CV	-	0.089		
Chla/P Slope	-	1.460		
Chla/P Intercept	-	0.076		
Chl-a Error CV	-	0.241		
Chla Temporal CV	-	0.600		
Non-Algal Turbidity	1/m	0.381		
Secchi/Chla Slope	m2/mg	0.016		
Secchi Error CV	-	0.193		
Secchi Temporal CV	-	0.320		
HOD Intercept	-	42.400		
HOD Slope		0.940		
HOD Error CV		0.230		
Spring DO Conc	ppm	12.000		
Hypol. Depth	m	8.340		
Stratified Period	days	183.000		
Scenario				
Outflow Volume	hm3/yr	399	1995-1999 Average	
Inflow Load	kg/yr	68752	1995-1999 Average	
Predicted Reponses	**Units**	**Mean**	**Low**	**High**
Outflow P Conc	ppb	103	87	123
Lake P Conc	ppb	57	49	65
Mean Chl-a	ppb	28	19	40
Algal Bloom Frequencies				
>	10	0.94	0.81	0.99
>	20	0.62	0.36	0.83
>	30	0.33	0.14	0.59
>	40	0.17	0.05	0.39
Mean Secchi Depth	m	1.34	1.61	1.08
Secchi Interval Frequencies				
<	1.2	0.42	0.22	0.69
<	2	0.92	0.80	0.98
Oxygen Depletion Rate	mg/m2-day	1887	1326	2686
Days of O2 Supply	days	53	75	37
Anoxic Period	days	130	108	146

CHAPTER 13

PROGRESS TOWARDS REMEDIAL GOALS

One of the primary objectives of the Ambient Monitoring Program is to characterize changes in water quality and ecological conditions of Onondaga Lake over time. Existing conditions form a baseline against which future improvements can be measured. Many aspects of the Onondaga Lake system have been well characterized. Data are available from multiple sources:

- Onondaga County's annual monitoring program,
- Research and monitoring performed by the Upstate Freshwater Institute,
  Monitoring and analysis in support of the remedial investigations and feasibility studies conducted for AlliedSignal (now Honeywell),
  Investigations completed for the Onondaga Lake Management Conference,
  Routine and special monitoring by NYSDEC,
  Miscellaneous projects completed by research scientists associated with area colleges and universities.

Comprehensive summaries of much of the existing data have been prepared, notably the 1996 book edited by S.W. Effler of the Upstate Freshwater Institute: "Limnological and Engineering Analysis of a Polluted Urban Lake: Prelude to Environmental Management of Onondaga Lake, New York" published by Springer-Verlag, New York. The data and analysis presented in this book serve as a comprehensive assessment of baseline conditions through 1992.

This chapter is a summary of the water quality status of the lake with respect to its restoration goals. Each water quality issue is presented as a hypothesis, and the monitoring programs are summarized as means to test the hypothesis and assess progress towards meeting restoration goals. The following summary pages reflect programs and water quality conditions through 1999. This presentation of the monitoring program as it relates to restoration goals may also serve to identify gaps in the monitoring efforts and the need for additional tools.

The summary tables in this chapter are updated each year and included in the Annual Report as a means to track progress towards lake restoration. Much of the information is also discussed in other chapters. The tables focus on issues related to the discharges of METRO and the CSOs. Water quality issues include ammonia nitrogen, phosphorus, dissolved oxygen, pathogens, chlorophyll *a* and Secchi disk transparency. Ecological issues include phytoplankton, zooplankton, macrophytes, macroinvertebrates and the fish community.

MANAGEMENT ISSUE: WATER QUALITY IMPROVEMENTS

A. Ammonia Nitrogen (Water Quality Standard)

Restoration Goal	
Compliance with the applicable ambient water quality standard in the upper waters and/or removal of ammonia toxicity as an impairment to designated best use for survival and propagation of a warmwater fish community.	
Baseline Conditions	
Major Sources	METRO effluent. Mean contribution: 90.9 % (S.D. 3.0)
Epilimnetic concentration	Annual mean 1988-1999: 0.84 mg/l (S.D. 0.53) 1999: 1.2 mg/l No trend through 1999
Compliance with Ambient Water Quality Standard	Days of violation (1992-1999 mean 188 days S.D 53) 1999: 112 days *sampling period approx. 280 days* Margin of violation (1992–1999 mean 0.78 mg/l S.D.0.52) 1999: 0.43 mg/l *calculated for exceedances only*
Factors Affecting Compliance	Hydrology, METRO performance, pH and temperature of receiving water
Planned Load Reductions (1998 – 2012)	
METRO SPDES Permit Requirement ***NOTE: The County is currently projected to meet the Stage 3 limits by May 1, 2004, 8 years ahead of schedule.***	Stage 1 Limit: Cap on Loading (effective Jan. 1998) • July 1 – Sept. 30: 8700 ppd (as NH_3) • Oct. 1 – June 30: 13,100 ppd (as NH_3) Stage 2 (effective May 1, 2004): • June 1 – Oct. 31: 2.0 mg/l (as NH_3) • Nov. 1 – May 31: 4.0 mg/l (as NH_3) Stage 3: (effective Dec. 2012) • June 1 – Oct. 31: 1.2 mg/l (as NH_3) • Nov. 1 – May 31: 2.4 mg/l (as NH_3) Or as required by a revised TMDL (anticipated in 2009)
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions will have no impact on the concentration of ammonia N in Onondaga Lake nor on compliance with the ambient water quality standard.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring, supplemented with samples collected during high flow conditions • Daily measurements of METRO effluent
Lake Monitoring	Annual County monitoring program • Biweekly profiles in Lake, April –Nov • Winter sampling as weather allows
Related Biological Monitoring	• Biennial assessment of fish community, begins in 2000 • Annual zooplankton monitoring
Tools for Decision Making	
Models	• UFI Nitrogen model dated 4/1/93 *NYSDEC to verify the ability of this model to simulate lake conditions following implementation of Phase 2 limits at METRO*
TMDL Allocations	NYSDEC Phase I TMDL 8/27/97 Phase II TMDL by January 2009
Ambient Water Quality Criteria and Standards	NYSDEC to review and revise its ammonia standards in the near future. Current standards are more stringent than the federal criteria.

B. Total Phosphorus (Guidance Value)

Restoration Goal	
Reduction in phosphorus sufficient to reduce the frequency and duration of nuisance algal blooms. Eliminate turbidity as an impairment to use of the lake for secondary water contact recreation (Class C segment) and primary water contact recreation (Class B segment). Compliance with site-specific guidance value appropriate for this urban lake considering all watershed sources of phosphorus.	
Baseline Conditions	
Major Sources	METRO effluent: 1988-1999 average contribution: 66% (S.D.10) 1999: 65% Nonpoint sources
Epilimnetic concentration	Summer average (1986 – 1999 data) 0.085 mg/l (S.D 0.036) 1994 – 1999: summer average 0.062 (S.D 0.012.) 1999: 0.061 mg/l
Compliance with Ambient Water Quality Standard and Guidance Value	Narrative standard for phosphorus not met Guidance value (0.020 mg/l summer average upper waters) not met
Factors Affecting Compliance	Hydrology, METRO performance, land use in watershed, CSO performance
Planned Load Reductions (1998 – 2012)	
METRO SPDES Permit Requirement ***NOTE: The County is currently projected to meet or exceed the Stage 2 limits by May 1, 2004, 2 years ahead of schedule.***	Stage 1 Limit: Cap on Loading (effective Jan. 1998) • 400 pounds TP per day (ppd) 12 month rolling average Stage 2 (effective April 2006): • METRO effluent TP 0.12 mg/l Stage 3: (effective Dec. 2012) • METRO effluent TP at 0.020 mg/l • Watershed nonpoint source reduction of approximately 50% (includes CSO)
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at METRO, watershed efforts to reduce nonpoint sources of P, and improvements to the wastewater collection system (CSO remediation) will have no impact on concentration of phosphorus in the upper waters of Onondaga Lake.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring, supplemented with samples collected during high flow conditions • Daily measurements of METRO effluent • Storm event monitoring in tributaries
Lake Monitoring	Annual County monitoring program • Biweekly TP, TSP, SRP profiles in Lake, April – Nov • Chlorophyll *a* and Secchi disk transparency (weekly in summer) LiCor measurements • Winter sampling as weather allows
Related Biological Monitoring	• Annual phytoplankton and zooplankton monitoring • Macrophyte survey every five years (begin in 2000)
Tools for Decision Making	
Models	• UFI phosphorus model dated 4/1/93 *NYSDEC to verify the ability of this model to simulate lake conditions following implementation of Phase 2 limits at METRO. Model improvements should address watershed nonpoint sources of TP* • Mass balance model of Dr. William Walker • Empirical relationship between TP, chlorophyll, Secchi • Eutrophication model by HydroQual for PTI (AlliedSignal RI/FS) • *Issue: Need for watershed TP model*
TMDL Allocations	NYSDEC Phase I TMDL 8/27/97 Phase II TMDL by January 2009
Ambient Water Quality	Possible site-specific guidance value for TP

Criteria and Standards	

C. Dissolved Oxygen DO (Water Quality Standard)

Restoration Goals

- Reduce volume-days of anoxia to one-half baseline conditions (from 6000 to 3000 10^6 m^3-days)
- Reduce volume-days of dissolved oxygen (DO) less than 2 mg/l to one-half baseline conditions (from 6800 to 3400 10^6 m^3-days)
- Maintain daily average DO equal to or greater than 5 mg/l throughout the water column during fall mixing.
- Maintain at least 3 mg/l DO at water depths of 9 m and above at all times to provide suitable habitat for cool water fish such as walleye and tiger musky.

Baseline Conditions

Major Sources	Oxygen depletion in the hypolimnion is primarily due to decomposing algal biomass (excess algae is caused by phosphorus load). Other sources include ultimate oxygen demand from organic material and reduced nitrogen species (primarily ammonia from METRO)
Epilimnetic concentration during fall mixing	Average minimum concentration (1988 – 1999 data) 3.2 mg/l (S.D. 1.46) 1999 minimum: 5.55 mg/l No trend
Volume-days of anoxia	**Anoxia**: Average 1992 – 1999: 5783 10^6 m^3-days (S.D. 931) **Less than 2 mg/l**: Average 1992 – 1999 6649 10^6 m^3-days (S.D. 1361) 1999 conditions: 4257 anoxia; 5343 $\leq$ 2 mg/l
Factors Affecting Compliance	Meteorology, algal abundance (related to phosphorus load)

Planned Load Reductions (1998 – 2012)

METRO SPDES Permit Requirement	See staged effluent limits for TP BOD limit through 2001: 21 mg/l (30 day avg)

Monitoring and Assessment Program

Hypothesis to be tested (H_0)	Implementation of improvements at METRO, including reduction in load of phosphorus and ultimate oxygen demand, will have no impact on the concentration of dissolved oxygen in Onondaga Lake nor on compliance with the ambient water quality standard for DO during fall mixing.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring, supplemented with samples collected during high flow conditions to estimate TP, N and BOD inputs • Daily measurements of METRO effluent Storm event monitoring in tributaries
Lake Monitoring	Annual County monitoring program • Biweekly DO profiles in Lake, April – Nov • Intensive sampling during fall, including tributary mouths • Monitoring buoy installed at South Deep for near-continuous measurements and transmittal of water quality data including DO • Winter sampling as weather allows
Related Biological Monitoring	• Annual phytoplankton monitoring • Annual zooplankton monitoring • Limited tracking of fish movement during fall mixing • Fish tagging program
Hypolimnetic Oxygenation Demonstration Project	• Status of this element of the Amended Consent Judgment is under review and discussion

Tools for Decision Making

Models	UFI oxygen model dated 4/1/93 HydroQual preliminary eutrophication model for PTI/Allied Signal Dr. William Walker mass-balance model and link to empirical eutrophication (including hypolimnetic oxygen depletion rate)
TMDL Allocations	NYSDEC Phase I TMDL for phosphorus 8/27/97 Phase II TMDL for phosphorus by January 2009
Hypolimnetic oxygenation	Cost benefit and broader environmental impacts (including effects on Hg

(status under review)	and CH_3-Hg) of injecting oxygen into hypolimnion

D. Pathogens and Indicator Bacteria (Water Quality Standard)

Restoration Goal	
Compliance with the standards for water contact recreation in the Class B segment and for secondary water contact recreation in Class C segment of Onondaga Lake	
Baseline Conditions	
Major Sources	Combined sewers Urban runoff (stormwater) METRO (effluent chlorination period April 1– Oct 15.) Other sources (wildlife, birds, etc.)
Epilimnetic concentration	Fecal coliform : 1988 – 1999 average: 99 cells/100 ml (S.D. 47) (Measured in surface waters, South Deep) 1999 average: 74 cells/100 ml; 96% compliance with 200 cells/100 ml No trend
Compliance with Ambient Water Quality Standard and Guidance Value	Approximately 80% of samples collected year-round meet Class B standard 200 cells/100 ml; 96% compliance during recreational season 1999 results: 100% compliance during summer; 96% compliance overall
Factors Affecting Compliance	METRO disinfection and CSO performance Meteorological conditions (rainfall, temperature, sunlight, winds) Lake water quality (turbidity) Abundance of waterfowl
Planned Load Reductions (1998 – 2012)	
METRO SPDES Permit Requirement Staged CSO remediation	Seasonal disinfection (4/1 – 10/15) of METRO effluent required through 2001 CSO phased plan to capture combined sewage and stormwater: • Stage 1 captures 62% of volume through best management practices • Stage 2 eliminates and/or captures 85% of volume and provides equivalent of primary treatment.
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of Stage 1 and 2 improvements to the wastewater collection system (CSO remediation) will have no impact on concentration of indicator organisms in Onondaga Lake and tributaries.
Loading estimates	Annual County monitoring program • Biweekly tributary monitoring supplemented with samples collected during high flow conditions. (Fecal coliform, E. coli and *Enterococcus*) • Daily measurements of METRO effluent and METRO bypass as necessary (Fecal coliform) • Storm event monitoring in tributaries, (Fecal coliform, E. coli and *Enterococcus*)
Lake Monitoring	Annual County monitoring program (Fecal coliform, E. coli and *Enterococcus*) • Weekly routine monitoring at South Deep, Class C segment • Eight nearshore stations baseline conditions and following storms
Tools for Decision Making	
Models	• UFI/Canale bacteria model (input loads, model routes bacteria using hydrodynamic routine, simulates bacteria dieoff based on light and temperature, predicts bacteria concentration in lake cells). • Storm Water Management Model (simulates bacteria loads in tributaries from collection system given rainfall conditions)
TMDL Allocations	Based on presumptive approach: percent capture of combined storm and wastewater. Must account for urban stormwater,
Ambient Water Quality Criteria and Standards	NYS indicator bacteria standards include total and fecal coliform. EPA criteria now use E. coli and Enterococcus as indicators. EPA urging states

	to revise standards for water contact recreation.

E. Chlorophyll *a* (Narrative Standard, Assessment Measure)

Restoration Goal	
Reduction in average and peak algal biomass and frequency and duration of bloom conditions. Mean chlorophyll *a* 10 µg/l Less than 10% chlorophyll *a* measurements exceed 30 µg/l (threshold for nuisance blooms) and Less than 25% chlorophyll *a* measurements exceed 15 µg/l	
Baseline Conditions	
Major Sources	Internal algal production based on nutrients (P is limiting), light, temperature
Epilimnetic concentration Summer average (mid-May through mid-September) 1992 – 1998 data	1992 – 1999 20 % observations >30 µg/l; 43 % observations >15 µg/l Mean 19.31 µg/l (S.D. 10.3) Peak 110 µg/l (August 1994) No trend 1999: 38 % observations >30 µg/l; 67 % observations >15 µg/l mean 24.8 µg/l; peak 72.1 (July 1999)
Compliance with Ambient Water Quality Standard and Guidance Value	No standards or guidance values for chlorophyll *a*. Narrative P standard references algal abundance at nuisance levels
Factors Affecting Compliance	Nutrients, light, temperature, grazing pressure
Planned Load Reductions (1998 – 2012)	
METRO SPDES Permit Requirement	• See planned reduction in TP from METRO • Staged reductions in CSO
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at METRO and improvements to the wastewater collection system (CSO remediation) will have no impact on the concentration of chlorophyll *a* in Onondaga Lake.
Lake Monitoring	• Weekly measurements at S. Deep, April – November
Related Biological Monitoring	• Phytoplankton community measurements biweekly April-November • Zooplankton community measurements biweekly April-November
Tools for Decision Making	
Models	• HydroQual eutrophication model for AlliedSignal, not complete • UFI lake models (phytoplankton is not modeled, chlorophyll is based on measured conditions in 1989, increased or decreased proportionally based on TP concentrations). • Dr. William Walker's mass balance TP framework and linked empirical eutrophication models
TMDL Allocations	See discussion of TP

F. Secchi Disk Transparency (Guidance Value)

Restoration Goal	
Summer average Secchi disk transparency 1.5 m or greater. At no time shall Secchi disk transparency be less than 1.2 m (bathing beach swimming safety guidance value).	
Baseline Conditions	
South Deep Station (June 1 – Sept 30 average)	Mean 1.98 m (1990 – 1999, N=119) standard deviation 1.17 m Increasing trend
Compliance with Ambient Water Quality Standard and Guidance Value	80 % of observations in this ten-year period met or exceeded guidance value of 1.2 m 65 % of observations greater than or equal to 1.5 m 1999 conditions 1.7 m June – Sept. average (S.D. 1.1m) 74 % $\geq$ 1.2 m 58 % $\geq$ 1.5 m
Factors Affecting Compliance	• Algal abundance (depends on light, temperature, nutrients and grazing pressure) • External loading of suspended solids • Resuspension of bottom sediments • Precipitation of calcite
Planned Load Reductions (1998 – 2012)	
METRO SPDES Permit Requirement	• Staged reduction in TP load from METRO • Staged implementation of CSO projects
Monitoring and Assessment Program	
Hypothesis to be tested (H_0)	Implementation of load reductions at METRO and improvements to the wastewater collection system (CSO remediation) will have no impact on the water clarity of Onondaga Lake as measured by Secchi disk transparency.
Lake Monitoring	• Biweekly measurements of Secchi disk at South Deep (increased to weekly between 6/1 and 9/30) • Nearshore Secchi disk measurements: baseline and following storm events
Related Biological Monitoring	Phytoplankton and zooplankton abundance and community composition
Tools for Decision Making	
Models	• Empirical relationship between TP and Secchi disk transparency, in UFI TP management model • Dr. William Walker's mass balance TP framework and linked empirical eutrophication models.

Category 2: Ecological Issues

A. PHYTOPLANKTON (Assessment Measure)

Restoration Goal	
Abundance and composition of the algal community typical of a eutrophic lake in the same geologic and climatic setting. Decreased importance of cyanobacteria (blue-green algae).	
Baseline Conditions	
Biomass and Community composition	1968 – 1996 data set (Phil Sze) Abundance of major groups Qualitative discussion of trends in annual lake reports, also in Effler (ed) 1996
Forcing functions	Nutrients, light. temperature, grazing pressure
Monitoring and Assessment Program	
Lake Monitoring	Biweekly sampling events: • Phytoplankton abundance (number per liter) • Biomass (µg/l) • Composition of the algal community (7 major groups) • Cell size divisions (nannoplankton and netplankton) Metrics to track over time: • Percent of major taxa • Blue-green algae dynamics and shits in N:P ratio of lake water • Number of taxa (1995 and later) • Diversity (1995 and later) • Percent dominance (1995 and later)
Tools for Decision Making	
Models	None developed

B. ZOOPLANKTON (Assessment Measure)

Restoration Goal	
Abundance and composition of the zooplankton community are comparable to reference eutrophic lake in same geologic and climatic setting.	
Baseline Conditions	
Biomass and Community composition	Density (numbers per ml for major types) documented since late 1960's Qualitative discussion in annual reports ,also in Effler (ed) 1996 Since 1995, biomass of organisms
Forcing functions	Food supply (algal abundance) grazing pressure (fish community structure), water quality (ammonia, chlorides, extent of aerobic habitat)
Monitoring and Assessment Program	
Lake Monitoring	• Biweekly monitoring for density (plankters per ml) and biomass (µg/l), March – November/December *Metrics to track over time* • Average size in spring (June 1 – 15) and fall (Sept. 1 – 15) • Relative biomass of major caldoceran types • Relative biomass of major copepod types • Number of crustacean taxa (1995 on)
Tools for Decision Making	
Models	None developed

C. MACROPHYTES (Assessment Measure)

Restoration Goal	
Expansion of the areal coverage and increase in diversity of macrophyte community. Number of species and biomass of macrophytes in the littoral zone comparable to other regional lakes	
Baseline Conditions	
Biomass	1991 survey (John Madsen, Army Corps of Engineers) reported number of transects with macrophytes present, no biomass or percent littoral zone coverage noted.
Community composition	Five species present in 1991 survey. In comparison, NY lakes average 18, Oneida has approx 16 species. Cross Lake has 5. No emergent or floating leaf species were present in Onondaga in 1991.
Forcing functions	• Sediment texture (oncolites are nutrient-poor and unstable, shifting with wind-driven waves in nearshore area) • Light penetration • Salinity levels • Harvesting by waterfowl
Monitoring and Assessment Program	
Lake Monitoring	• Survey species composition and biomass every 5 years, beginning in 2000. • Annual aerial photographs of littoral zone to estimate percent cover *Metrics to track over time* • Number of species • Percent cover • Biomass
Tools for Decision Making	
Qualitative and quantitative assessment	Compare to baseline survey in 2000

D. MACROINVERTEBRATES (Assessment Measure)

Restoration Goal	
Abundance and composition of the macroinvertebrate community are comparable to reference eutrophic lake in same geologic and climatic setting.	
Baseline Conditions	
Biomass	Based on 1992 survey by PTI approx: • 10,000 individuals per m^2 oligochaetes • 2,500 individuals per m^2 chironomids • 400 individuals per m^2 amphipods at water depths less than 7.5 m
Community composition	Baseline conditions: more than 70 taxa in the lake's littoral zone. Communities dominated by oligochaetes and chironomids.
Forcing functions	• Sediment texture • Depth of anoxia • Sediment contamination
Monitoring and Assessment Program	
Lake Monitoring	A total of 180 littoral samples will be collected once every five years, beginning in 2000 (baseline monitoring was completed in 1999 to finalize program design). Sampling includes 36 replicates from water depths 0.5 – 1.5 m in each of 5 strata (defined based on substrate composition and wind energy).
Tools for Decision Making	
Metrics	• NYSDEC macroinvertebrate indices based on species diversity and presence/absence of pollution tolerant species. • Percent oligochaetes

E. FISH COMMUNITY (Assessment Measure)

Restoration Goal	
Expand habitat for fish community and promote water quality conditions that support diverse warmwater fish community. Reduction in dominance of planktivorous fishes and restoration of a balanced community.	
Baseline Conditions	
Biomass	Growth rates, age distribution and mortality rate comparable to other systems. Biomass relatively high with minimal fishing pressure (catch and release)
Community composition	Warmwater fish community dominated by gizzard shad and white perch (planktivores). Insectivorous sunfishes in littoral zone. Some sport fish present (channel catfish, smallmouth bass, largemouth bass, walleye). 48 species from 20 families collected in lake (1989 – 1992). 16 reproduce in lake. Diversity comparable to other regional lakes. Open connection with Seneca River important to community structure.
Forcing functions	Ammonia toxicity Extent of aerobic habitat Abundance of preferred food sources Habitat for spawning and juveniles
Monitoring and Assessment Program	
Lake Monitoring	Every two years, beginning in 2000: • Pelagic/inshore larvae • Juvenile fish • Community structure • Angler census
Tools for Decision Making	
Quantitative and qualitative analysis	Data collection techniques and data analysis comparable to standard procedures used throughout New York.

CHAPTER 14

CONCLUSIONS AND RECOMMENDATIONS

14.1 CONCLUSIONS

A. In January 1998, Onondaga County signed an Amended Consent Judgement (ACJ) committing the County to designing, testing, and constructing improvements to the wastewater collection and treatment system. The ACJ includes a revised and expanded program of monitoring Onondaga Lake, the lake tributaries, and the Seneca River for which Onondaga County Department of Drainage and Sanitation is responsible. The new monitoring program, called the Ambient Monitoring Program (AMP) officially began on August 1, 1998. The 1999 Annual Report reflects the changes and additions to the monitoring program required by the ACJ.

B. 1999 precipitation was well below normal in the Syracuse area. The effects of the dry year are evident in the measurements of tributary loading and lake water quality. Treated effluent from the Syracuse Metropolitan Wastewater Treatment Plant (METRO) represented approximately 18 % of the hydrologic inflow, making it the third largest tributary to the lake. The 1999 estimated hydraulic retention time of the lake was 5 months; water was replaced 2.3 times. This flushing rate was below the long-term average of 3.8 flushes per year (hydraulic retention time 3.2 months).

C. The 1999 proportional contribution of each tributary to the total load of suspended solids, nutrients, and salts was generally consistent with long-term trends, with one notable exception. Nine Mile Creek has historically been the largest source of calcium and chloride to Onondaga Lake. In 1999, Onondaga Creek was the largest source of chloride. As noted in the 1998 Annual Report, chloride concentrations in this stream have increased. The monitoring site was relocated downstream from Spencer St. to Kirkpatrick St. Chloride concentrations increase in this stream reach, apparently due to groundwater inflow.

   Effluent from METRO continued to dominate loads of ammonia, nitrite, and Kjeldahl nitrogen. In 1999, METRO effluent contributed approximately 65 % of the total phosphorus load to Onondaga Lake (fully-treated plus bypass flows). The relative contribution of METRO phosphorus to the annual external load to the lake varies each year in response to hydrologic (precipitation and streamflow) conditions and treatment level at the plant.

D. Complete mixing of the lake's water column occurred in both the spring and fall of 1999. Thermal stratification developed by early June and persisted through late October. The lake's lower waters were rapidly depleted of dissolved oxygen following the onset of thermal stratification. The rate of hypolimnetic oxygen depletion calculated from the 1999 DO data (1.249 $g \cdot m^{-2} \cdot d^{-1}$) is within the historical range of 1.1 - 1.87 $g \cdot m^{-2} \cdot d^{-1}$ reported by Effler (1994). Volume-days of anoxia and dissolved oxygen less than 2 mg/l were slightly reduced in 1999. Dissolved oxygen levels remained above the state's minimum standard during fall mixing.

E. Onondaga Lake continued to exhibit water quality characteristic of a eutrophic system. The volume-averaged TP concentration in the lake's upper waters between mid May and mid September was 61 µg/l. Chlorophyll *a* concentration measured over the same period was 23.5 µg/l, and Secchi disk transparency averaged 1.8 meters (median value 2 meters). Compliance with the New York State swimming safety guidance value of 1.2 meters was achieved on seven of 13 weekly sampling dates during the recreational season (June, July, and August). New York has adopted a TP guidance value for phosphorus in lakes of 20 µg/l. Compliance is assessed by averaging biweekly TP measurements collected at one-meter depth at a mid-lake station between June and September. The 1999 TP concentration in Onondaga Lake measured at this depth and averaging period was 55 µg/l.

   Based on a paleolimnological investigation of Dr. Chandler Rowell, the diatom assemblage in the lake sediments indicates that prior to 1800, Onondaga Lake was a moderately productive alkaline lake with sediment characteristics typical for a north temperate setting. The lake became more productive following European settlement during the early to mid 1800s and was highly polluted by the mid 1900s.

F. The 1999 average concentrations of total Kjeldahl nitrogen (TKN) and ammonia nitrogen (NH_3-N) in the lake's upper waters have continued to decline. This reduction in nitrogen is the direct result of improved ammonia removal at METRO. Measured concentrations of ammonia in the lake water exceeded the state's ambient water quality standard. The margin and duration of contravention of the standard were the lowest recorded to date. In late 1999, EPA issued revised water quality criteria for ammonia. With minor exceptions, the 1999 measured ammonia levels met the federal criteria. NYSDEC is evaluating the federal criteria to determine whether to revise the state standards to be consistent.

G. Exceedances of the New York State ambient water quality standard for nitrite (100 µg/l, designed to be protective of the warm water fish community) were recorded in the lake's upper waters in 1999. Results measured from March through early November were at or close to the standard. In mid November (after fall mixing was complete) nitrite concentrations peaked at levels close to 600 µg/l. This spike in nitrite concentration appears to be related to internal lake processes, not external loading. There was no shift in the nitrogen species in METRO effluent during this period; the phenomenon appeared to be incomplete transformation of ammonia in the lake's lower waters.

H. Onondaga Lake waters were monitored for trace concentrations of mercury on three occasions in 1999 (April, August and October). Samples were analyzed for total and methyl mercury by Frontier Geosciences, a NY state-certified specialty laboratory proficient in analyses of metals present at very low concentrations. Results indicate that ambient concentrations of total mercury were in the range of 2 – 25 ng/l. These concentrations are below the limit of detection of the method used historically to measure mercury in surface waters (cold vapor atomic absorption, Method 245.1, detection limit 200 ng/l). Methyl mercury concentrations ranged from 0.1 – 14 ng/l. Temporal and spatial differences in mercury concentration and the fraction of methyl mercury were evident.

Dr. Edward Mills and his colleagues at the Cornell Biological Field Station completed the annual analysis of community structure of lower trophic levels in Onondaga Lake. Data collected in 1999 were compared with historical information. In 1999, algal abundance and biomass were highest in the spring during the spring diatom bloom and in mid-summer and early fall when cyanophyta (blue-green algae) dominated the phytoplankton community. This pattern of phytoplankton abundance was consistent with conditions observed in 1998. However, algal abundance and chlorophyll *a* concentrations were higher in 1999 due to increased abundance of microflagellates. There was a shift in the dominant species of blue-green algae from *Aphanizomenon flos-aquae* to *Oscillatoria limnetica*. The colonial form *Microcystis aeruginosa* was also predominant in the phytoplankton community.

The zooplankton community also exhibited distinct seasonal changes in species composition and abundance. Copepod abundance was higher than cladoceran abundance in the zooplankton community from late March through early August. Cladoceran abundance was higher for the remainder of the sampling period. The cladoceran zooplankton community was dominated by *Daphnia galeata* from spring to mid-summer. In contrast to conditions measured in other years, the dominant cladoceran zooplankton shifted to *Bosmina longirostris* from mid summer to late fall.

The mean size of the crustacean zooplankton community was 0.61 mm in the spring, 0.47 mm in the summer and 0.37 mm in the fall. The mean size for the entire sampling period was 0.49 mm. This small size reflects the large number of naupilii present in every sample. If nauplii are excluded, the mean size increases to 0.63 mm over the sampling period. These data suggest that zooplanktivory is generally high but not intense.

Dreissenid veliger larvae were absent from the plankton community at all stations for all dates. This result was consistent with annual measurements since 1996.

Violations of the State's ambient water quality standards for dissolved oxygen, ammonia, and nitrite have been measured in the Seneca River. Low flow conditions represent the worst case for river water quality. In 1999 the lowest flows in the Seneca River remained above critical MA_7CD_{10} conditions, defined as minimum 7-day average with a return period of once in ten years (MA_7CD_{10}), which is used by NYSDEC as the critical low flow condition

for permitting point source discharges. Even at the higher river flows, ambient water quality standards for dissolved oxygen in the lower waters were violated at several monitoring points along the river.

Water quality is affected by zebra mussel activities, the Onondaga Lake outlet, and to a lesser extent, the wastewater treatment facilities at Baldwinsville, Wetzel Road, and Oak Orchard. Density stratification downriver of the Onondaga Lake outlet appears to be a contributing factor to the water quality standard violations.

Currently, efforts are underway by QEA, LLC to evaluate and modify the water quality model of the Seneca – Oneida - Oswego River (the Three Rivers model). A water quality model of the system was developed by Canale et al. in 1995 based on extensive data collection in 1991. Zebra mussels invaded the River system after 1991and altered the cycling and transformation of nutrients and energy. The revised Three Rivers model will accommodate effects of the zebra mussel. Beak Consultants is collecting field and laboratory data to define mussel population density, size distribution, feeding activity, and respiration rates. Field surveys have been conducted to characterize the organic content and oxygen demand of sediments in the River system. These data will be used to support the model development effort.

K. Dr. William Walker has expanded the mass-balance framework for Onondaga Lake that integrates tributary loading with lake water quality response. The mass balance framework uses lake and tributary water quality and hydrologic data to computes mass balances for water quality parameters. The phosphorus balance is now linked to a network of empirical models for predicting trophic state indicators including chlorophyll-a, transparency, and hypolimnetic oxygen depletion rate.

14.2 RECOMMENDATIONS

A. Implementation of the Ambient Monitoring Program in August 1998 represents an important transition for the Onondaga Lake monitoring program. The long-term data set on the lake and its tributaries, which included mostly chemical indicators of water quality, will be expanded to incorporate additional biological indicators. Some sampling techniques and locations have been altered, although an effort was made to maximize utility of the historical database. Additional storm event and high flow sampling of the lake tributaries has begun to provide more accurate estimates of external loading.

NYSDEC and EPA have designated Onondaga County as the primary agency responsible for monitoring Onondaga Lake, the lake tributaries, and the Seneca River. The monitoring data will be used (along with other analyses) to update the TMDL analysis for Onondaga Lake and thus evaluate the effectiveness of the improvements to METRO and the CSOs. Continued data screening and documentation of sampling and analytical procedures is critically important. All monitoring data should be incorporated into an integrated database.

B. As improvements to METRO and the CSOs are phased in, a combination of monitoring and modeling will be used to evaluate their effectiveness and define the need for additional controls. A model would enable lake managers to evaluate the relative importance of factors, such as weather and abatement activities, in affecting lake and tributary water quality. The mass-balance framework developed by Dr. Walker and presented in Chapter 9 of this document is an example of a relatively simple, interactive modeling approach to integrate the loading and lake concentration data. This mass-balance model can be a useful tool for the County and NYSDEC to refine the monitoring program and examine trends in response to abatement actions.

The Upstate Freshwater Institute developed mathematical models of Onondaga Lake's phosphorus, nitrogen, and dissolved oxygen under contract to NYSDEC and the Onondaga Lake Management Conference. Hydroqual developed a eutrophication model of the Lake on behalf of PTI and AlliedSignal as part of the remedial investigation of the lake. Dr. William Walker has developed a mass-balance modeling framework for Onondaga Lake that computes mass balances for water quality parameters using hydrologic and water quality data. The phosphorus balance is linked to a network of empirical models for predicting trophic state indicators including chlorophyll-a, transparency, and hypolimnetic oxygen depletion rate. An update and revision to the Three Rivers model is underway by Quantitative Environmental Analysis (QEA), LLC.

As part of the Amended Consent Judgement, the NYSDEC will convene an expert panel to review the existing models and recommend a modeling framework for use in revised Total Maximum Daily Load allocations for phosphorus and ammonia. We support this effort, and recommend that the County and its Technical Advisory Committee fully participate in selection and implementation of the modeling effort.

C. Storm event monitoring is an important element of tracking the effectiveness of improvements to the wastewater collection system and elimination of combined sewer overflows. Three storm events were completed in 1999 as part of the initial three-year effort to characterize baseline conditions. Specific recommendations to improve the storm event monitoring effort are discussed in Chapter 5.

D. Consider adding equipment for continual monitoring of chlorophyll *a*, fluorescence, and/or turbidity to the water quality buoy moored at the South Deep station. These data would enable lake managers to assess short-term variations in algal biomass.

E. Remedial goals for Onondaga Lake include reduction in phosphorus loading to realize a reduction in the lake's productivity (i.e. a change in trophic state). Additional data are needed to assay the biological availability of phosphorus from the various external sources. The parameter total dissolved phosphorus has been added to the monitoring program. An assessment of algal growth potential (a bioassay) would provide managers with additional information needed to define priority areas for reductions in external loading.

Appendix A

Onondaga Lake Ambient Monitoring Program 1999 Annual Report

November 2000

A.1
Bibliography of Onondaga Lake References

BIBLIOGRAPHY OF TECHNICAL MATERIAL PERTAINING TO ONONDAGA LAKE, NEW YORK

Addess, J.M. and S.W. Effler. 1995. Summer Methane Fluxes and Fall Oxygen Resources of Onondaga Lake, NY. Lake and Reservoir Management 12(1): 91-101.

Aiston, S.T. 1987. Allied Chemical Plant History Syracuse Works, Barton and Logudice, P.C Liverpool, NY.

, C. and W. Sanderson. 1947. Investigation of Onondaga Lake, Onondaga County NYS Department of Health, Albany, NY.

Apogee Research, Inc. Benefits Assessment for the Onondaga Lake Cleanup, August 23, 1993

Apogee Research, Inc. Analysis of Rates and Costs for Wastewater Services: Onondaga County and Comparable Systems Nationwide, September 1993.

Apogee Research, Inc. Preliminary Capital Plan for the Onondaga Lake Cleanup, October 1993.

Auer, M.T. 1989. Monitoring Fecal Coliform Bacteria in Onondaga Lake and its Tributaries - 1987 Submitted to CNY Regional Planning and Development Board (for NYSDEC), Syracuse, NY.

, M.T. and N.A. Johnson. 1989. Phosphorus Release from Onondaga Lake Sediments. Submitted to CNY Regional Planning and Development Board (for NYSDEC), Syracuse, NY.

Auer, M.T. and S.L. Niehaus. 1989. Fecal Coliform Bacteria Kinetics in Onondaga Lake, NY Submitted to CNY Regional Planning and Development Board (for NYSDEC), Syracuse, NY.

Auer, M.T. and M.L. Storey. 1989. Growth Kinetics of Onondaga Lake Phytoplankton. Submitted to the CNY Regional Planning and Development Board, Syracuse, NY.

Auer, M.T., M.L. Storey, S.W. Effler, and N.A. Auer. 1990. Zooplankton Impacts on Chlorophyll and Transparency in Onondaga Lake, NY, U.S.A. Hydrobiologia/Dev. Hydrobiol. 200/201, 603-617.

, M.T., N.A. Johnson, M.R. Penn, and S.W. Effler. 1992. Measurement and Verification of Rates of Sediment Phosphorus Release for a Hypereutrophic Urban Lake. Hydro Biologia 253: 301-309.

Auer, M.T. S.W. Effler, T. M. Heidtke, and S. M. Doerr. Hydrologic Budget Considerations and Mass Balance Modeling Onondaga Lake, February 1992.

, M.T., N.A. Johnson, M.R. Penn, and S.W. Effler. 1995. Pollutant Sources, Depositional Environment, and the Surficial Sediment of Onondaga Lake, New York. Journal of Environmental Quality.

Auer, M.T. and S.L. Niehaus. 199-. Modeling Fecal Coliform Bacteria: I. Field and Laboratory Determination of Loss Kinetics. Water Research 27: 693-701.

Babiarz, P. and K. Pilon. 1979. Water Quality Management on the Eastern Oswego River Basin. CNY Regional Planning and Development Board, Syracuse, NY. 31 p.

Beilman, M.D. 1989. The Problem of Nonpoint Sources. Clearwaters, NYWPCA 19(4): 7-18.

Blasland and Bouck Engineers, P.C. 1989. Hydrogeological Assessment of the Allied Waste Beds in the Syracuse Area. Volumes 1 and 2. AlliedSignal, Inc., Solvay, NY.

Bloom, N.S. and S.W. Effler. 1990. Seasonal Variability in the Mercury Speciation of Onondaga Lake (NY). Water, Air, and Soil Pollution 53: 251-265.

Brainerd, W.F. 1922. Dana Glacial Lake Terrace and the Great Delta of Onondaga Valley: Syracuse, NY. Masters Thesis, Syracuse University. 89 p.

Brennan, P.J. 1967. Proposed Studies for the Restoration of an Urban Natural Resource, Onondaga Lake. Department of Civil Engineering, Syracuse University, Syracuse, NY.

Brennan, P.J., C.S. Grove, Jr., D.F. Jackson, M. Katz, N.L. Nemerove, and M.C. Rand. 1968. Investigations Leading to the Restoration of Urban Lakes with Applications to Onondaga Lake, NY. Department of Civil Engineering, Syracuse, University, Syracuse, NY. (Unpublished).

Brooks, C.M. and S.W. Effler. 1989. The Distribution of Selected Nitrogen Species on Onondaga Lake, NY. Submitted to CNY Regional Planning and Development Board, Syracuse, NY.

Brooks, C.M. and S.W. Effler. The Distribution of Nitrogen Species in Polluted Onondaga Lake, NY, U.S.A. Water, Air, and Soil Pollution 52: 247-262.

Burdick, G. and M. Lipschuetz. 1947. A Supplementary Report to the Survey of Onondaga Lake and Tributary Streams in 1946 and 1947. NYS Conservation Department, Albany, NY.

Calocerinos and Spina Consulting Engineers. 1981 Onondaga Lake Monitoring Program Report. December 1982. Prepared for OCDDS.

Calocerinos and Spina Consulting Engineers. 1982 Onondaga Lake Monitoring Program Report, November 1983. Prepared for OCDDS.

Calocerinos and Spina Consulting Engineers. 1983 Onondaga Lake Monitoring Program Report, December 1984. Prepared for OCDDS.

Calocerinos and Spina Consulting Engineers. 1984 Onondaga Lake Monitoring Program Report, November 1985. Prepared for OCDDS.

Calocerinos and Spina Consulting Engineers. 1978. Thermal Study of Tributary 5-A to Onondaga Lake, Syracuse, NY.

Calocerinos and Spina Consulting Engineers. 1982. Draft Environmental Impact Statement - Application for a Permit to Continue Operation of an Existing Solid Waste Management Facility for Industrial Non-Hazardous Solid Wastes. Prepared for Crucible, Inc., Syracuse, NY.

Calocerinos and Spina Consulting Engineers. 1983. In-Water Combined Sewer Overflow Abatement Study, Onondaga County Department of Drainage and Sanitation.

Calocerinos and Spina Consulting Engineers, HydroQual, Inc., and Joseph C. Lu, P.E., P.C. 1984. Three Rivers Study, Water Quality Assessment, Phase I, with Data Appendix. Prepared for Department of Drainage and Sanitation, Onondaga County, NY.

Calocerinos and Spina Consulting Engineers and Hydroqual, Inc. 1984. Users Guide to the Three Rivers Water Quality Model, Hydroqual, Inc., Mahwah, NJ.

Calocerinos and Spina Consulting Engineers. 1985. Revised Landfill Closure Plan. Prepared for Crucible Specialty Metals, Syracuse, NY.

Calocerinos and Spina Consulting Engineers. 1985. Quarterly Groundwater Monitoring and Site Reports Regarding the Crucible Landfill at Onondaga Lake Wastebeds. Prepared Under Contract for Crucible Specialty Metals, Syracuse, NY.

Canale, R.P. 1988. A Water Quality Planning Framework for Onondaga Lake. EnginComp Software, Inc., Anne Arbor, MI.

Canale, R.P. and S.W. Effler. 1989. Stochastic Phosphorus Model for Onondaga Lake. Research 23: 1009-1016.

Canale, R.P., M.T. Auer, E.M. Owens, T.M. Heidtke, and S.W. Effler. 1993. Modeling Fecal Coliform Bacteria: II. Model Development and Application. Water Research 27: 703-714.

Canale, R.P., E.M. Owens, M.T. Auer, S.W. Effler. 1995. Validation of a Water Quality Model for the Seneca River. Journal of Water Resources Planning and Management 121(3): 241-250.

Canale, R.P., R. Gelda, and S.W. Effler. 1995. Development and Testing of a Nitrogen Model for Onondaga Lake, NY. Lake and Reservoir Management 12(1): 151-164.

Connors, S.D., M.T. Auer, and S.W. Effler. 1996. Phosphorus Pools, Alkaline Phosphatase Activity, and Phosphorus Limitation in Hypereutrophic Onondaga Lake, NY. Lake and Reservoir Management 12(1): 47-57.

Central New York Regional Planning and Development Board, 1979, Central New York Water Quality Management Program, Onondaga County Subplan.

Devan, S.P. and S.W. Effler. 1984. The Recent History of Phosphorus Loading to Onondaga Lake, NY. Journal Environmental Engineering Division ASCE 110: 93-109.

Doerr, S.M., S.W. Effler, K.A. Whitehead, M.T. Auer, M.G. Perkins, and T.M. Heidtke. Chloride Model for Polluted Onondaga Lake. Water Research 28: 849-861.

Doerr, S.M., R.P. Canale, and S.W. Effler. 1995. Development and Testing of a Total Phosphorus Model for Onondaga Lake, NY. Lake and Reservoir Management 12(1): 141-150.

Doerr, S.M., S.W. Effler, E.M. Owens. Forecasting Impacts of a Hypolimnetic Wastewater Discharge on Lake Water Quality, January 13, 1995.

Driscoll C.T. and W. Wang. Summary Report on Mercury Sampling in Onondaga Lake May 19, 1992.

Driscoll, C.T., S.W. Effler, M.T. Auer, S.M. Doerr, and M.R. Penn. 1993. Supply of phosphorus to the water column of a productive hardwater Lake: controlling mechanisms and management considerations. Hydrobiologia 253: 61-72.

Driscoll, C.T., S.W. Effler, and S.M. Doerr. 1994. Changes in Inorganic Carbon Chemistry and Deposition of Onondaga Lake, NY. Environmental Science and Technology 28: 1211-1218.

Driscoll, C.T. and W. Wang. Concentrations and Transport of Mercury in Onondaga Lake, (Final Report), January 25, 1994.

Ducey, P.K. and W. Newman. 1994. Final Report for the Preliminary Survey of Reptiles and Amphibians of the Onondaga Lake Ecosystem, 1994. Department of Biological Sciences, SUNY-Cortland. Unpublished report, 14 pp.

Ducey, P.K., SUNY Cortland. Wetland-Lake Connections and Amphibian Communities of the Onondaga Lake Ecosystem, Final Report for 1996.

Duncombe, W., and W. Wong/Syracuse University. Onondaga County's Economic Performance Since 1980 and Prospects for Next Decade, 5/29/96 (Preliminary Report - Report #1).

Duncombe, W. and B. Jump, Jr./Syracuse University. The Outlook for Onondaga County's Finances: Baseline Scenario, 12/96 (Preliminary Report - Report #3).

Duncombe, W., S. Felt, J. Follain and B. Jump, Jr./Syracuse University. The Economic and Fiscal Impact of Lake Remediation on Onondaga County, 12/96 (Preliminary Report - Report #4).

Effler, S.W. and W.E. Dean. 1975. Chemical Stratigraphy of Onondaga Lake Sediments. Geol. Soc. Am. (Northeast Program), 1975, Annual Meeting, Syracuse, NY, p. 53.

Effler, S.W., M.C. Rand, and T. Tamayo. 1979. Effects of Heavy Metals and Other Pollutants on the Sediments of Onondaga Lake. Water, Air, and Soil Pollution 12(2): 117-134.

Effler, S.W. and D.L. Johnson. 1980. Heavy Metal Distribution in Particles from the Flocculent Sediments of Onondaga Lake, NY in: Trace Substances in Environmental Health - XIV, D.D. Hemphill, Ed., University of Missouri, Columbia.

Effler, S.W., S.D. Field, M.A. Meyer, and P. Sze. 1981. Response of Onondaga Lake to Restoration Efforts, J. Env. Eng. Div., ASCE 107(EE1): 191-210.

Effler, S.W., M.C. Wodka, S.D. Field, and M.G. Perkins. 1982. Gelbstoff in Onondaga Lake, NY. Paper Presented at 45th Annual Meeting of the American Society of Limnology and Oceanography, Raleigh, NC, p. 17 of Abstracts.

Effler, S.W., S.P. Devan, P. Rodgers, and C.T. Driscoll. 1983. The Recent History (1970-1982) and Nature of Chloride Loading to Lake Ontario from Onondaga Lake, NY. Paper Presented at the 26th Conference on Great Lakes Research, Oswego, NY.

Effler, S.W., P. Jaran, and C.R. Carter. 1983. Onondaga Lake and Dissolved Oxygen in the Seneca River, J. Env. Eng. Div., ASCE 109(4): 945-951.

Effler, S.W., M.G. Perkins, and S.D. Field. 1984. Onondaga Lake and the Dynamics of Chloride in the Oswego River. Water, Air, and Soil Pollution 23: 69-80.

Effler, S.W., M.C. Wodka, and S.D. Field. 1984. Scattering and Absorption of Light in Onondaga Lake. Journal Environmental Engineering Division ASCE 110: 1134-1145.

Effler, S.W 1985 Attenuation Versus Transparency J. Env. Eng. Div., ASCE 1 448-459

Effler, S.W., S.P. Devan, and P. Rodgers. 1985. Chloride Loading to Lake Ontario from Onondaga Lake, NY. Journal Great Lakes Research 11: 53-58.

Effler, S.W., C.T. Driscoll, M.C. Wodka, R. Honstein, S.P. Devan, P. Jaran, and T. Edwards. 1985. Phosphorus Cycling in Ionically Polluted Onondaga Lake, New York. Water, Air, and Soil Pollution 24: 121-130.

Effler, S.W. and C.T. Driscoll. 1985. Calcium Chemistry and Deposition in Ionically Polluted Onondaga Lake, NY. Environmental Science and Technology 19: 716-720.

Effler, S.W. and C.T. Driscoll. 1985. A Chloride Budget for Onondaga Lake, NY .S.A. Water, Air, and Soil Pollution 27: 29-44.

Effler, S.W., E.M. Owens, and K.A. Schimel. 1985. Density Stratification in Ionically Polluted Onondaga Lake, U.S.A. Water, Air, and Soil Pollution 27: 247-258.

Effler S.W. and E.M Owens. Density Stratification in Onondaga Lake: 1968-1994, September 29, 1994.

Effler, S.W., K. Schimel, and F.J. Millero. 1986. Salinity, Chloride, and Density Relationships in Ion Enriched Onondaga Lake, NY. Water, Air, and Soil Pollution 27: 169-180.

Effler, S.W., M.C. Wodka, C.T. Driscoll, C. Brooks, M.G. Perkins, and E.M. Owens. 1986. Entrainment-Based Flux of Phosphorus in Onondaga Lake. Journal Environmental Engineering Division ASCE 112: 617-622.

Effler, S.W. and Owens, E.M. 1986. The Density of Inflows to Onondaga Lake, U.S.A., 1980 and 1981. Water, Air, and Soil Pollution 28: 105-115.

Effler, S.W. 1986. Response of Onondaga Lake to Reduced Phosphorus Input. Submitted to CNY Regional Planning and Development Board, Upstate Freshwater Institute, Syracuse, NY, 31 p.

Effler, S.W., M.G. Perkins, and C. Brooks. 1986. The Oxygen Resources of the Hypolimnion of Ionically Enriched Onondaga Lake, NY, U.S.A. Water, Air, and Soil Pollution 29: 93-108.

Effler, S.W. 1987. Hypereutrophy and Pollution in Onondaga Lake, NY. Proceedings of the American Water Resources Association, Symposium on Monitoring, Modeling, and Mediating Water Quality, Syracuse, NY, p. 87-101.

Effler, S.W. 1987. The Impact of a Chlor-alkali Plant on Onondaga Lake and Adjoining System: Water, Air, and Soil Pollution 33: 85-115.

Effler, S.W. and E.M. Owens. 1987. Modifications in Phosphorus Loadings to Onondaga Lake, U.S.A., Associated with Alkali Manufacturing. Water, Air, and Soil Pollution 32: 177-182.

Effler, S.W. and E.M. Owens. 1987. Modifications in Phosphorus Loading to Onondaga Lake, U.S.A., Associated with Alkali Manufacturing. Water, Air, and Soil Pollution 32: 177-182.

Effler, S.W. and M.G. Perkins. 1987. Failure of Spring Turnover in Onondaga Lake, NY, U.S.A. Water, Air, and Soil Pollution 34: 285-291.

Effler, S.W., J.P. Hassett, M.T. Auer, and N. Johnson. 1988. Depletion of Epilimnetic Oxygen, and Accumulation of Hydrogen Sulfide in the Hypolimnion of Onondaga Lake, NY, U.S.A. Water, Air, and Soil Pollution 39: 59-74.

Effler, S.W., R. Roop, and M.G. Perkins. 1988. A Simple Technique for Estimating the Absorption and Scattering Coefficients. Water Resources Bulletin 24: 397-404.

Effler, S.W 1988. Secchi Disc Transparency and Turbidity. J. Env. Eng. Div., ASCE 114 1436-1447.

Effler, S.W 1989. How Bad Is It? Clearwaters, NYWPCS 19(4): 14-16.

Effler, S.W., S.M. Doerr, C.M. Brooks, and C. Rowell. 1990. Chloride in the Pore Water and Water Colume of Onondaga Lake, NY, U.S.A. Water, Air, and Soil Pollution 51: 215-326.

Effler, S.W., C.M. Brooks, M.T. Auer, and S.M. Doerr. 1990. Free Ammonia in a Polluted, Hypereutrophic, Urban Lake. Journal Water Pollution Control Federation 62(6): 771-779.

Effler, S.W., C.M. Brooks, J.M. Address, S.M. Doerr, M.L. Storey, and B.A. Wagner. 1991. Pollutant Loadings from Solvay Waste ISEDS to Lower Nine Mile Creek, NY. Water, Air, and Soil Pollution 55: 427-444.

Effler, S.W., D.L. Johnson, J. Jiao, and M.G. Perkins. 1992. Optical Impacts and Sources of Suspended Solids in Onondaga Creek, U.S.A. Water Resources Bulletin 28: 252-262.

Effler, S.W. (Editor). 1996. Limnological and Engineering Analysis of a Polluted Urban Lake: Prelude to Environmental Management of Onondaga Lake, New York. Springer-Verlag, New York.

Effler, S.W./UFI. Oswego River Water Quality Monitoring Data 1992, January 25, 1993

Effler, S.W. and E.M. Owens. 9/29/94. Density Stratification in Onondaga Lake: 1968-1994. Lake and Reservoir Management 12(1): 25-33.

Effler, S.W., C.M. Brooks, and K.A. Whitehead. 1995. Domestic Waste Inputs of Nitrogen and Phosphorus to Onondaga Lake and Water Quality Implications. Lake and Reservoir Management 12(1): 127-140.

Effler, S.W., M.G. Perkins, K.A. Whitehead, and E.A. Romanowicz. 1995. Ionic Inputs to Onondaga Lake: Origins, Character, and Changes. Lake and Reservoir Management 12(1): 15-23.

Effler, S.W. and M.G. Perkins. 1995. An Optics Model for Onondaga Lake. Lake and Reservoir Management 12(1): 115-125.

Effler, S.W. and R. Hennigan. 1995. Onondaga Lake: Legacy of Pollution. Lake and Reservoir Management 12(1): 1-13.

Effler, S.W., C.M. Brooks, M.G. Perkins, S.M. Doerr, K.A. Whitehead, B.A. Wagner, and C.T. Driscoll. Onondaga Lake Monitoring Report, 1993 (Final Report), April 1995.

Effler, S.W., C.M. Brooks, M.G. Perkins, S.M. Doerr, K.A. Whitehead, B.A. Wagner, and C.T. Driscoll. Onondaga Lake Monitoring Report, 1994 (Final Report), July 1995.

Effler, S.W., S.M. Doerr, and E.M. Owens. Salinity Stratification in Seneca River, NY: Changes Since Closure of a Soda Ash Facility,May 1995.

Effler, S.W., M.G. Perkins, C.M. Brooks, S.M. Doerr, K.A. Whitehead, S. Boone, B.A. Wagner, and E. Haslam. Studies of the Seneca and Oswego Rivers, and Oswego Harbor, 1993 (Final Report), August 1995.

Effler, S.W., M.G. Perkins, C.M. Brooks, S.M. Doerr, K.A. Whitehead, B.A. Wagner, S.B. Boone, and E. Haslam. Studies of the Seneca and Oswego Rivers, 1994, November 1995.

Effler, S.W. (ed.) 1996. Limnological and Engineering Analysis of a Polluted Urban Lake Prelude to Environmental Management of Onondaga Lake, New York. Springer-Verlag. New York, NY.

Effler, S.W. and C. Siegfried. Zebra Mussel Populations in the Seneca River, New York: Impact on Oxygen Resources, June 16, 1994.

Effler, S.W., C.M. Brooks, M.G. Perkins, S.M. Doerr, K.A. Whitehead, B.A. Wagner, C.A. Siegfried, L.Walrath, and R. Canale. Impact of Zebra Mussel Invasion of River Water Quality, June 16, 1994.

Effler, S.W. and C.M. Brooks. Dry Weight Deposition in Polluted Onondaga Lake, New York, U.S.A., April 8, 1996.

Effler, S.W., C.M. Brooks, and C.T. Driscoll. Depositing Seston in a Ca^{2}+ Enriched Lake: Long-Term Changes in Rates and Stoichiometry, July 1996.

Esser, A., Soil Conservation Service. Onondaga Lake Watershed, Rural Nonpoint Source Management Plan (Draft), May 1993

Etter, T.R. 1966. Report on Nine Mile Creek. Syracuse, NY. (Unpublished).

Federal Water Pollution Control Administration and New York Department of Health, 1968. Water Pollution Control Problems and Improvement Needs, Lake Ontario and St. Lawrence River

Basins. Fed. Water Pollution Control Administration, Chicago and New York Department of Health, Albany, NY. 125 p.

Field, S.D. 1980. Nutrient-Saturated Algal Growth in Hypereutrophic Onondaga Lake, Syracuse, NY. Ph.D. Dissertation, Syracuse University, Syracuse, NY. 172 p.

Field, S.D. and S.W. Effler. 1979. Diurnal Dissolved Oxygen in Hypereutrophic Onondaga Lake, NY. Paper Presented at the 42nd Annual Meeting of the American Society Limnology and Oceanography, Stony Brook, NY.

Field, S.D. and S.W. Effler. 1980. Indication of Heterotrophic Activity in Hypereutrophic Onondaga Lake, Syracuse, NY. Paper Presented at 43rd Annual Meeting American Society Limnology and Oceanography, Knoxville, TN.

Field, S.D. and S.W. Effler. 1983. Light-Productivity Model for Onondaga Lake, NY. Journal Environmental Engineering Division, ASCE 109: 830-844.

Follain, J.R., S. Felt and S. McCoskey/Syracuse University. A Review and Forecast of the Onondaga County Economy, 5/14/96 (Preliminary Report - Report #2).

Garofalo, J.E. and S.W. Effler. 1987. Coating of Zooplankton with Calcium in Onondaga Lake, NY. Environmental Science and Technology 21: 604-606.

Gbondo-Tugbawa, S. 1996. Concentrations and Fluxes of Total and Methylmercury to Onondaga Lake, Syracuse, New York. Master's Thesis, Syracuse University, Syracuse, New York.

Gbondo-Tugbawa, S., and C.T. Driscoll. 1998. Application of the Regional Mercury Cycling Model (RMCM) to Predict the Fate and Remediation of Mercury in Onondaga Lake. Water, Air, and Soil Pollution 105: 417-426.

Gelda, R.R. and M.T. Auer. 1995. Development and Testing of a Dissolved Oxygen Model for a Hypereutrophic Lake, NY. Lake and Reservoir Management 12(1): 165-179.

Gelda, R.R., M.T. Auer, S.W. Effler, S.C. Chapra, and M.L. Storey. 199-. Determination of Reaeration Coefficients: A Whole Lake Approach. Journal Environmental Engineering ASCE 122(4): 269-275.

Harman, W.N. 1968. Replacement of Pleurocerids by Bithynia in Polluted Waters of Century New York. The Nautilus 81(3): 77-83.

Harman, W.N. 1970. New Distribution Records and Ecological Notes on Central New York Unionacea. American Midland Naturalist 84(1): 46-58.

Harman, W.N. and C.O. Berg. 1970. Freshwater Mollusca of the Finger Lakes Region of New York. Ohio Journal Science 70(3): 146-150.

Hassett, J.P., and S.M. Hubbard. Sources of Organic Contaminants to Onondaga Lake (Final Report), (not dated).

Heidtke, T.M. 1989. Onondaga Lake Loading Analyses: Fecal Coliforms. Submitted to CNY Regional Planning and Development Board (for NYSDEC), Syracuse, NY.

Hennigan, J.J. 1975. Precast Concrete Piles Cut Plant Construction Cost. Public Works 106(10) 84-85.

Hennigan, R.D. and S.W. Effler. 1985. Onondaga Lake and Watershed Management Project. Prepared for the NYSDEC, CNY Regional Planning and Development Board.

Hennigan, R.D. 1989. America's Dirtiest Lake. Clearwaters, NYWPCA 19(4): 8-12.

Herrell, C. 1975. The Image of Onondaga Lake: A Content Analysis of Environmental Information. Department of Geography, Syracuse University, Syracuse, NY.

Hewlett, J.D. 1956. The Development of Vegetation on the Solvay Wastebeds. Masters Thesis, State University College of Forestry, Syracuse, NY. 143 p.

Hindenlong, D.M., P. Rudewicz, and D.E. Smith. 1981. Analysis of Onondaga Lake Fish Samples for Benzene and Chlorobenzene. Allied Chemical Corporation, memorandum to R.S. Price.

Hornstein, R.L. 1981. An Assessment of Mechanisms by Which Phosphorus may be Regulated within the Sediments of Onondaga Lake, NY. Masters Thesis, Syracuse University, Syracuse, NY.

Hornstein, R., C.T. Driscoll, D.L. Johnson, and S.W. Effler. 1982. Phosphorus Chemistry in the Pore Water of the Flocculent Layers of Onondaga Lake. Paper Presented at the 45th Annual Meeting of American Society Limnology and Oceanography, Raleigh, NC.

Jackson, D.F. 1968. Onondaga Lake, NY - An Unusual Algal Environment, in Jackson, D.F. (ed.), Algae, Man and the Environment. Syracuse University Press, Syracuse, NY. p. 515-524.

Johnson, D.L., F. Jaio, G. DeSantos, and S.W. Effler. 1991. Individual Particle Analysis of Suspended Materials in Onondaga Lake, NY. Environmental Science and Technology 25: 736-744.

Kantrowitz, I.H. Ground Water Resources in the Eastern Oswego River Basin, New York, (prepared for the Eastern Oswego Regional Water Resources Planning Board).

Kappel, W.M., Sherwood, D.A. and Johnston, W.H., 1996, Hydrogeology of the Tully Valley and Characterization of Mudboil Activity, Onondaga County, New York, U.S. Geological Survey, Water Resources Investigations Report 96-4043.

Knowledge Systems and Research, Inc. Perceptions, Attitudes and Behavior Toward Onondaga Lake - Survey of Community Leaders and General Population in Onondaga County, Preliminary Results, Findings and Recommendations, April 12, 1993.

Lake and Reservoir Management, Vol 12, No. , March 1996.

This is an international journal of the North American Lake Management Society. The entire issue is devoted to research conducted on Onondaga Lake.

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m. Doerr, Canale, Effler; Development and Testing of a Total Phosphorus Model for Onondaga Lake.

n. Canale, Gelda and Effler; Development and Testing of a Nitrogen Model for Onondaga Lake.

o. Gelda and Auer; Development and Testing of a Dissolved Oxygen Model for a Hypereutrophic Lake.

p. Effler and Doerr; Water Quality Model Evaluations for Scenarios of Loading Reductions and Diversion of Domestic Waste Effluent Around Onondaga Lake.

q. Owens and Effler; Modeling the Impacts of a Proposed Hypolimnetic Wastewater Discharge on Stratification and Mixing in Onondaga Lake.

r. Doerr, Effler, and Owens; Forecasting Impacts of a Hypolimnetic Wastewater Discharge of Lake Water Quality

Limnofix Inc. Report on Evaluation of Liquid Oxygen Injection to Improve Dissolved Oxygen in Onondaga Lake, 1994.

Limno Tech, Inc. 1978. Mathematical Modeling of the Impact of Storms on Water Quality in Onondaga Lake (prepared for Stearns & Wheler Engineers and Onondaga County).

Limno Tech, Inc. 1983. Development of a Microcomputer Water Quality Model for Onondaga Lake.

Lincoln, D.F. 1982. Glaciation in the Finger Lakes Region of New York. American Journal of Science 144(26): 290-301.

Madsen, J.D., R.M. Smart, L.W. Eichler, C.W. Boylen, J.W. Sutherland and J.A. Bloomfield. 1993. Submersed littoral vegetation distribution: Field quantification and experimental analysis of sediment types from Onondaga Lake, New York. Technical Report A-93-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS. August 1993.

Madsen, J.D., R.M. Smart, J.W. Sutherland, J.A. Bloomfield, L.W. Eichler, and C.W. Boylen. 1993. Onondaga Lake, New York: Distribution and abundance of aquatic vegetation related to the fertility of oncolite sediments. pp. 657-662. In: Landin, M.C., ed. Wetlands: Proceedings of the 13th Annual Conference of the Society of Wetland Scientists, New Orleans, LA, June 1992.

Madsen, J.D., J.A. Bloomfield, J.W. Sutherland, L.W. Eichler, and C.W. Boylen. 1996. The aquatic macrophyte community of Onondaga Lake, New York: Field survey and plant growth bioassays of lake sediments. Lake and Reservoir Management, 12:73-79.

Makarewicz, J.C., B. Cady, T. Lewis, J. Buttner and J. Haynes of SUNY Brockport. Phytoplankton, Zooplankton, Macrobenthos and Ichthyoplankton Abundance, Biomass and Species Composition in Onondaga Lake 1994, and the Photographic Record of Taxonomic Features Used in Identification of Onondaga Lake Zooplankton and Phytoplankton Collected in 1994, February 1995.

Makarewicz, J.C., B. Cady, T. Lewis, J. Buttner, and J. Haynes. 1995. Phytoplankton, Zooplankton, Macrobenthos, and Ichthyoplankton Abundance, Biomass and Species Composition in Onondaga Lake. 1994. Onondaga Lake Management Conference.

Marzec, G.M. 1988. Onondaga Lake Transparency/Bacteria Study. 1987. Masters Degree Report on an Internship with Onondaga County Department of Drainage and Sanitation, SUNY College Environmental Science and Forestry, Syracuse, NY. (Unpublished)

McAlear, J.A. 1996. Concentrations and Fluxes of Total Mercury and Methylmercury within a Wastewater Treatment Plant. Master's Thesis, Syracuse University, Syracuse, NY.

Metcalf, L. and H.P. Eddy. 1920. Report to Syracuse Intercepting Sewer Board upon the Treatment and Disposal at Syracuse. Metcalf and Eddy, Consulting Engineers, Boston, MA.

Meyer, M.A., S.D. Field, S.W. Effler, and M.C. Rand. 1979. Temporal and Spatial Distribution of Limnetic Zooplankton in Onondaga Lake, Syracuse, NY. Paper Presented at the 42nd Annual Meeting American Soc. Limnology and Oceanography, Stony Brook, NY.

Meyer, M.A. and S.W. Effler. 1980. Changes in the Zooplankton of Onondaga Lake, 1969-1978. Environmental Pollution (Ser. A) 23(2): 131-152.

Moffa & Associates. 1985 Onondaga Lake Monitoring Program. With Appendix A, April 1987. Prepared for OCDDS.

Moffa & Associates. 1986 Onondaga Lake Monitoring Program with Appendix A April 1988. Prepared for OCDDS.

Moffa, P.E. and M.C. Rand. 1970. Engineering Considerations of an Eutrophic Water Body. International Association Great Lakes Research, 13th Conference Great Lakes Research, Proc., Buffalo, NY, p. 693-706.

Moffa, P.E., F.J. Drehwing, J.M. Karanik, J.J. Hennigan. 1971. Comprehensive Abatement Program for an Eutrophic Lake. International Association Great Lakes Research, 14th Conference Great Lakes Research, Proc., Toronto, Ontario, p. 690-705.

Moffa, P.E., J.C. Byron, S.W. Effler, R.C. Canale, and J.M. Karanik. 1978. The Impact of Combined Sewer Overflows on an Urban Lake (Onondaga Lake). Paper Presented at the 1978 NYWPCF Conference.

Moffa, P.E., J.C. Byron, S.D. Freedman. 1979. Cost-effective Abatement of Combined Sewer Overflow Discharges Through the Assessment of Water Quality Impacts. Presented at NYWPCA, October 1979.

Moffa, P.E., J.C. Byron, S.D. Freedman, J.M. Karanik, and R. Ott. 1980. Methodology for Evaluating the Impact and Abatement of Combined Sewer Overflows; A Case Study of Onondaga Lake, NY. USEPA Report EPA-600/8-80-048, 137 p.

Moffa, P.E., S.J. Nix, and A. Russell. A Watershed Approach, Water Quality Impacts of CSO's and Cost-Effective Abatement presented at Water Environmental Federation Conference, October 1994.

Moffa, P.E., S. Nix, C.R. Smithgall, J. Karanik, and A. Russell. Strategizing for CSO Abatement as Part of the Onondaga Lake Management Plan, Proceedings WEF Specialty Conference: A Global Perspective for Reducing CSO's, Louisville, KY, July 1994.

Moffa, P.E., P.P. Davis, H.M. Goebel, C.R. Smithgall, J.M. Karanik, A.R. Russell, S.W. Martin. Compliance with the National CSO Abatement Policy for Syracuse, New York, presented at the 1997 Water Environment Federation Meeting, Chicago, Ill.

Murphy, C.B., Jr., Onondaga Lake, in Lakes of New York, Volume II - Ecology of the Lakes of Wester New York, edited by J. Bloomfield, Acedamic Press, 1978. (Pgs 223-365).

Nalepa, T.F. and G.L. Fahnenstiel (Eds.), 1995. Zebra Mussels in the Saginaw Bay, Lake Huron Ecosystem. Special Section in Journal of Great Lakes Research 21(4).

New York State Department of Environmental Conservation, Region 7. 1985. The Allied Closure Environmental Issues 1985. 47 p. with App.

New York State Department of Environmental Conservation. 1985. Onondaga Lake Mercury Trend Analysis: Sampling Protocol. NYSDEC, Bureau Environmental Protection, Division of Fish and Wildlife, 15 p.

New York State Department of Environmental Conservation. 1987. An Overview of Mercury Contamination in the Fish of Onondaga Lake. NYSDEC Tech Rep 87-1.

New York State Department of Health. 1951. The Onondaga Lake Drainage Basin: Recommended Classifications and Assignments of Standards of Quality and Purity for Designated Waters of NYS. NYS Department of Health, Albany, Oswego River Drainage Basin Survey Ser. Report. 1, 151 p.

New York State Department of Health. 1955. Oswego River and Lower Seneca River Drainage Basin. NYS Department of Health, Oswego River Drainage Basin Survey Ser. Report 3, 71 p.

New York State Department of Public Works. 1953. Report on Northwest Arterial Connection of the NYS Thruway and West Shore Development of Lake Onondaga, Syracuse, NY; Syracuse, NY Department of Public Works.

Nix, S.J., J. Hassett, and L. Wright. Preliminary Management Plan for Urban Runoff Pollution to Onondaga Lake,; April 1994.

Noble, R.L. and J.L. Forney. 1969. Fish Survey of Onondaga Lake Summer 1969. Masters Thesis, Cornell University, Ithaca, NY 9 p.

O'Brien and Gere Engineers. 1952. Onondaga Lake Watershed. Onondaga County Department of Public Works, Syracuse, NY.

O'Brien and Gere Engineers. 1952. Sewage Treatment Facilities, Metropolitan Syracuse. Report to Onondaga County Public Works Commission, Syracuse, NY.

O'Brien and Gere Engineers. 1971. Wastewater Facilities Report, Metropolitan Sewage Treatment Plant Expansion. Syracuse, NY.

O'Brien and Gere Engineers. 1973. Environmental Assessment Statement, Syracuse Metropolitan Sewage Treatment Plant and West Side Pump Station and Force Main. Onondaga County, NY.

O'Brien and Gere Engineers. Onondaga Lake Monitoring Program 1971, June 1972. Prepared for Onondaga County Department of Public Works.

O'Brien and Gere Engineers. Onondaga Lake Monitoring Program 1972, (not dated). Prepared for Onondaga County Department of Public Works.

O'Brien and Gere Engineers. Onondaga Lake Monitoring Program 1973, February, 1975. Prepared for Onondaga County Department of Public Works.

O'Brien and Gere Engineers. Onondaga Lake Monitoring Program 1974, June 1975. Prepared for OCDDS.

O'Brien and Gere Engineers. Onondaga Lake Monitoring Program 1975, November 1976. Prepared for OCDDS.

O'Brien and Gere Engineers. 1977. Water Quality Survey of Seneca-Oneida-Oswego Rivers. Submitted to CNY Regional Planning and Development Board, Syracuse, NY.

O'Brien and Gere Engineers. 1977, 1979, 1987. Combined Sewer Overflow Abatement Program for Metropolitan Syracuse Treatment Plant Service Area, Department of Drainage and Sanitation, Onondaga County.

Onondaga County. 1994. Draft Municipal Compliance Plan/Draft Environmental Impact Statement, Onondaga County Wastewater Collection and Treatment.

Onondaga County, Onondaga Lake Study (prepared for the Water Quality Office, Environmental Protection Agency), April 1971.

Onondaga County Soil and Water Conservation District. Onondaga Lake Non-Point Source Information and Education Program and Best Management Practice Implementation Demonstration (Final Report), June 1994.

Owens, E.M. and S.W. Effler. 1985. A Stratification Model for Onondaga Lake, NY. Submitted to CNY Regional Planning and Development Board. A Contribution of the Upstate Freshwater Institute, Syracuse, NY.

Owens, E.M. and S.W. Effler. 1986. Changes in Stratification in Onondaga Lake, NY. Submitted to CNY Regional Planning and Development Board, Syracuse, NY.

Owens, E.M. and S.W. Effler. Forecasting Impacts of a Hypolimnetic Wastewater Discharge on Lake Stratification and Mixing, November 21, 1994.

Owens, E.M. and S.W. Effler. 1987. Meteorologically-Based Variations in Thermal Stratification. Presented at the 51st Annual Meeting American Soc. Limnology and Oceanography, Madison, WI.

Owens, E.M. and S.W. Effler. 1989. Changes in Stratification in Onondaga Lake, NY Resources Bulletin 25: 587-597.

PTI Environmental Services, Waltham, MA. 1992. Onondaga Lake RI/FS Calcite Modeling Plan. Prepared by HydroQual, Inc., Mahwah, NJ. 30 p.

PTI Environmental Services, Waltham, MA. 1992. Onondaga Lake RI/FS Sediment Processes Study Work Plan and Sampling and Analysis Plan.

PTI Environmental Services, Waltham, MA. 1992. Onondaga Lake RI/FS Preliminary Overview of Sediment Remediation Alternatives. 44 p.

PTI Environmental Services, Waltham, MA. 1992. Onondaga Lake RI/FS Site History Report. 107 p.

PTI Environmental Services, Waltham, MA. 1992. Onondaga Lake Mercury Modeling Plan.

PTI Environmental Services, Waltham, MA. 1992 Onondaga Lake RI/FS Geophysical Survey Report. 8 p.

PTI Environmental Services, Waltham, MA. 1993 Onondaga Lake RI/FS Bioaccumulation Investigation Data Report. 62 p.

PTI Environmental Services, Waltham, MA. 1993. Onondaga Lake RI/FS Substance Distribution Investigation Data Report. 90 p.

PTI Environmental Services, Waltham, MA. Onondaga Lake RI/FS. 1993 Mercury and Calcite Mass Balance Investigation Data Report. 32 p.

PTI Environmental Services, Waltham, MA 1993. Onondaga Lake RI/FS Ecological Effects Investigation Data Report. 54 p.

PTI Environmental Services, Waltham, MA. 1993. Onondaga Lake RI/FS. Substances Distribution Investigation Data Report. Appendix B Field Methods.

PTI Environmental Services, Bellevue, WA. 1993. Onondaga Lake RI/FS Mercury and Calcite Mass Balance Investigation Data Report - Appendix B Field Methods.

PTI Environmental Services, Bellevue, WA. 1994. Onondaga Lake RI/FS Calcite Modeling Report, Prepared by HydroQual, Inc. and PIT Environmental Services, Bellevue, WA.

PTI Environmental Services, Waltham, MA. 1994. Onondaga Lake RI/FS Mercury Modeling Report. Prepared for AlliedSignal, Inc. 17 p.

Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon. 1974. National Eutrophication Survey Methods for Lake Samples in 1972. USEPA National Eutrophication Survey, Working Paper 1, 39 p.

Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon. 1974. An Approach to a Relative Trophic Index System for Classifying Lakes and Reservoirs. USEPA, National Eutrophication Survey, Working Paper 24, 44 p.

Penn, M.R., J.J. Pauer, R.K. Gelda, and M.T. Auer. Technical Report, Laboratory Measurement of Chemical Exchange at the Sediment, Water Interface of Onondaga Lake. January 27, 1994.

Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon. 1974. The Relationship of Phosphorus and Nitrogen to the Trophic State of Northeast and North-Central Lakes and Reservoirs. USEPA, National Eutrophication Survey, Working Paper 33, 35 p.

Perkins, M.G. and S.W. Effler. 1995. Optical Characteristics of Onondaga Lake 1968-1990. Lake and Reservoir Management 12(1): 103-113.

Perkins, M.G., E.A. Romanowicz, and E.T. Haslam of UFI. Hydrogeologic Investigation of the Nearshore Area of Onondaga Lake from Ley Creek to Onondaga Creek, Including the Barge Canal Terminal Area. January 1996.

Pitts, N.F. 1948. Pollution Survey of Onondaga Lake and Tributaries within the City of Syracuse. City Engineer, Department of Engineering, Syracuse, NY.

Rand, M.C., S.W. Effler, and T. Tamatyo. 1977. The Effects of Pollution on the Sediments of Onondaga Lake. Paper Presented at the 1977 National Water Pollution Control Federation Conference.

Ringler N. H. Fish Communities and Habitats of Onondaga Lake System, January 2, 1992.

Romanowicz , E.A. and M.G. Perkins. Hydrologic Investigation of Tully Mud Boils,; October 6. 1993.

Rupp, L 1989. Paradise Lost and Found? Clearwaters, NYWPCA 19(4): 20-23

Scrudato, R.J. and R.H. Sugat. 1983. State Pollutant Discharge Elimination System (SPDES): Toxic Loadings to the Oswego River Drainage Basin, North Central, NY. Submitted to the Legislative Commission on Science and Technology, NYS SUNY, Oswego, 96 p.

Seeger, E.S. 1980. The Fate of Heavy Metals in Onondaga Lake Masters Thesis, Clarkson College, Potsdam, NY 169 p.

Shero, B.R., M. Parker, and K.M. Stewart. 1978. The Diatoms, Productivity, and Morphometry of 43 Lakes in New York State, U.S.A. Int. Revue ges. Hydrobiol. 63(3): 365-387.

Siegfried, C.A., N.A. Auer, S.W. Effler. 1995. Changes in Zooplankton of Onondaga Lake: Causes and Implications. Lake and Reservoir Management 12(1): 59-71.

Stearns & Wheler. Bioaccumulation of Organic Compounds in Fish Flesh in Onondaga Lake (final report), January 1993.

Stearns & Wheler. Onondaga Lake Monitoring Program 1976 Annual Report, October 1977 Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1977 Annual Report, August 1978. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1978 Annual Report, December 1979 Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1979 Annual Report, December 1980 Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1980 Annual Report, August 1981 Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1987 Annual Report, with Appendix B, February 1989. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1988 Annual Report, with Appendix B April 1990. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1989 Annual Report, with Appendix B, April 1991,Tables and Graphs April, 1990. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1990 Annual Report, with Appendix B December 1991, Tables and Graphs, August, 1991. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Cooperative Monitoring Program 1991 Annual Report, with Appendix B and C. August1993.

Stearns & Wheler. Onondaga Lake Cooperative Monitoring Program 1992 Annual Report, with Appendix B. August 1993.

Stearns & Wheler. Onondaga Lake Monitoring Program 1993 Annual Report, with Appendix B. August 1994. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1994 Annual Report, with Appendix B, July 1995. Addendum, October, 1995. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1995 Annual Report, with Appendix A, October 1996, Appendix B,C, and D, August 1996. Prepared for OCDDS.

Stearns & Wheler. Onondaga Lake Monitoring Program 1996 Annual Report, September 1997, with Appendix B,C, and D, July 1997. Prepared for OCDDS.

Stewart, K.M. 1978. Infrared Imagery and Thermal Transects of Onondaga Lake, New York. Verh. Internat. Verin. Limnol. 20: 496-501.

Struthers, P.H. 1928. Carp Control Studies in the Erie Canal, in a Biological Survey of the Erie-Niagara System. NYS Conservation Department. 18th Annual Report Supplement, p. 208-219.

Sutherland, J.C. 1969. Geochemical Systems in Onondaga Lake (Central NYS) Compared with the Great Lakes. International Association. Great Lakes Research, 12th Conference. Great Lakes Research, Proc., Ann Arbor, MI. p. 357-363.

Swanson, J.C., D. Mendelsohn, and A. Odulo. Onondaga Lake Outlet Hydrodynamic Study (Draft), July 1994.

Syracuse University. 1970. Benefits of Water Quality Enhancement. USEPA and Syracuse University Department of Civil Engineering, 194 p.

Sze, P. 1972. The Phytoplankton of Onondaga Lake. Ph.D. Dissertation, Cornell University, Ithaca, NY. 177 p.

Sze, P. 1975. Possible Effects of Lower Phosphorus Concentrations on the Phytoplankton in Onondaga Lake, NY, U.S.A. Phycologia 14(4): 197-204.

Sze, P. 1980. Seasonal Succession of Phytoplankton in Onondaga Lake, NY (U.S.A.) Phycologia 19(1): 54-59.

Sze, P. and J.M. Kingsbury. 1972. Distribution of Phytoplankton in a Polluted Saline Lake, Onondaga Lake, NY. Journal Phycology 8(1): 25-37.

Sze, P. and J.M. Kingsbury. 1974. Interactions of Phytoplankters Cultured from a Polluted Saline Lake, Onondaga Lake, NY. Journal Phycology 10(1): 5-8.

Tamayo, T.A. 1976. An Investigation of the Possible Existence of a Previously Unstudied Portion of Sediment in Onondaga Lake. Masters Thesis, Syracuse University, Syracuse, NY.

Thomsen Associates and Calocerinos and Spina. 1980. Hydrogeologic Studies, Onondaga Lake, Crucible Landfill.

United States Army Corps of Engineers. 1971. Flood Plain Information: Ley Creek, Salina and Dewitt Townships, Onondaga County, NY. Army Engineer District, Buffalo, NY. Prepared for Eastern Oswego Basin-Regional Water Resources Planning Board, 44 p.

United States Environmental Protection Agency. 1973. Report of Mercury Source Investigation Onondaga Lake, NY and Allied Chemical Corporation, Solvay, NY. National Field Investigations Center, Cincinnati, OH and Region II, New York. 67 p.

United States Environmental Protection Agency. 1974. Environmental Impact Statement on Wastewater Treatment Facilities Construction Grants for the Onondaga Lake Drainage Basin. USEPA, Region II, New York, NY, 246 p.

Upstate Freshwater Institute. Responses to Onondaga County Comments of May 5, 1993 on UFI Onondaga Lake/Seneca River Water Quality Models, August 31, 1993.

Upstate Freshwater Institute. The State of Onondaga Lake, Volumes I and II, 1994.

U.S. Army Corp of Engineers. Environmental Assessment and Finding of No Significant Impact (FONSI) for the Onondaga Lake Inner Harbor Dredging Design Project, Syracuse, New York, November 1996.

VanDruff, L.W. and M.A. Pike. Wildlife and Habitats of the Onondaga Lake Area - A Review. August 1992.

Wagner, B. A. and S. W. Effler. Near Shore Benthic Macroinvertebrates of Onondaga Lake, New York, January 1993.

Walker, W.W. September 1995. Documentation for AUTOFLUX, prepared for Stearns & Wheler, LLC and Onondaga County Department of Drainage and Sanitation.

Wang, W. 1993. Patterns of Total Mercury Concentration in Onondaga Lake. Master's Thesis, Syracuse University, Syracuse, New York.

Wang, W. and C.T. Driscoll. 1995. Patterns of Total Mercury Concentration in Onondaga Lake, New York. Environmental Science and Technology. 29: 2261-2266.

Wodka, M.C., S.W. Effler, C.T. Driscoll, S.D. Field, and S.D. Devan. 1983. Diffusivity - Based Flux of Phosphorus in Onondaga Lake. Journal Environmental Engineering Division ASCE 109: 1403-1415.

Wodka, M.C., S.W. Effler, and C.T. Driscoll. 1985. Phosphorus Deposition from the Epilimnion of Onondaga Lake. Limnology and Oceanography 30: 833-843.

Womble, R.N., C.T. Driscoll, S.W. Effler 1995. Calcium Carbonate Deposition in Ca^{2}+ Polluted Onondaga Lake, New York, U.S.A., Master's Thesis, Syracuse University, Syracuse, New York.

Womble, R.N., C.T. Driscoll, S.W. Effler. 1996. Calcium Carbonate Deposition in Ca^{2+} Polluted Onondaga Lake, New York, U.S.A. Water Research 30: 2139-2147.

Wurst, L., State University of New York at Binghamton. Public Archaeology Facility Report, July 22, 1994.

Yin, C. 1982. A Research of Sources and Budget of mineral Sediments in Onondaga Lake, Central New York. Masters Thesis, SUNY College of Environmental Science and Forestry, Syracuse, NY.

Yin, C.Q., D.L. Johnson, and S.W. Effler. 1982. Individual Particle Characterizations of Suspended Mineral Sediments in the Three Rivers System. Paper Presented at 45th Annual Meeting American Society Limnology and Oceanography, Raleigh, NC.

Yin, C. and D.L. Johnson. 1983. Sedimentation and Particle Class Balances in Onondaga Lake, NY. Limnology and Oceanography 29: 1993-1201.

Young, T.C., J.V. DePinto, and E.S. Seger. 1982. Transport and Fate of Heavy Metals in Onondaga Lake, NY. Bulletin Environmental Contamination and Toxicology 29(5): 554-561.

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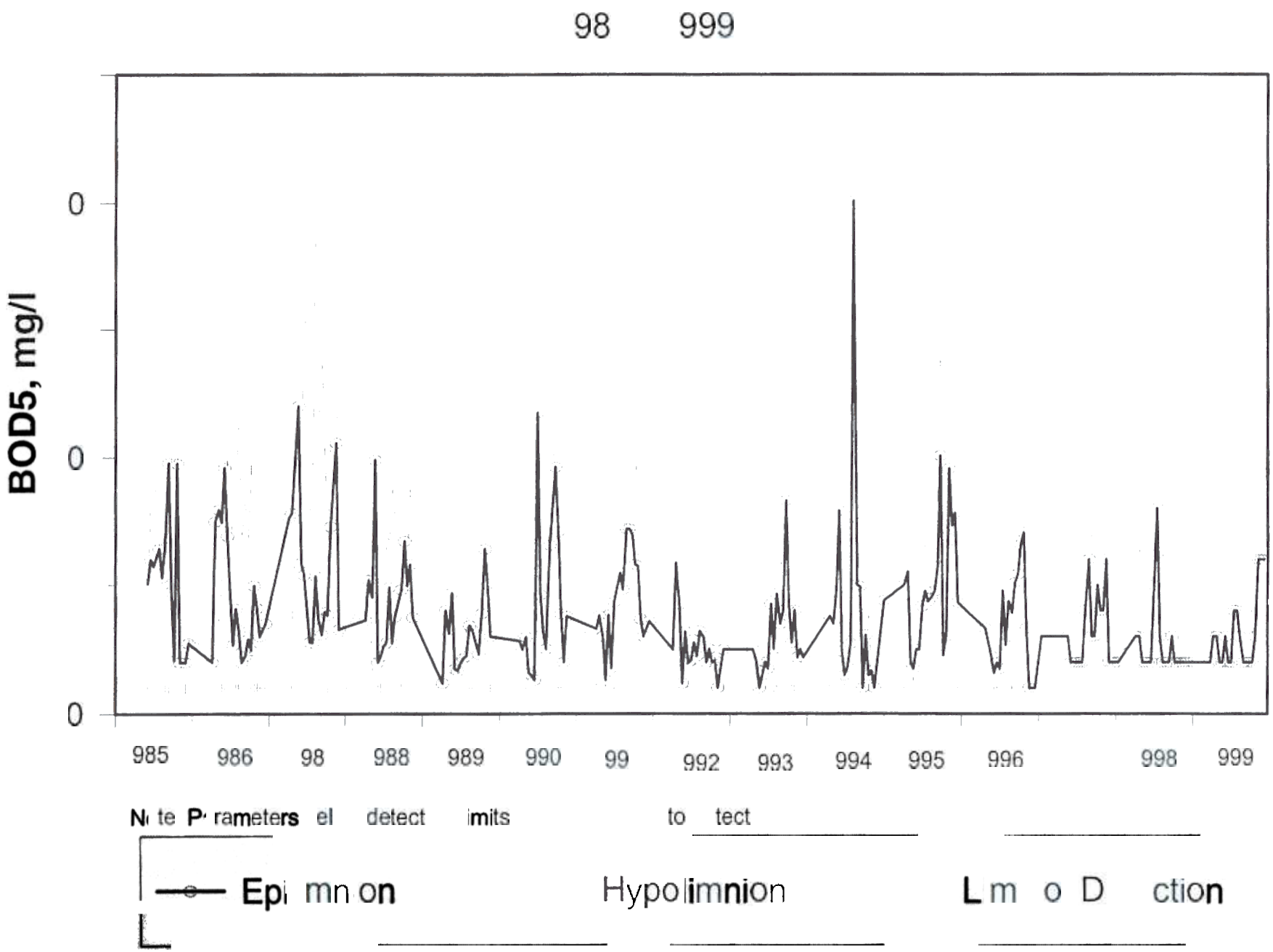
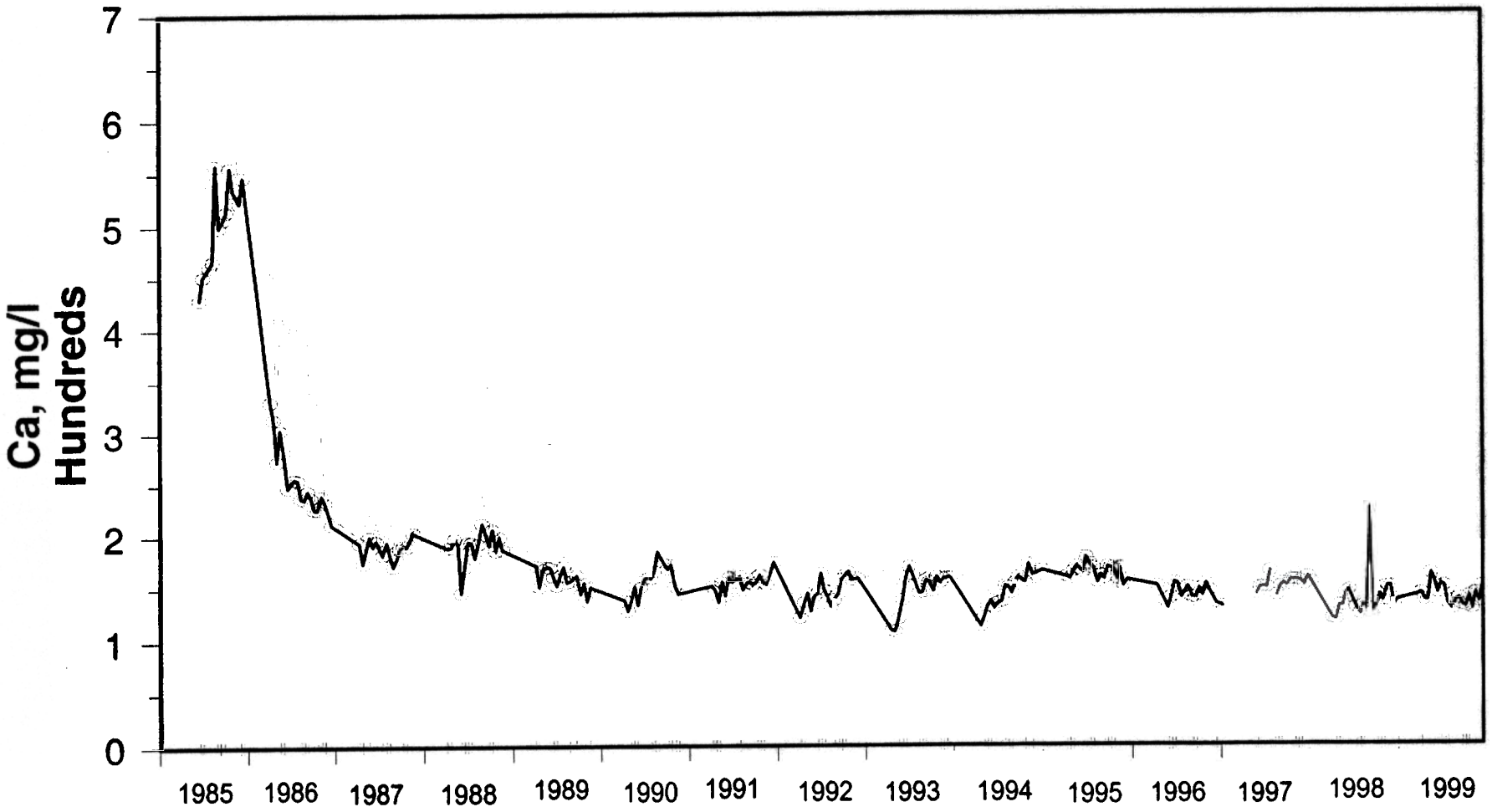
A.2
Onondaga Lake Historic Data Plots for Epilimnion and Hypolimnion, 1985 to 1999

Onondaga Lake - 5 Day BOD



Onondaga Lake -Total Calcium

1985 - 1999



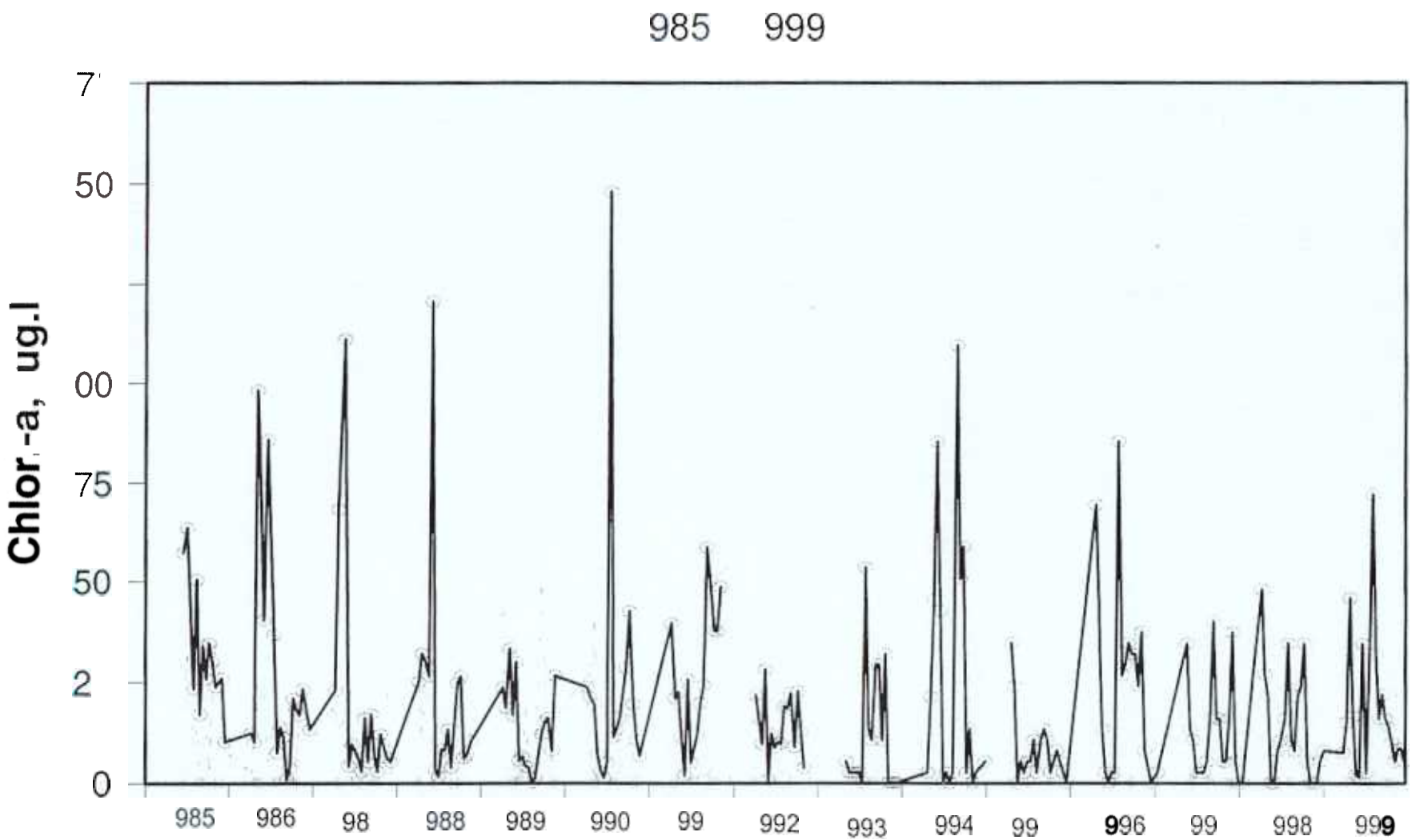
Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion

Hypolimnion

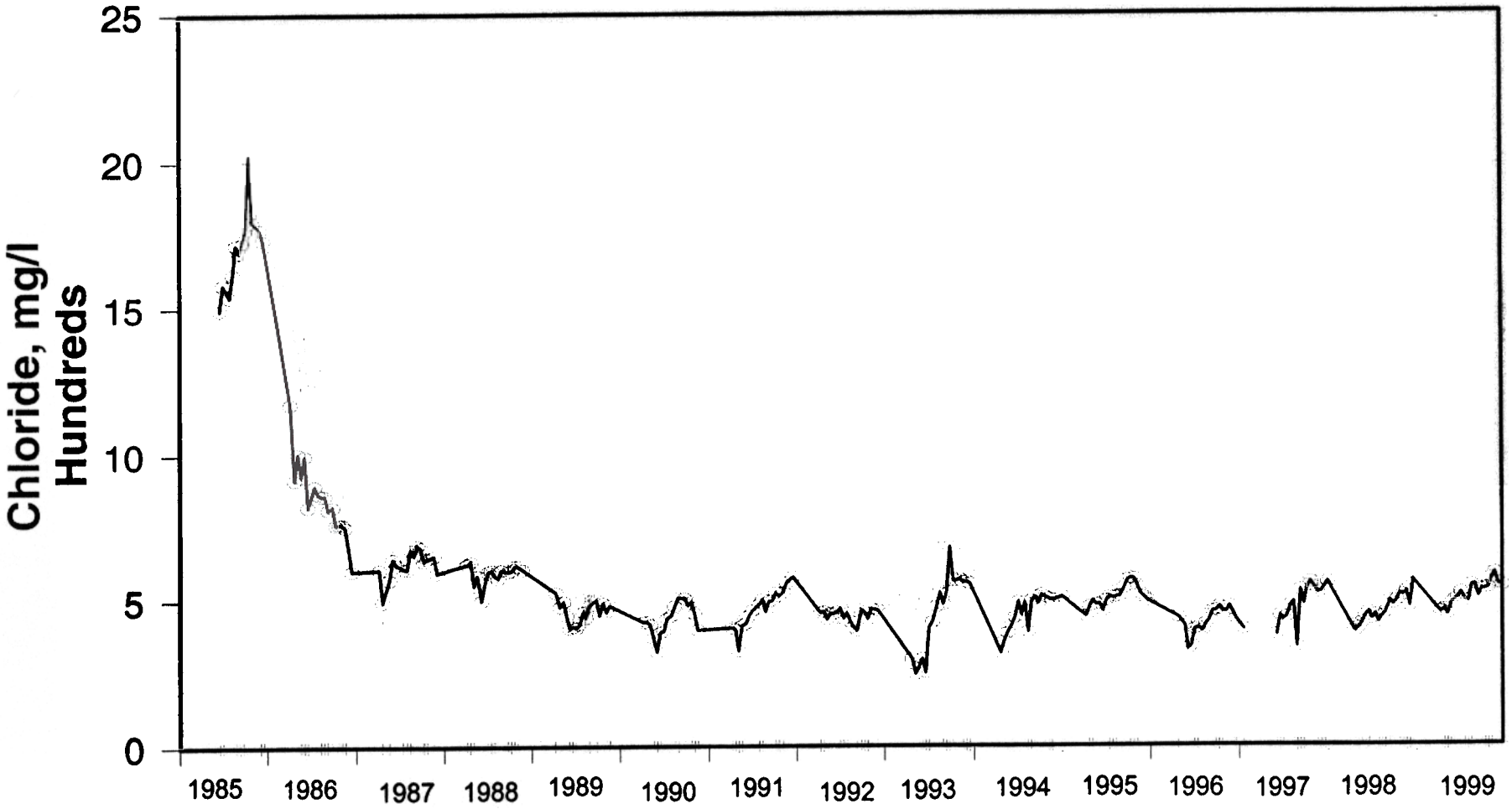
Limit of Detection

Onondaga Lake - Chlorophyll-a



Onondaga Lake - Chloride

1985 - 1999

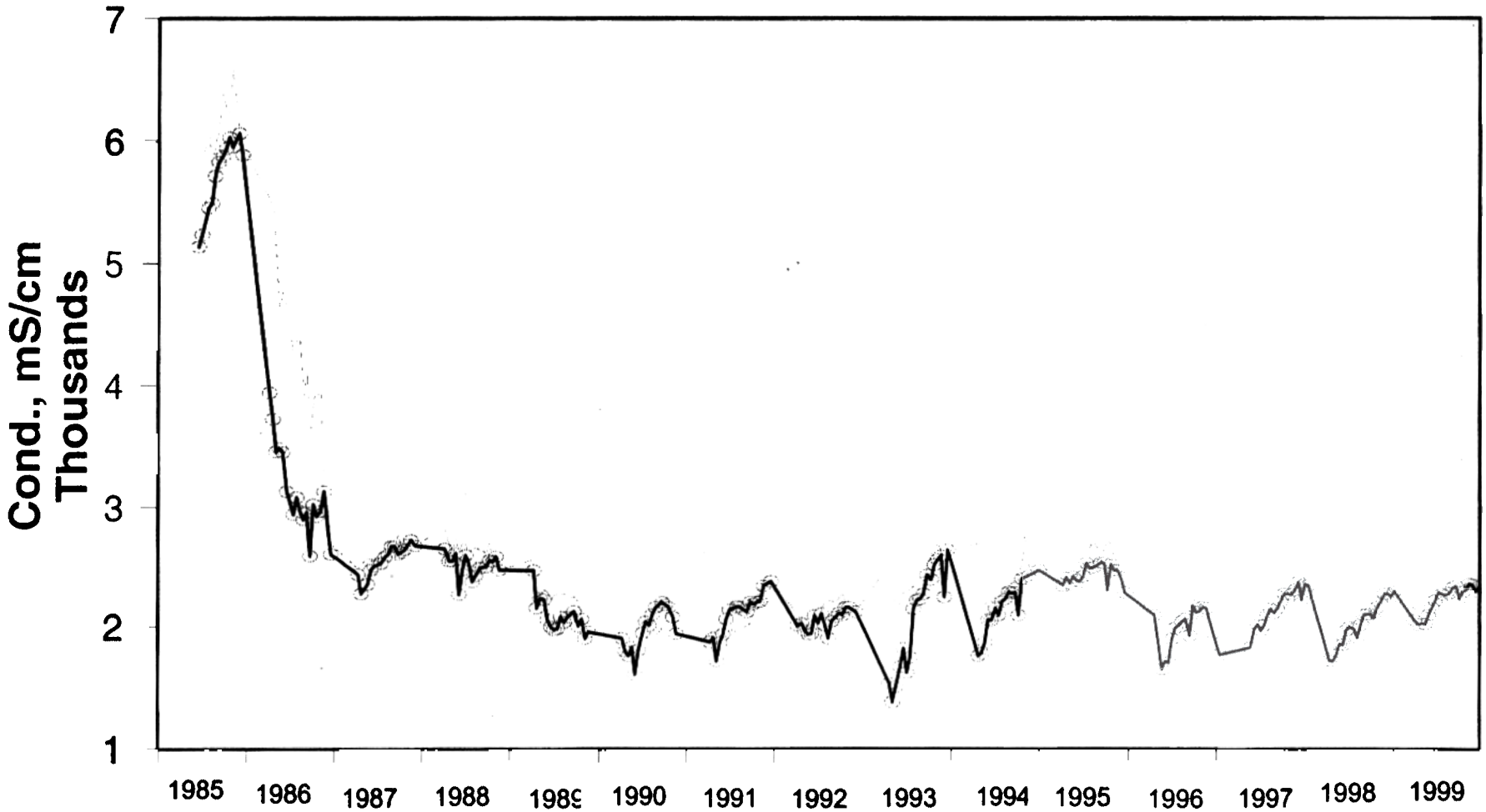


Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion Limit of Detection

Onondaga Lake - Conductance

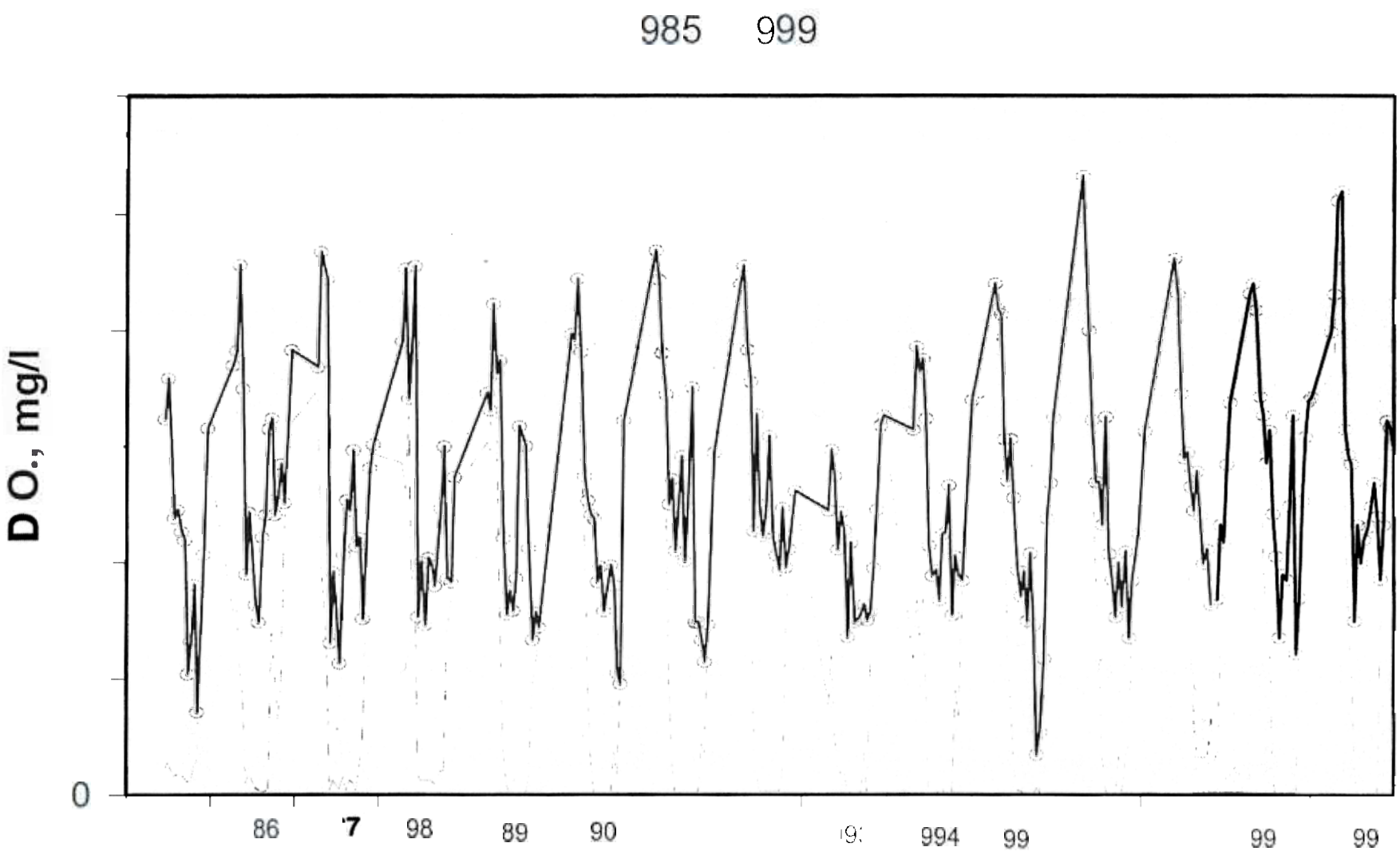
1985 - 1999



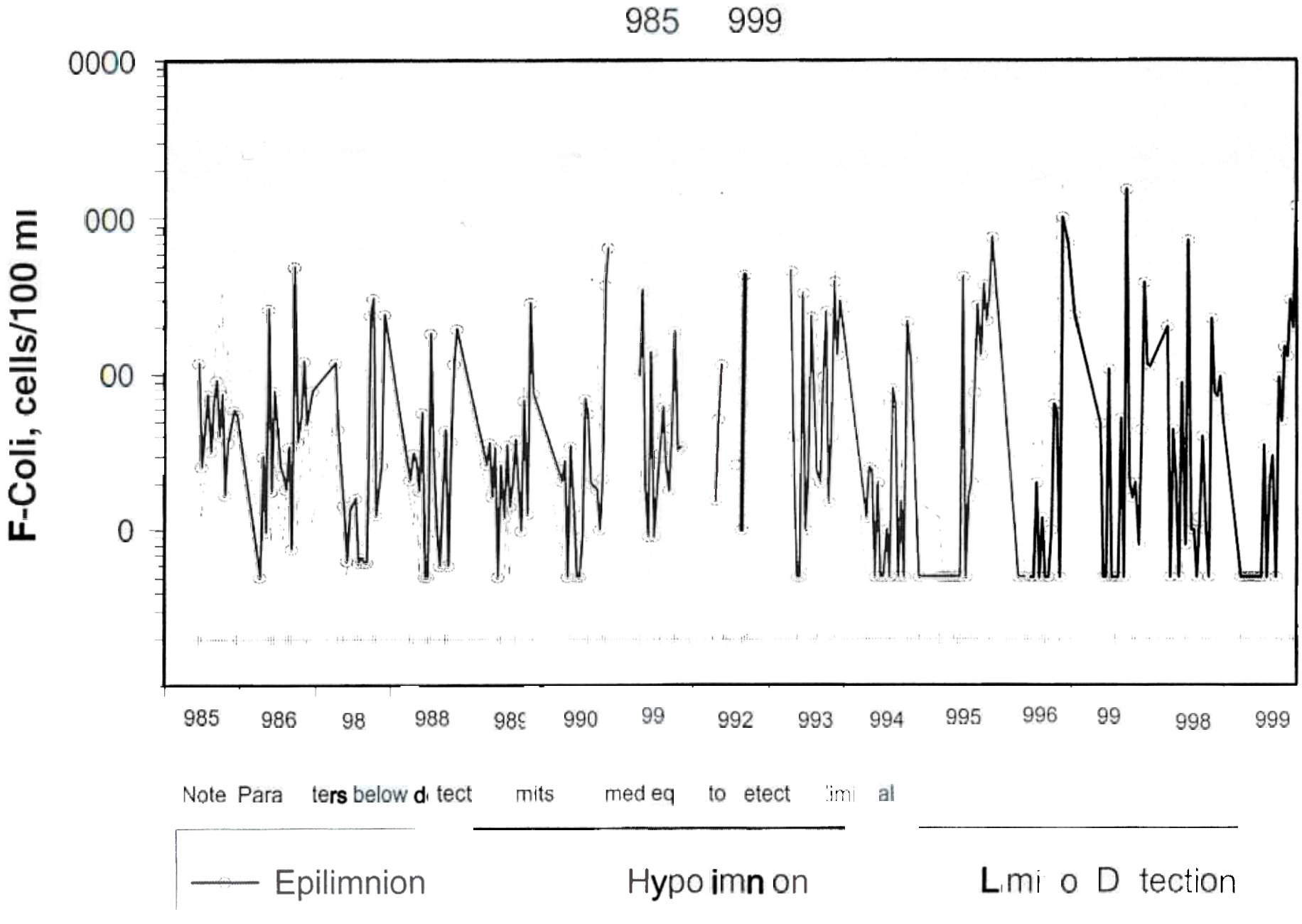
Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion

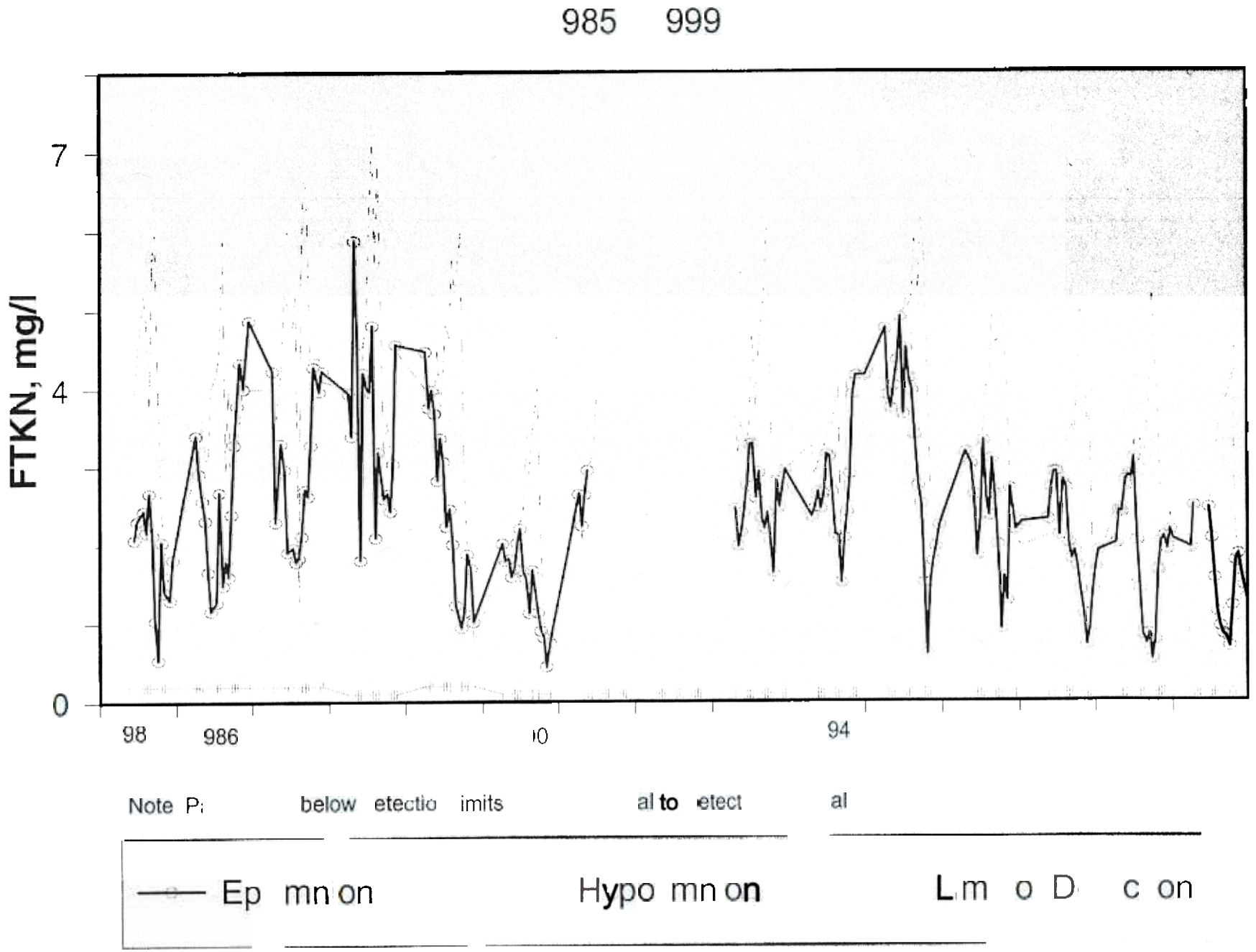
Onondaga Lake - Dissolved Oxygen



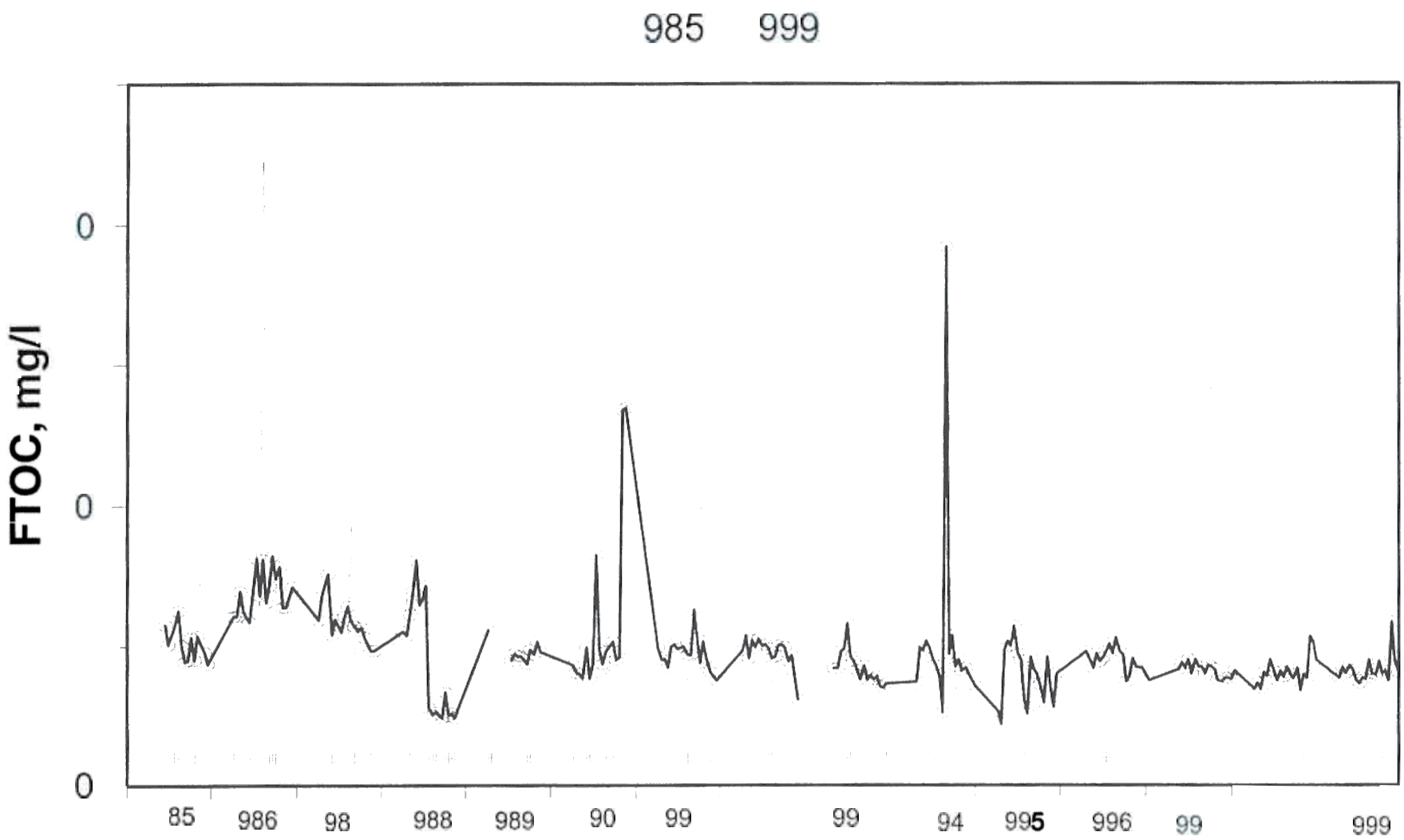
Onondaga Lake - F. Coli



Onondaga Lake - Filtered TKN

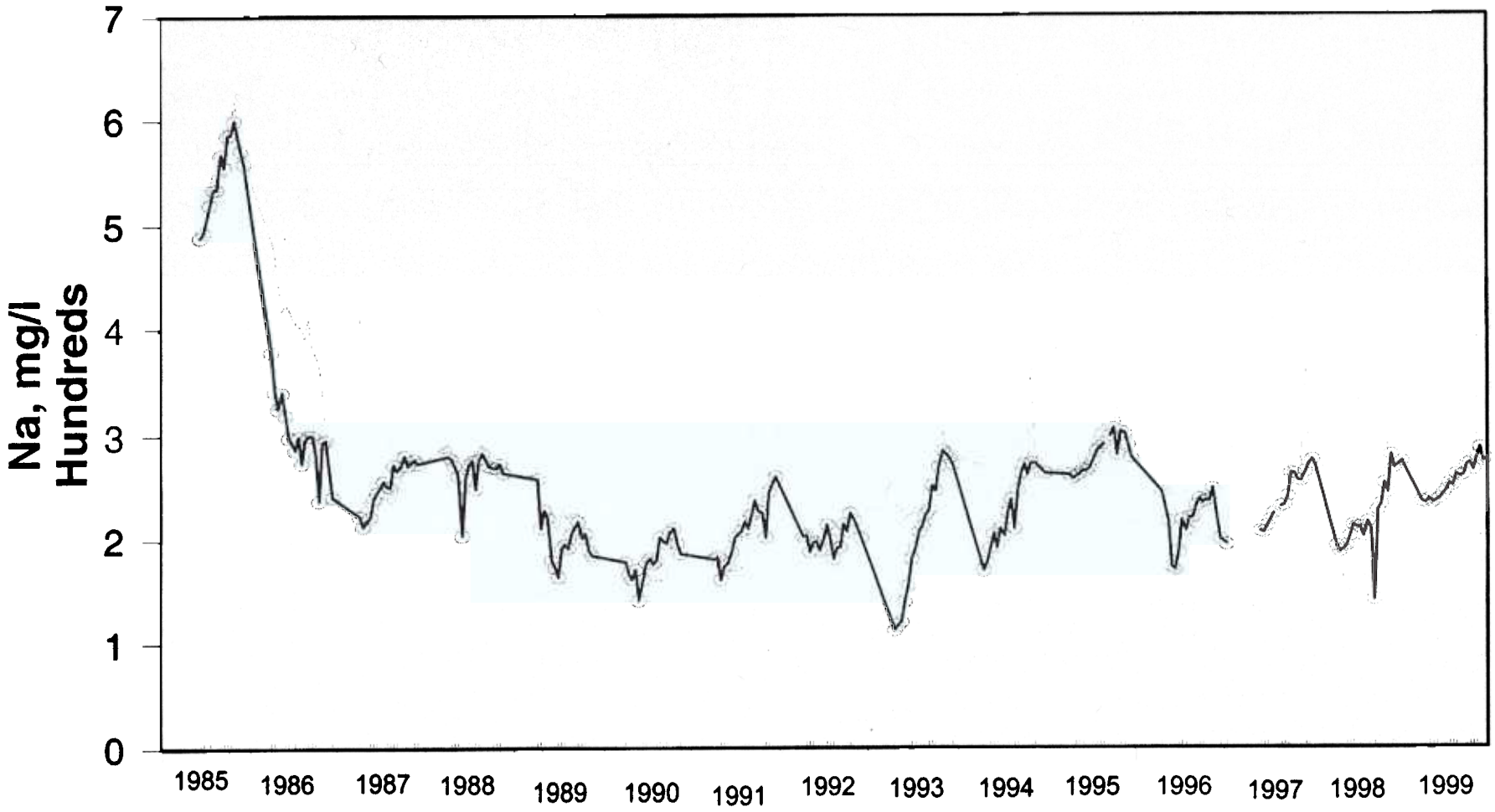


Onondaga Lake - Filtered TOC



Onondaga Lake - Total Sodium

1985 - 1999

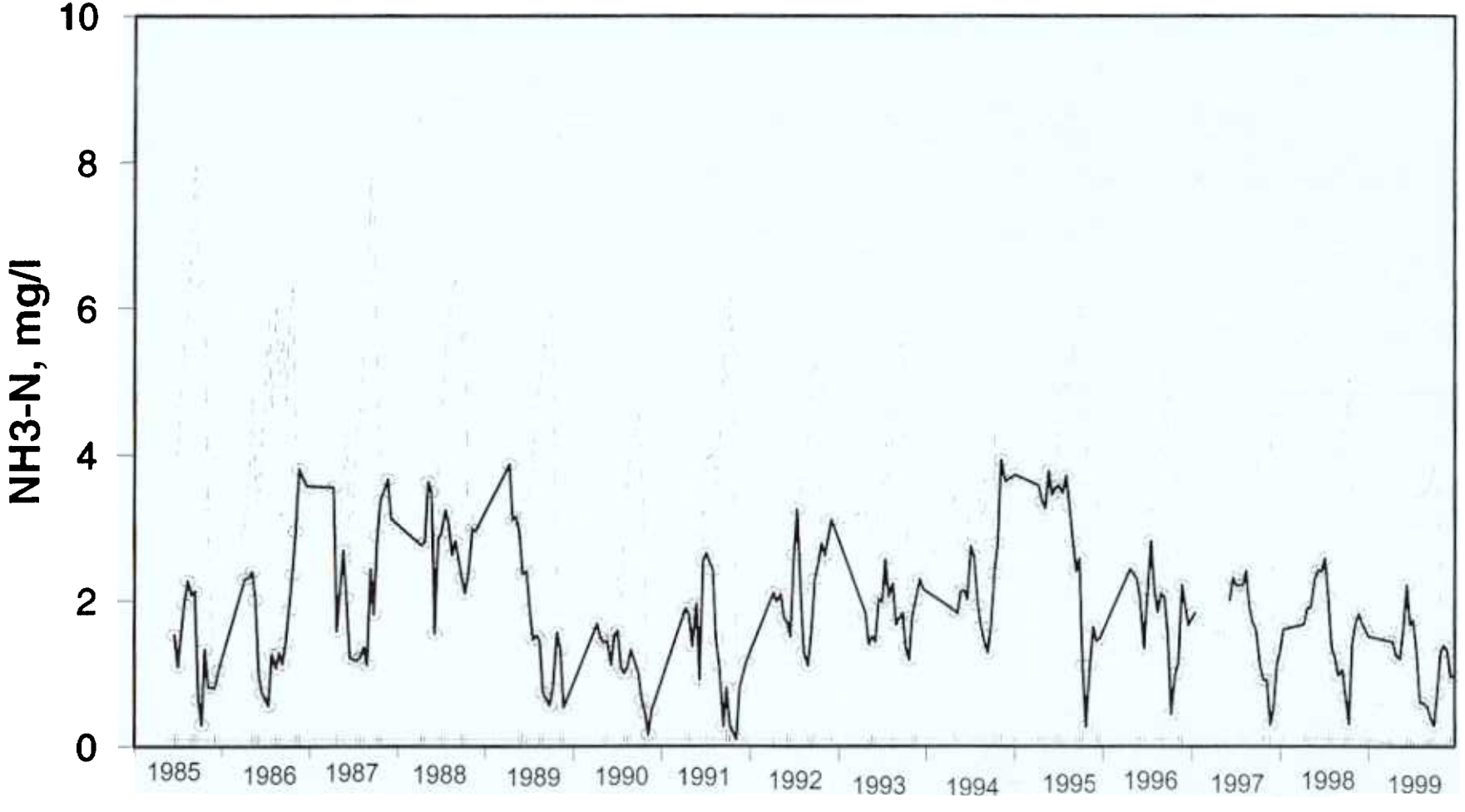


Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion Limit of Detection

Onondaga Lake - Ammonia as N

1985 - 1999



Note: Parameters below detection limits assumed equal to detection limit values

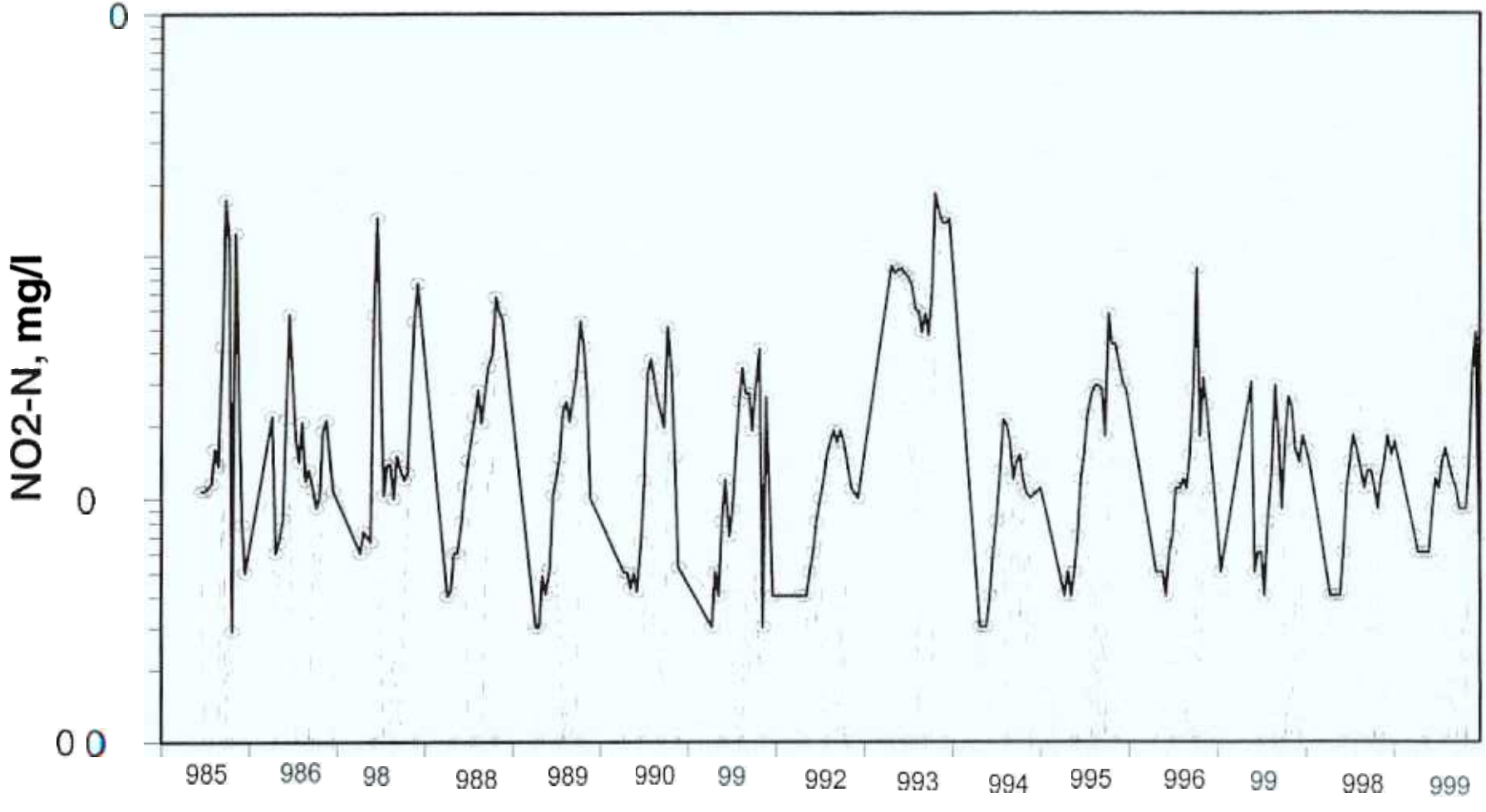
Epilimnion

Hypolimnion

Limit of Detection

Onondaga Lake - Nitrite as N

985 999



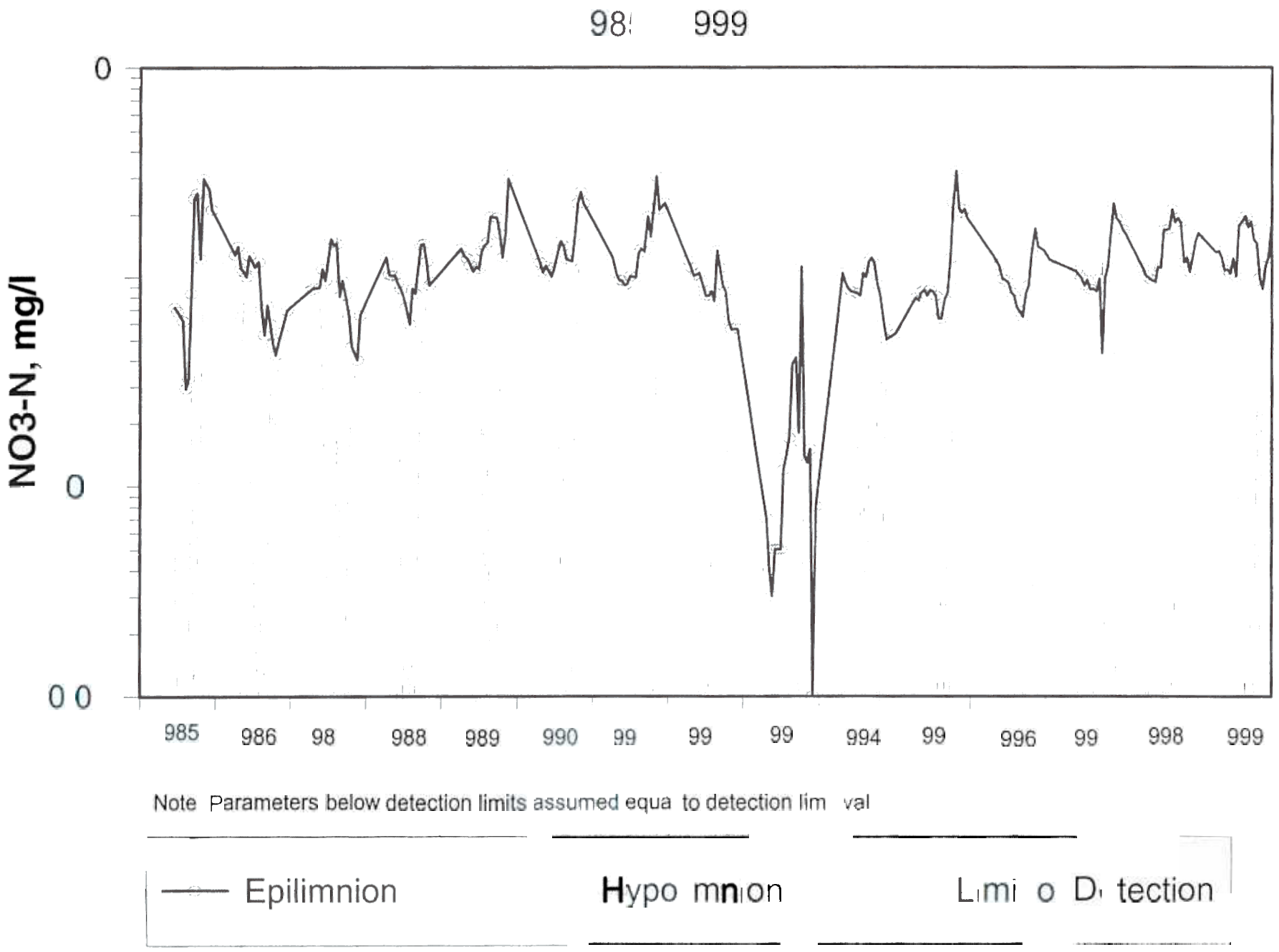
Note: Parameters below detection imits assumed equal to detection limit values

Epilimnion

Hypo mn on

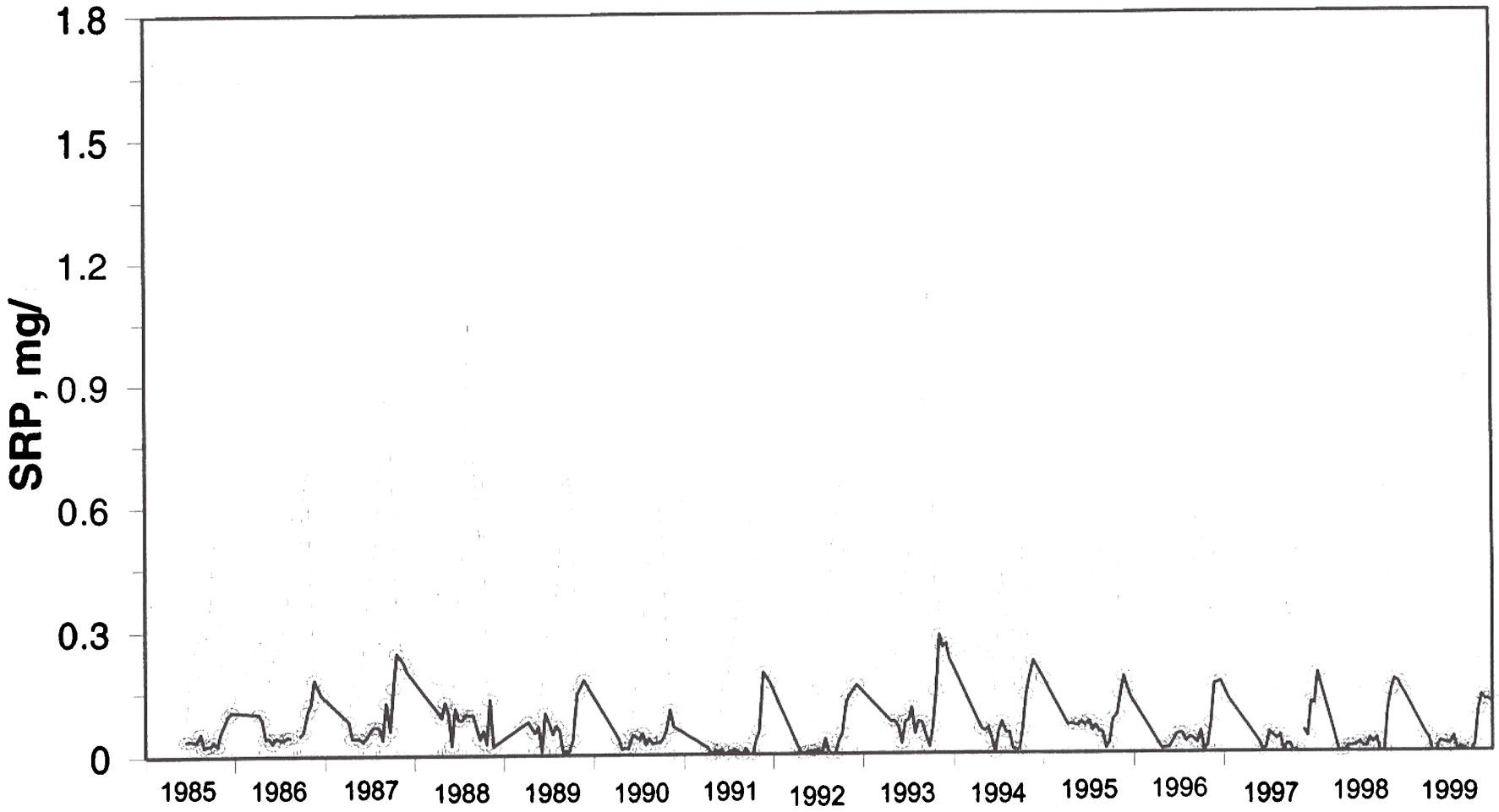
L.m o D tection

Onondaga Lake - Nitrate as N



Onondaga Lake - Soluble Reactive P

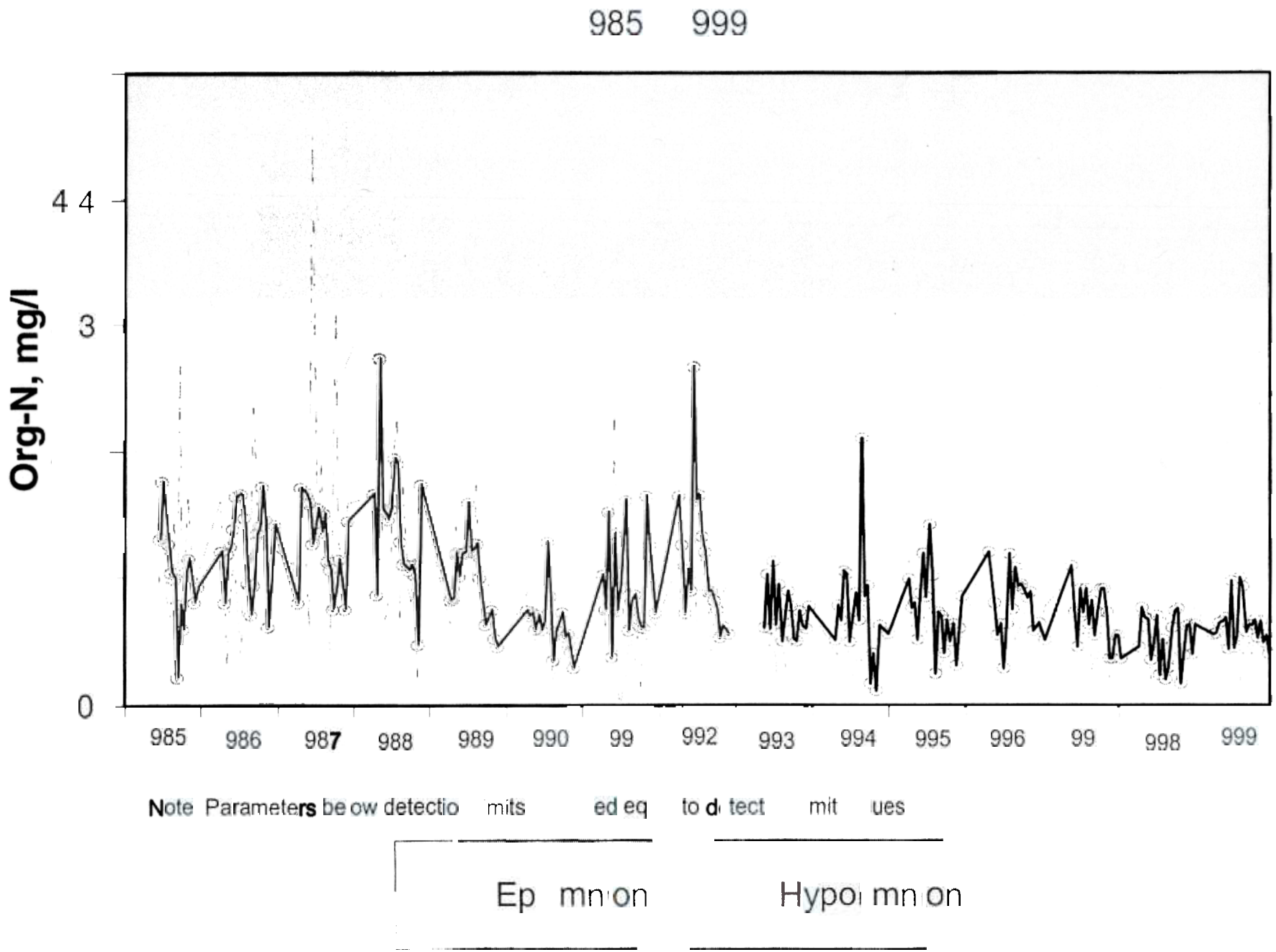
1985 - 1999



Note: Parameters below detection limits assumed equal to detection limit values

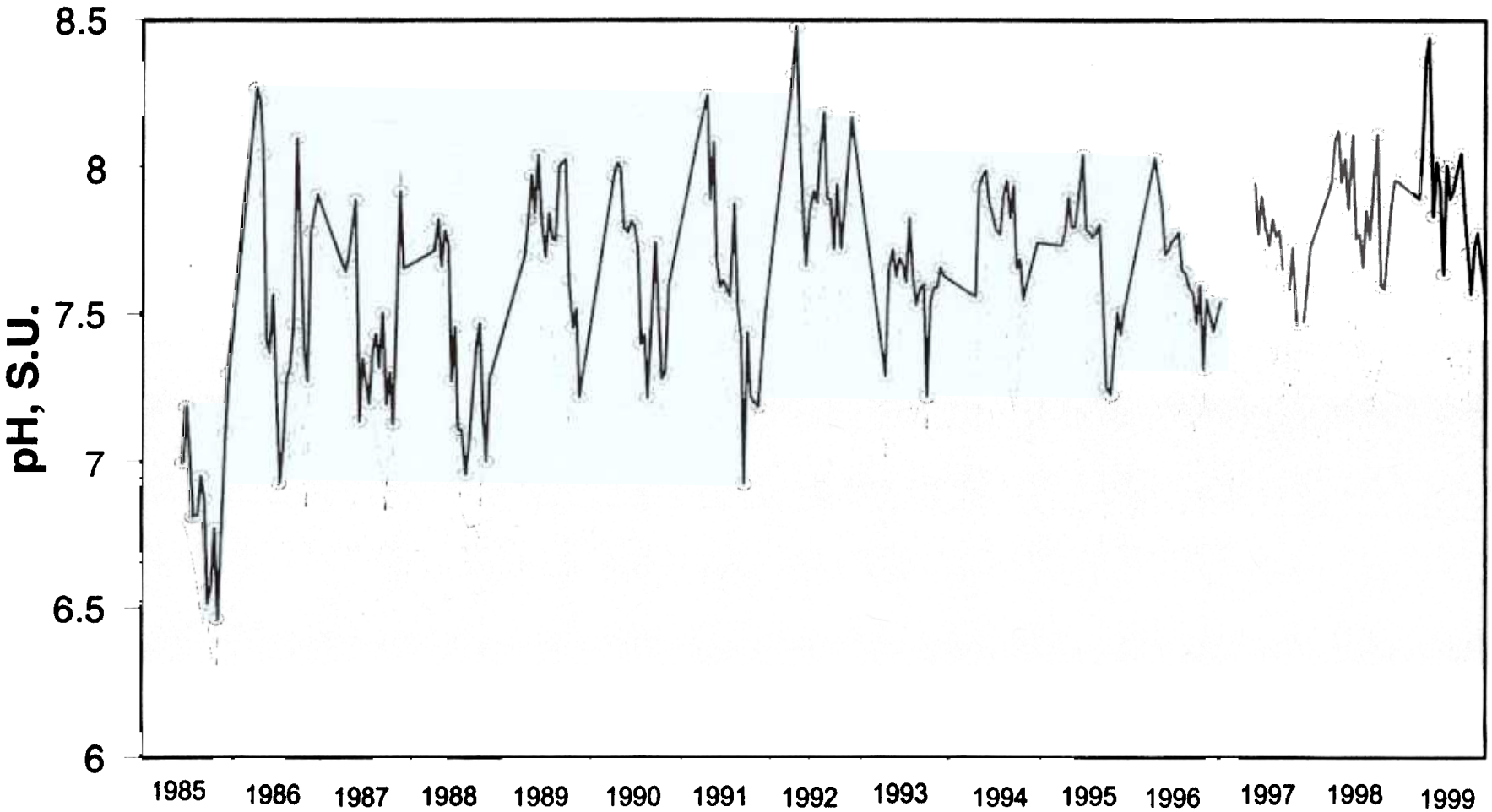
Epilimnion Hypolimnion Limit of Detection

Onondaga Lake - Organic N



Onondaga Lake - pH

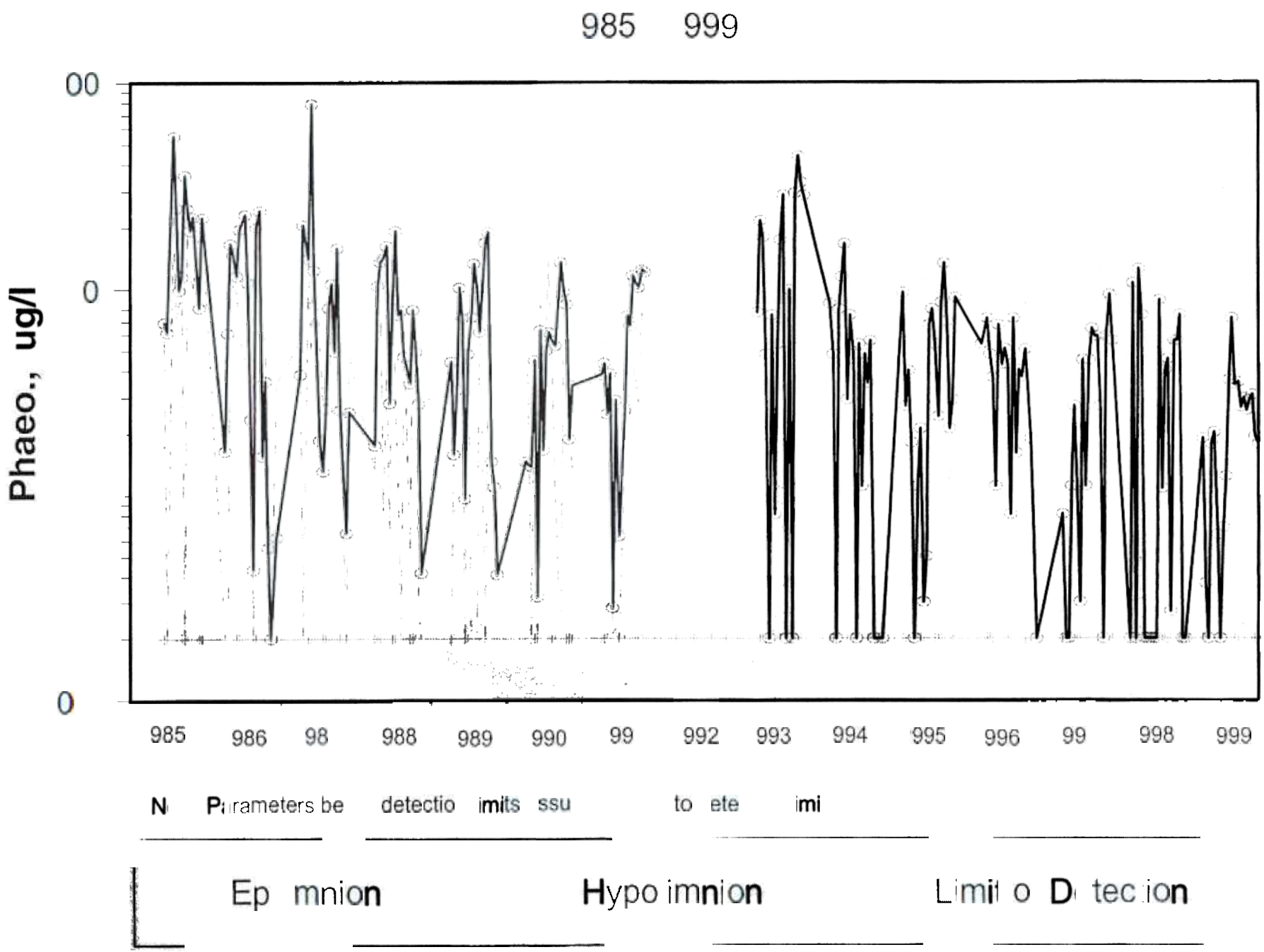
1985 - 1999



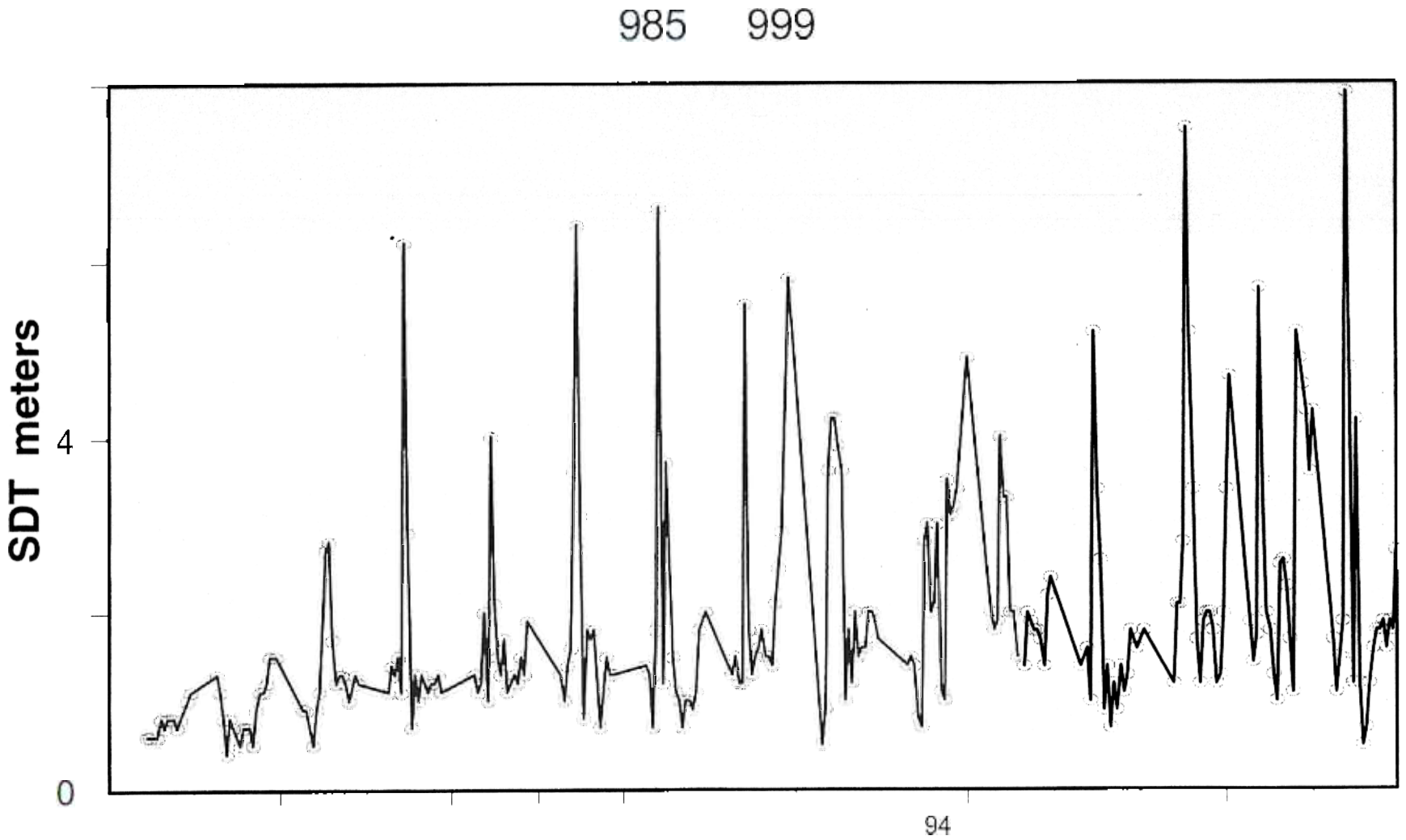
Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion

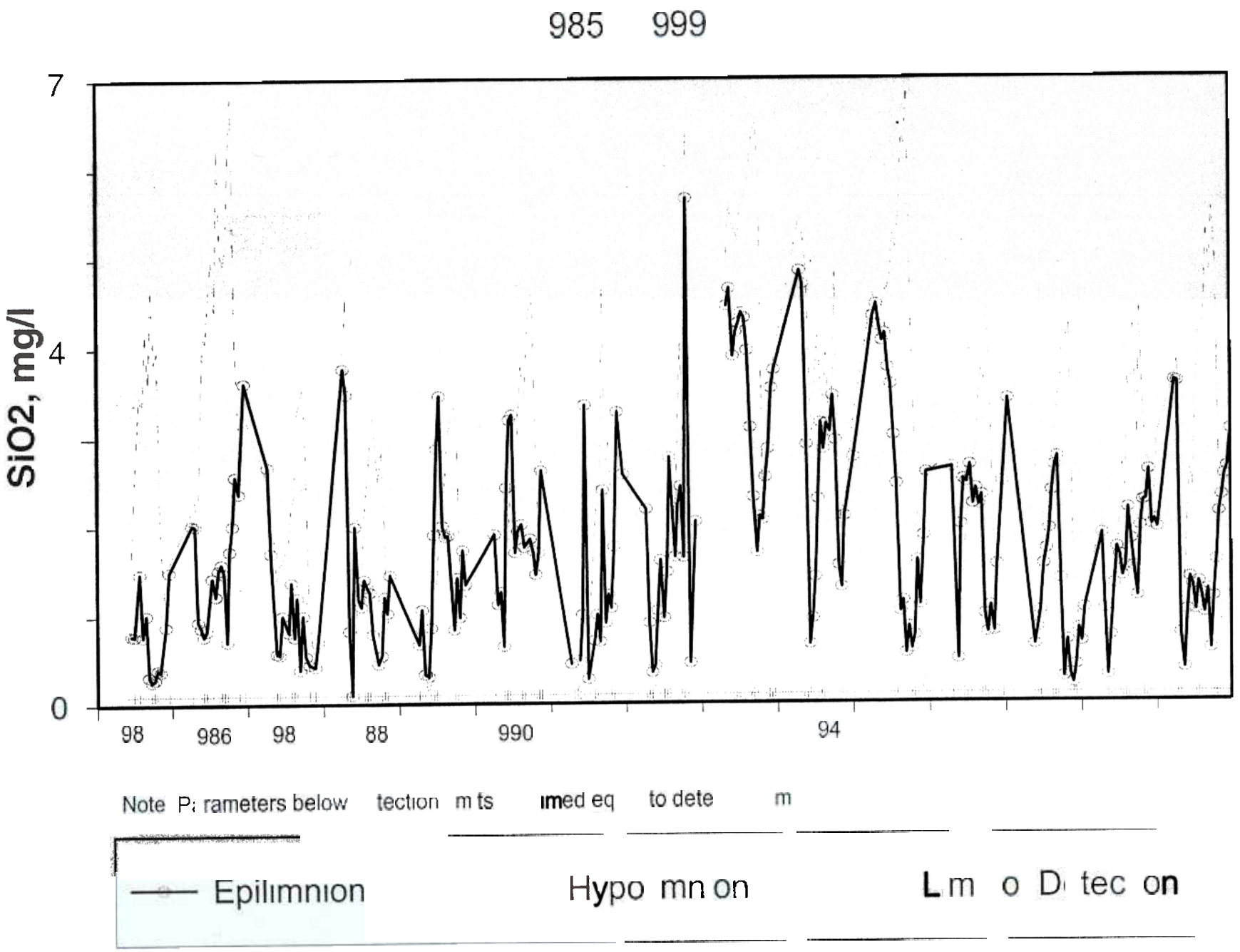
Onondaga Lake - Phaeopigments



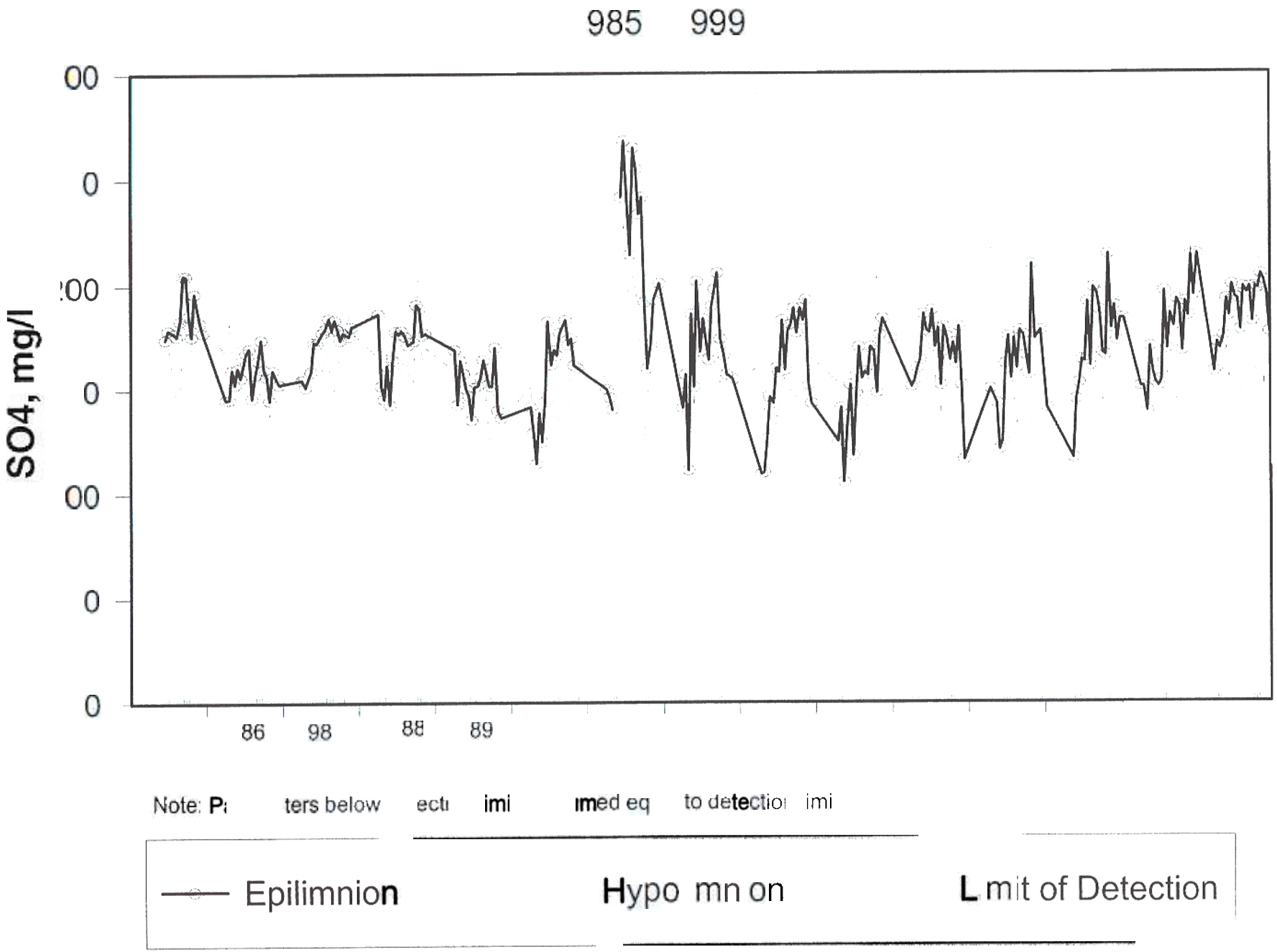
Onondaga Lake - Secchi Disk



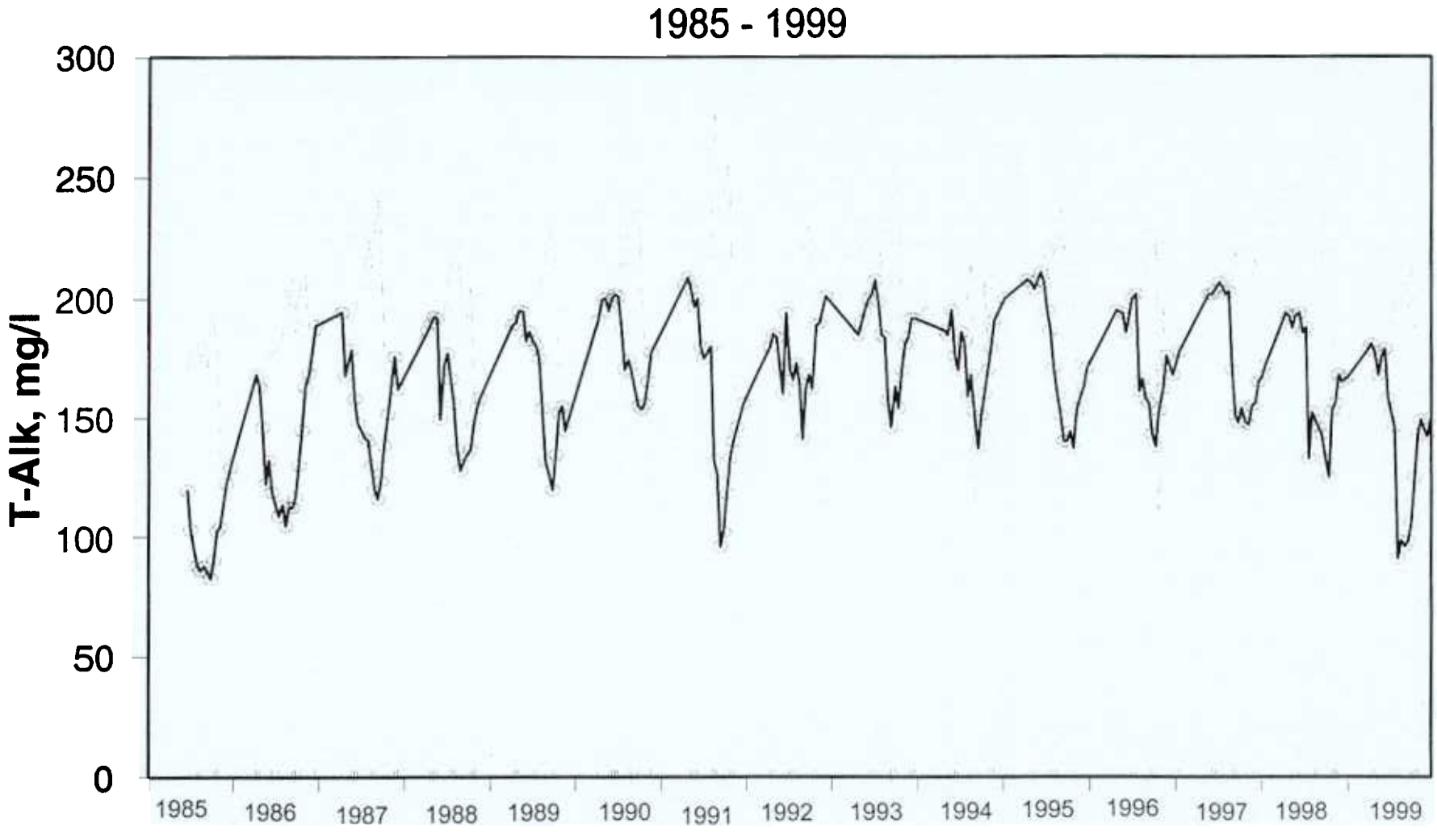
Onondaga Lake - Silica



Onondaga Lake Sulfate



Onondaga Lake Total Alkalinity - CaCO3

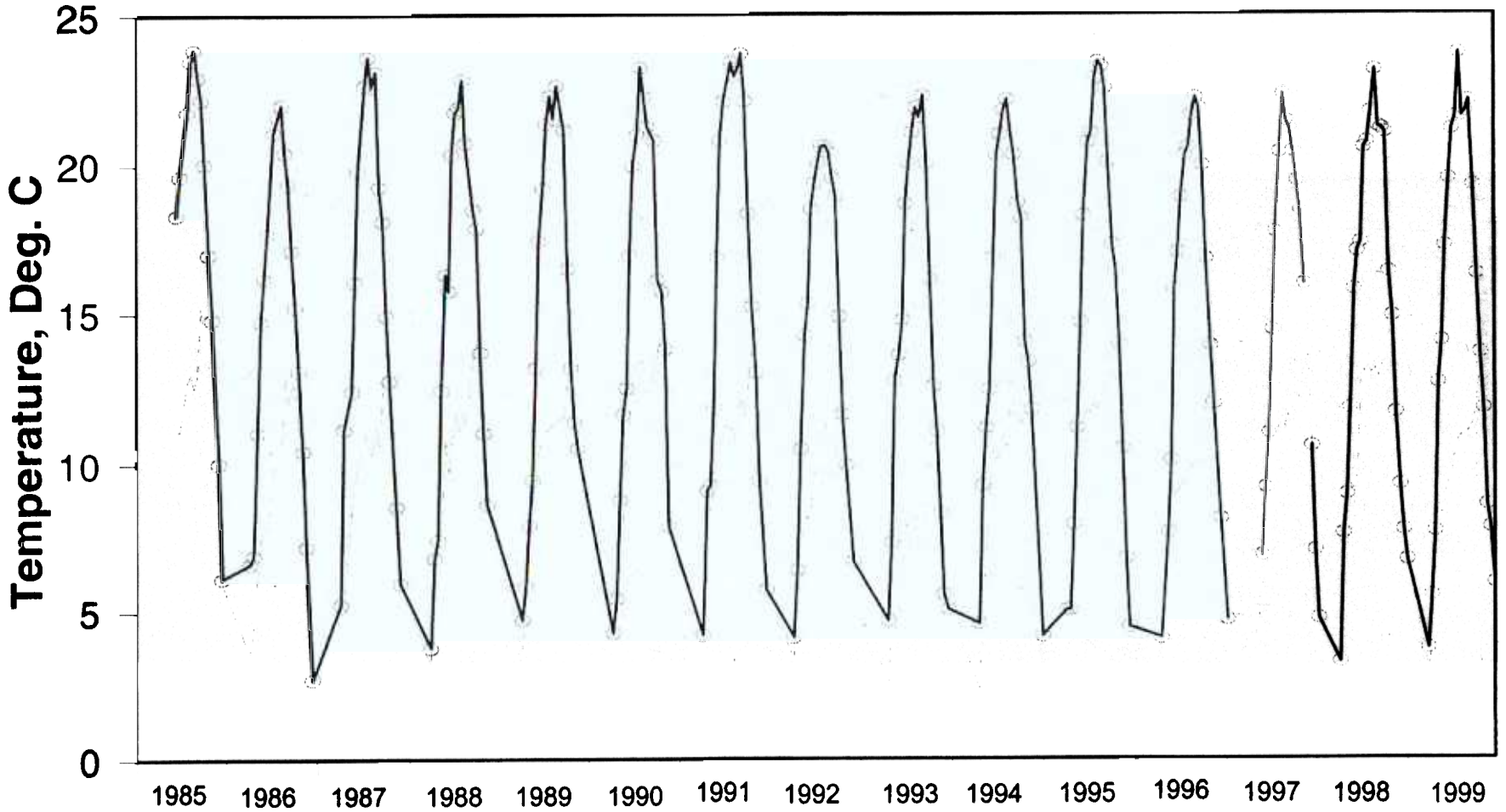


Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion Limit of Detection

Onondaga Lake Temperature

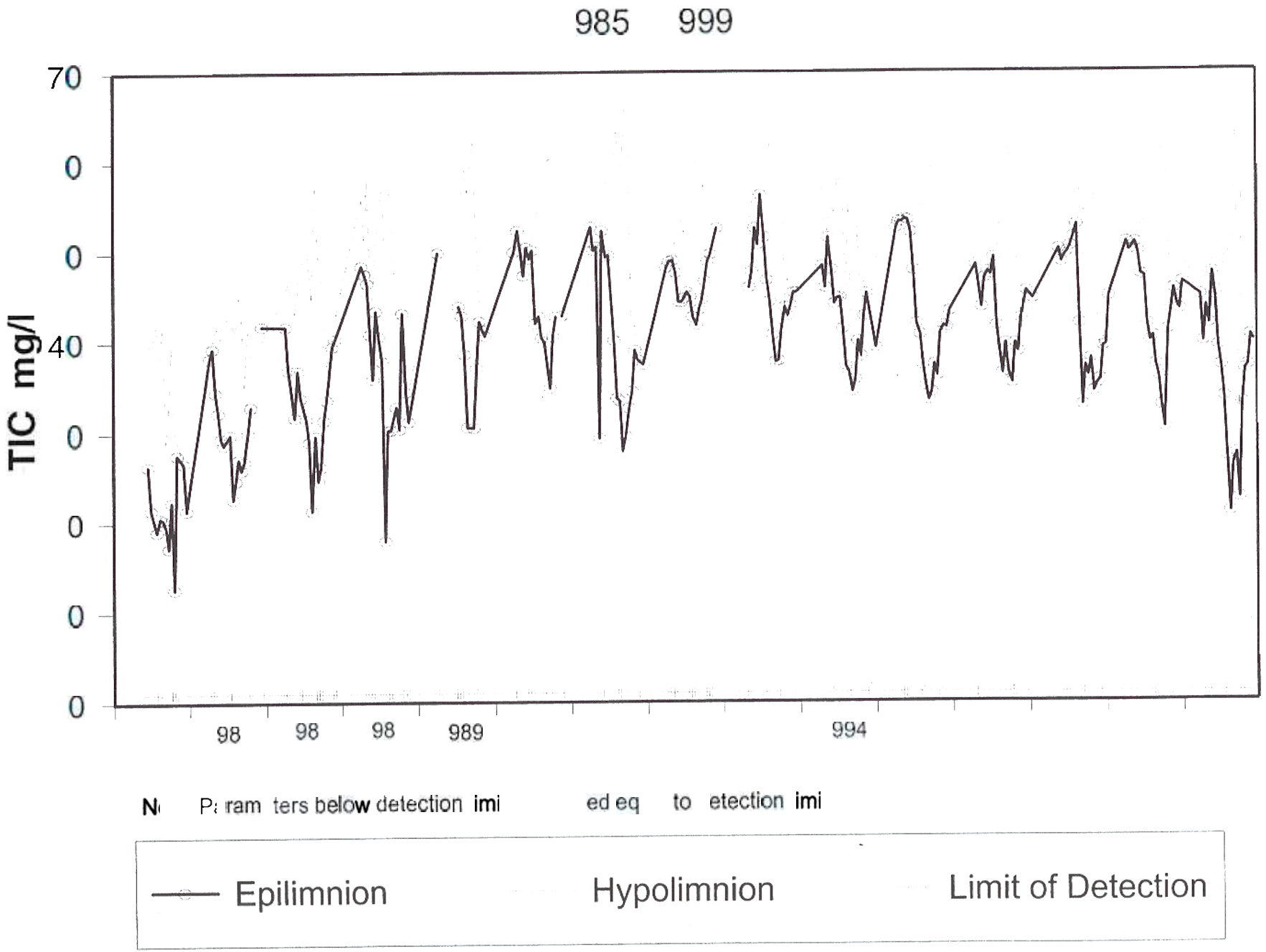
1985 - 1999



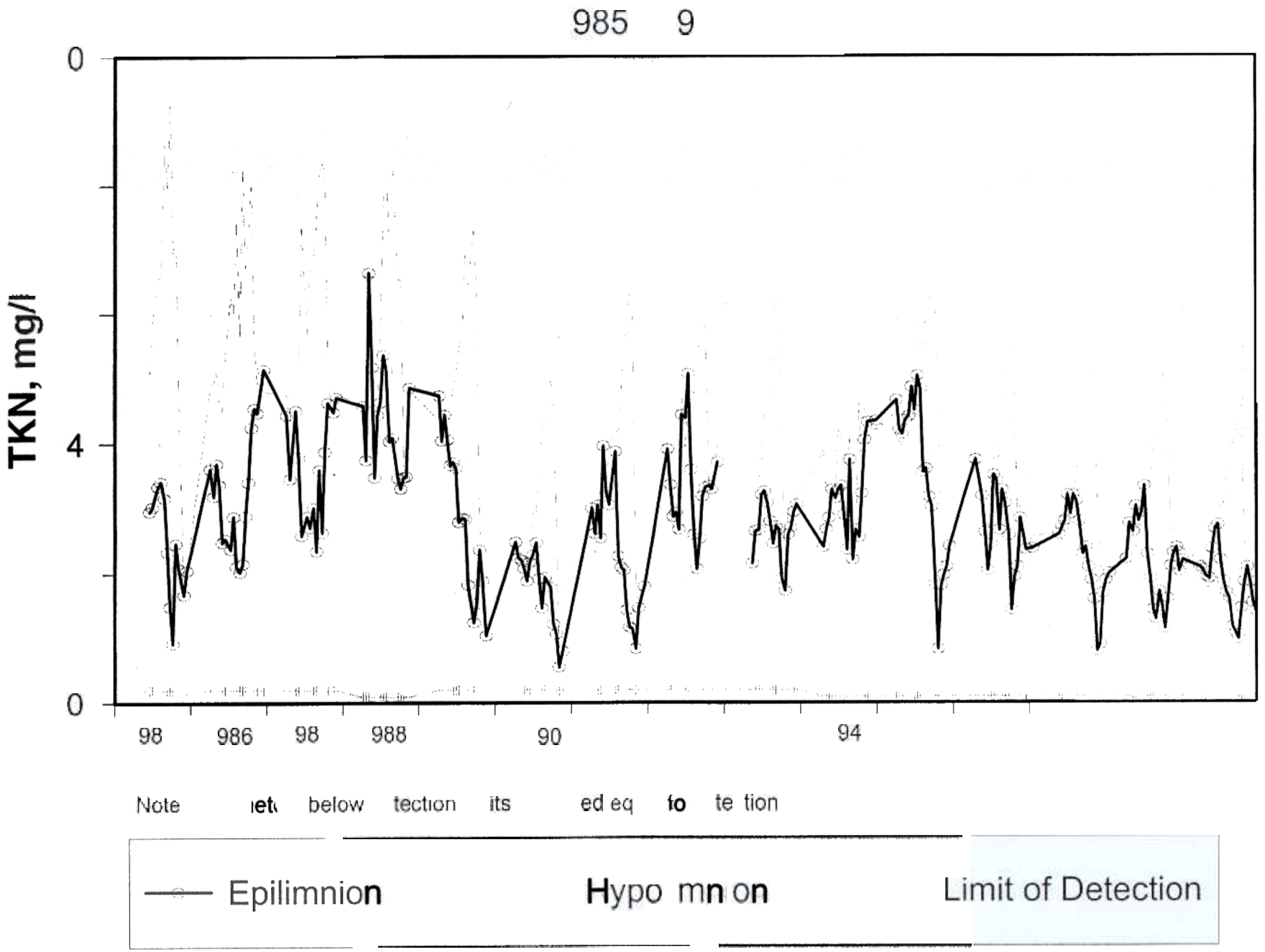
Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion

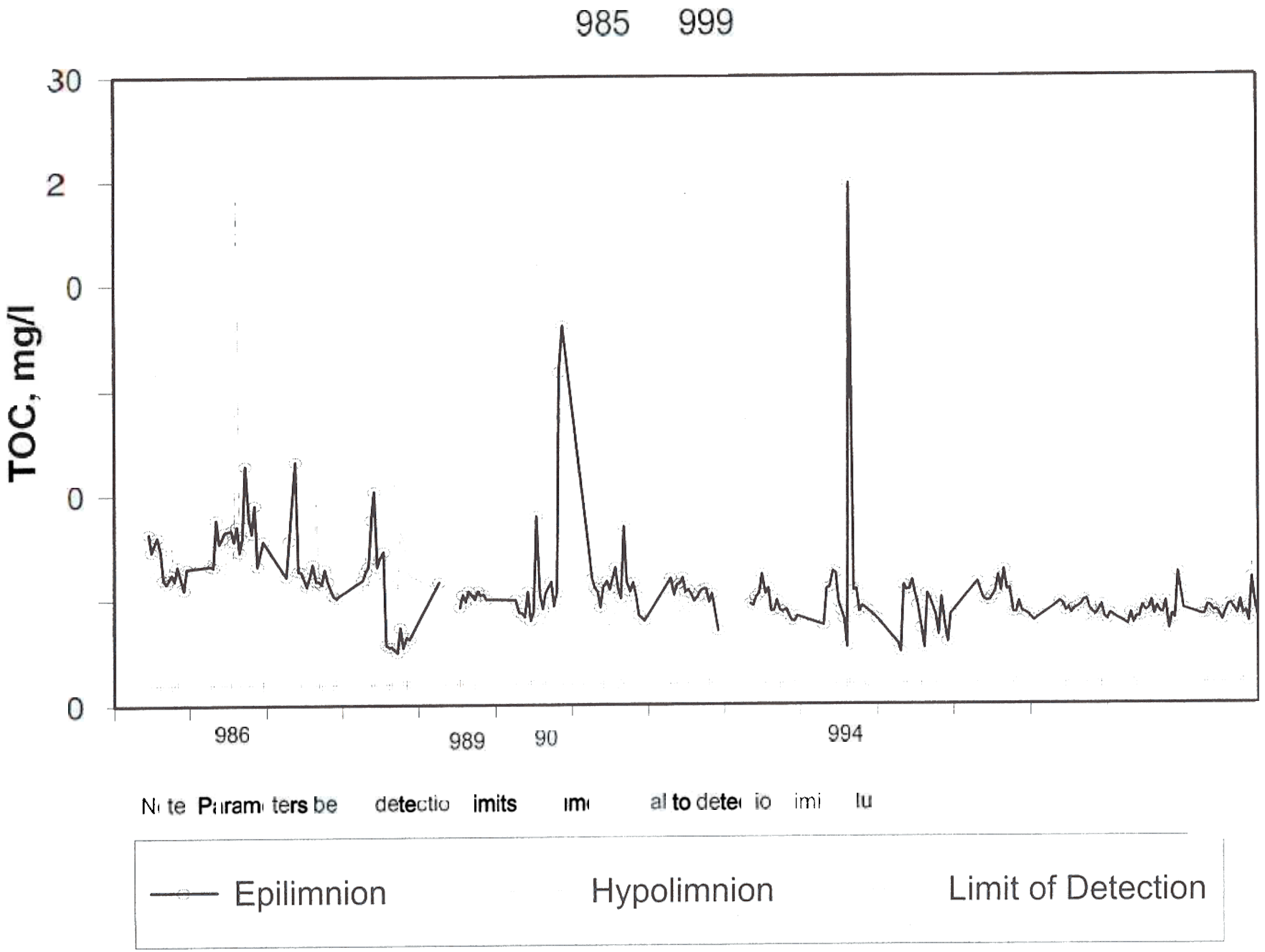
Onondaga Lake T· Inorganic Carbon



Onondaga Lake -Total Kjeldahl Nitrogen

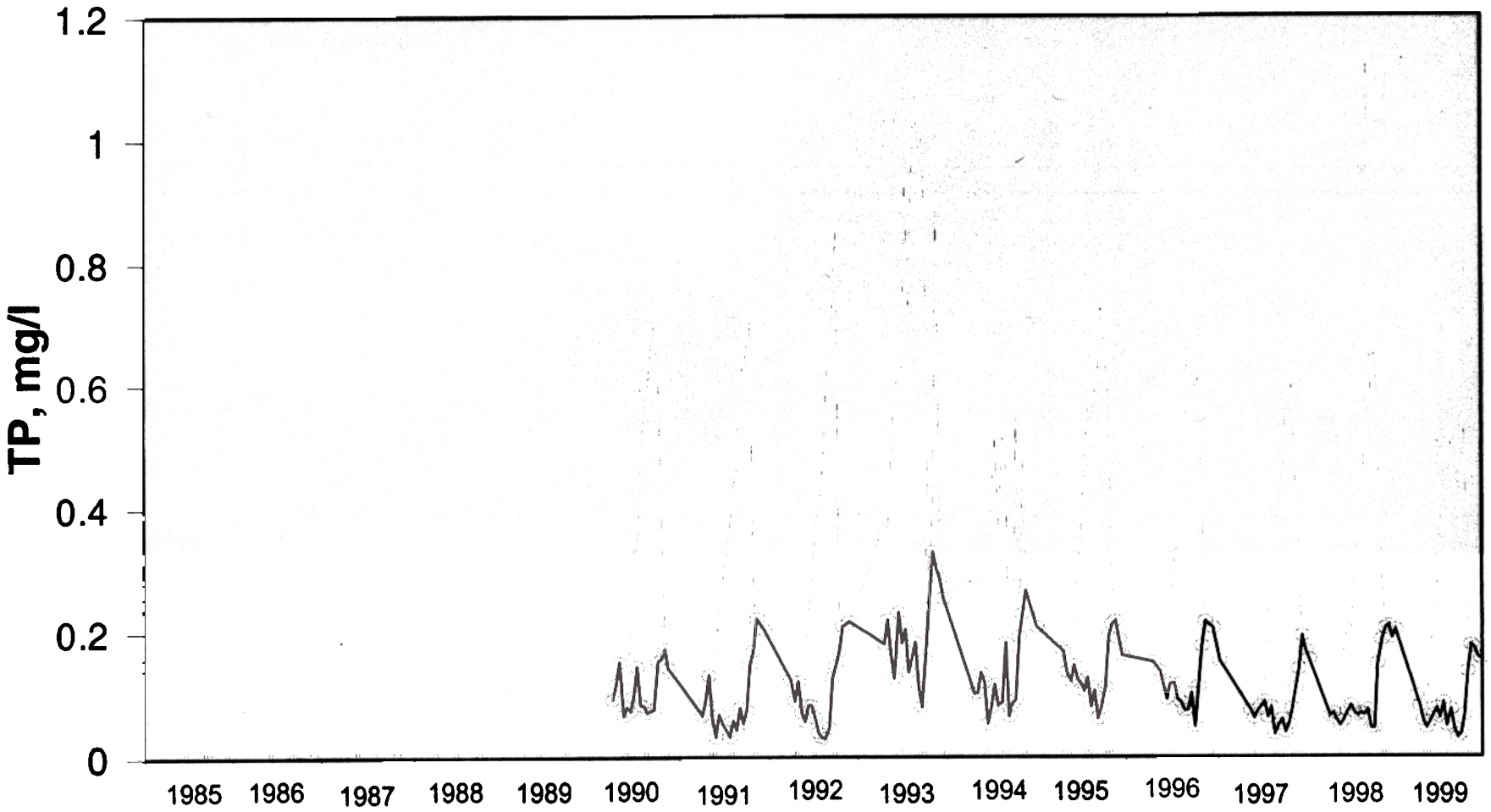


Onondaga Lake Total Organic Carbon



Onondaga Lake - Total Phosphorus

1985 - 1999

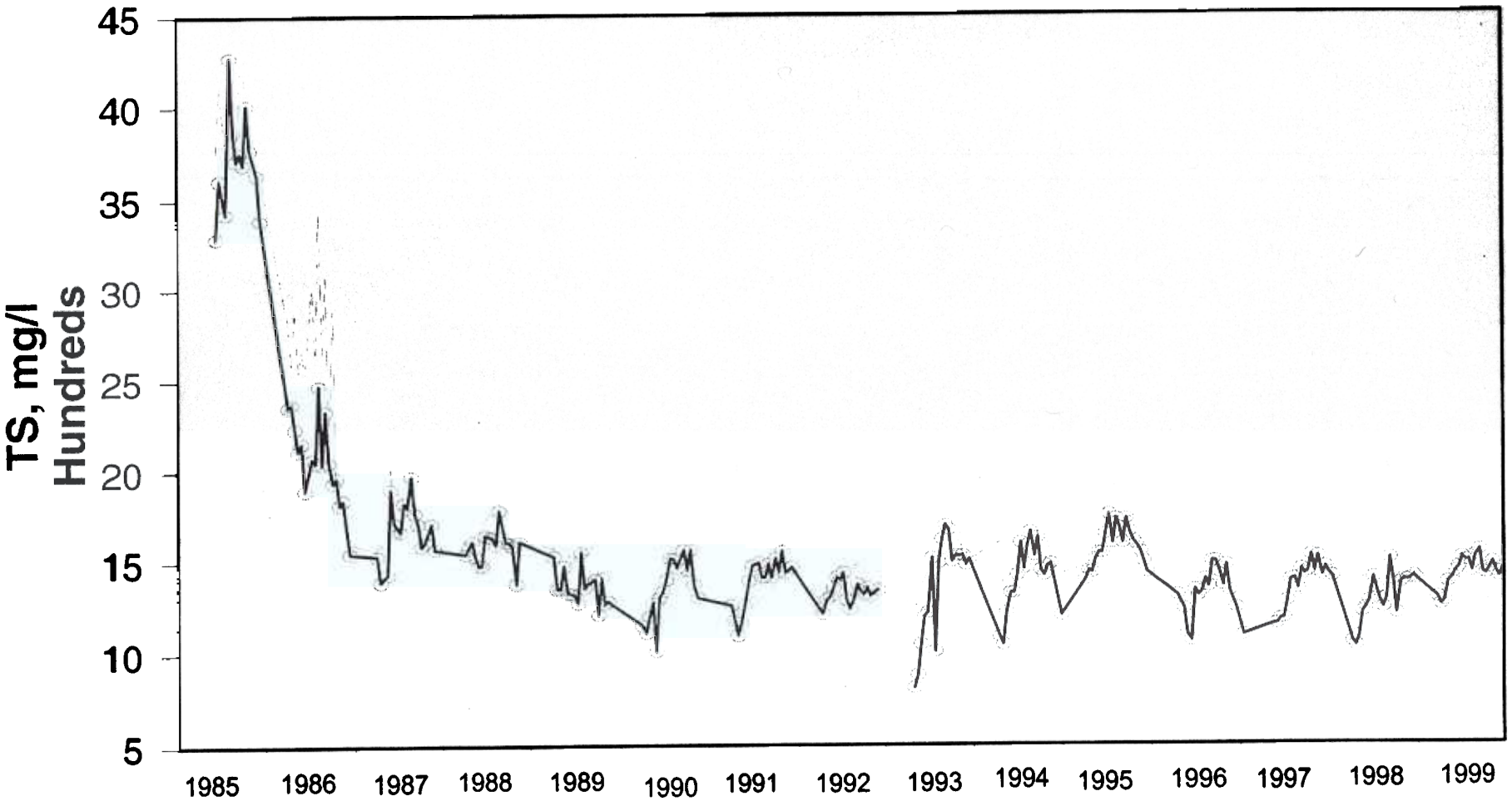


Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion Limit of Detection

Onondaga Lake - Total Solids

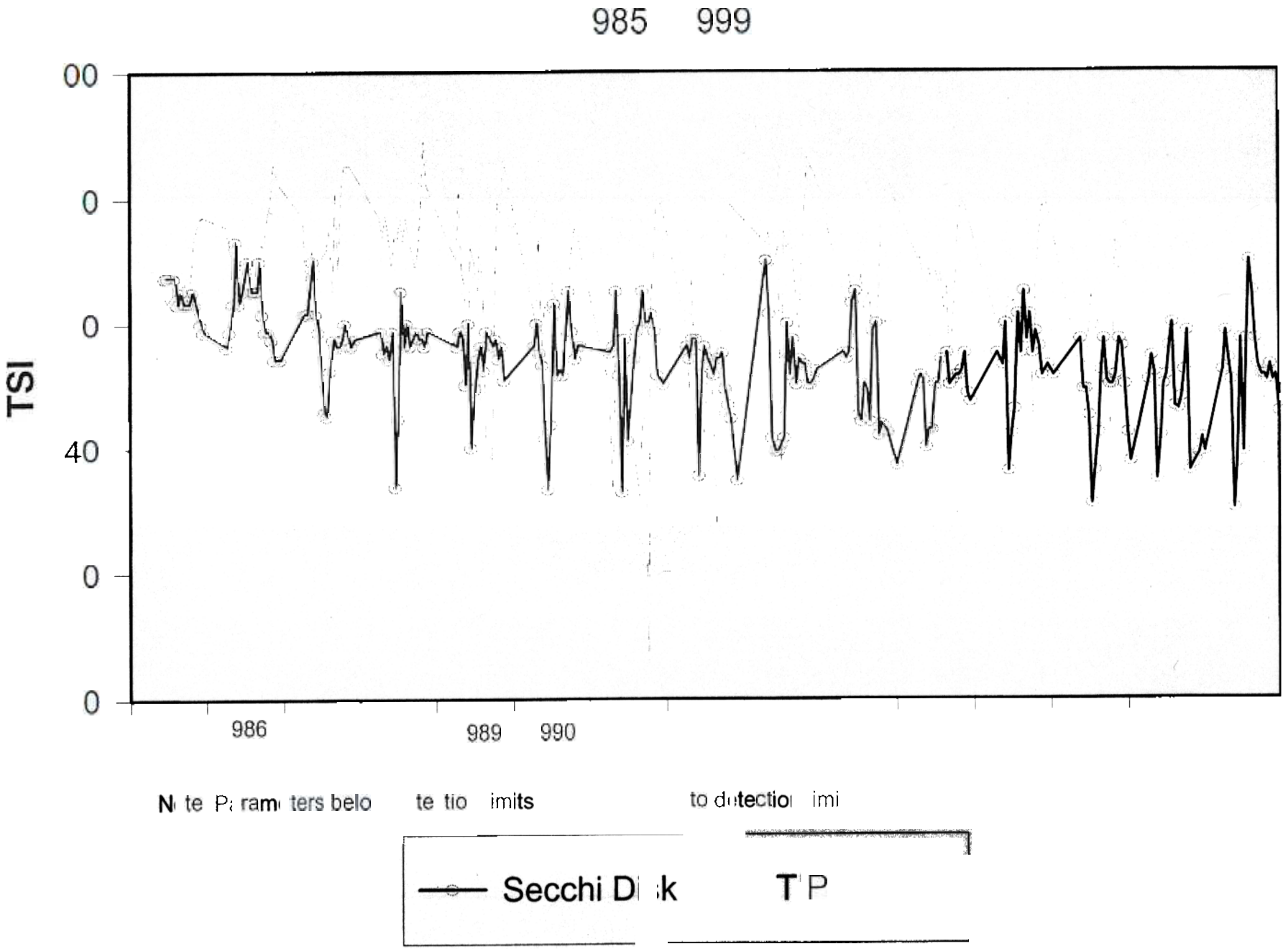
1985 - 1999



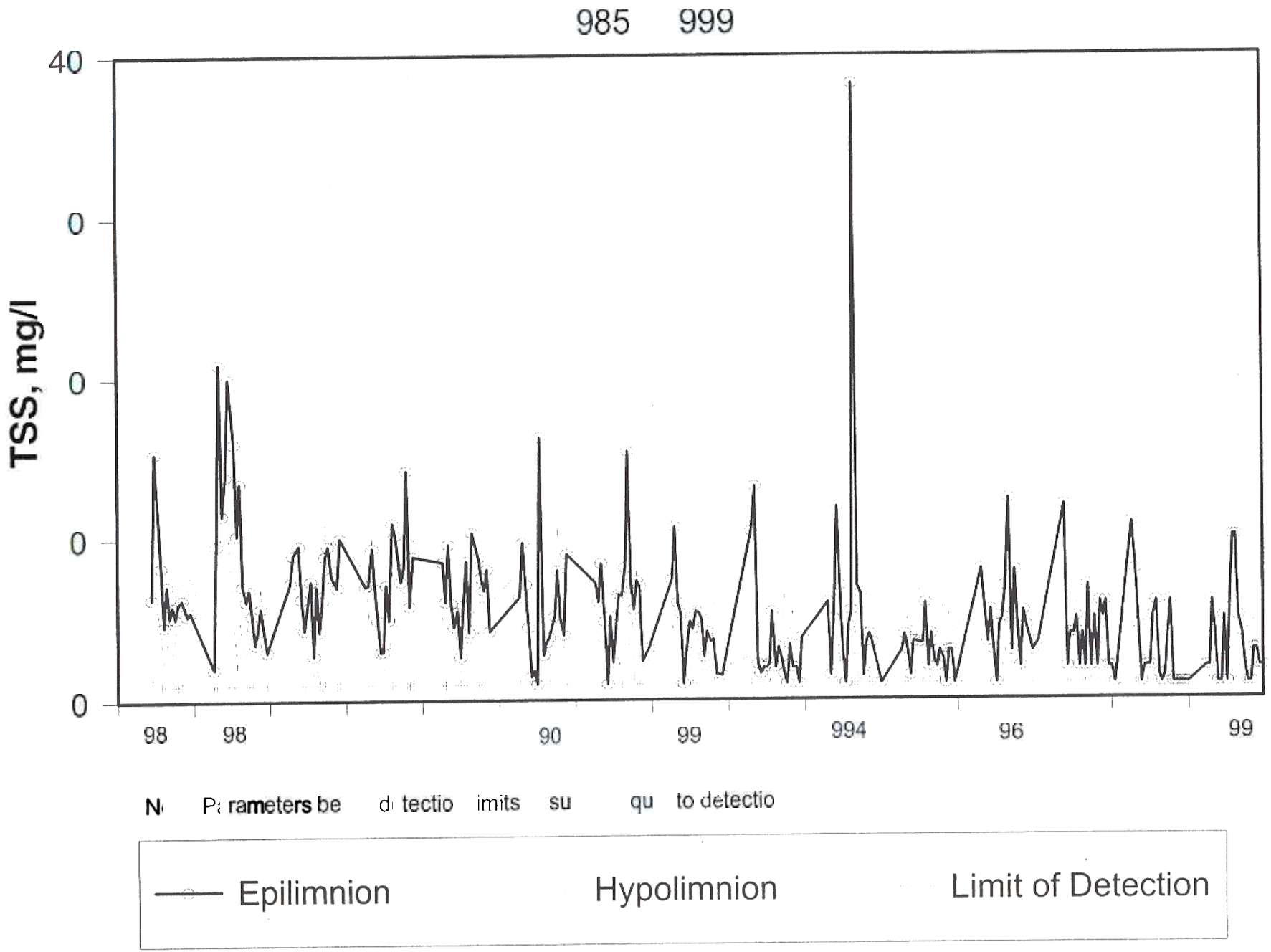
Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion

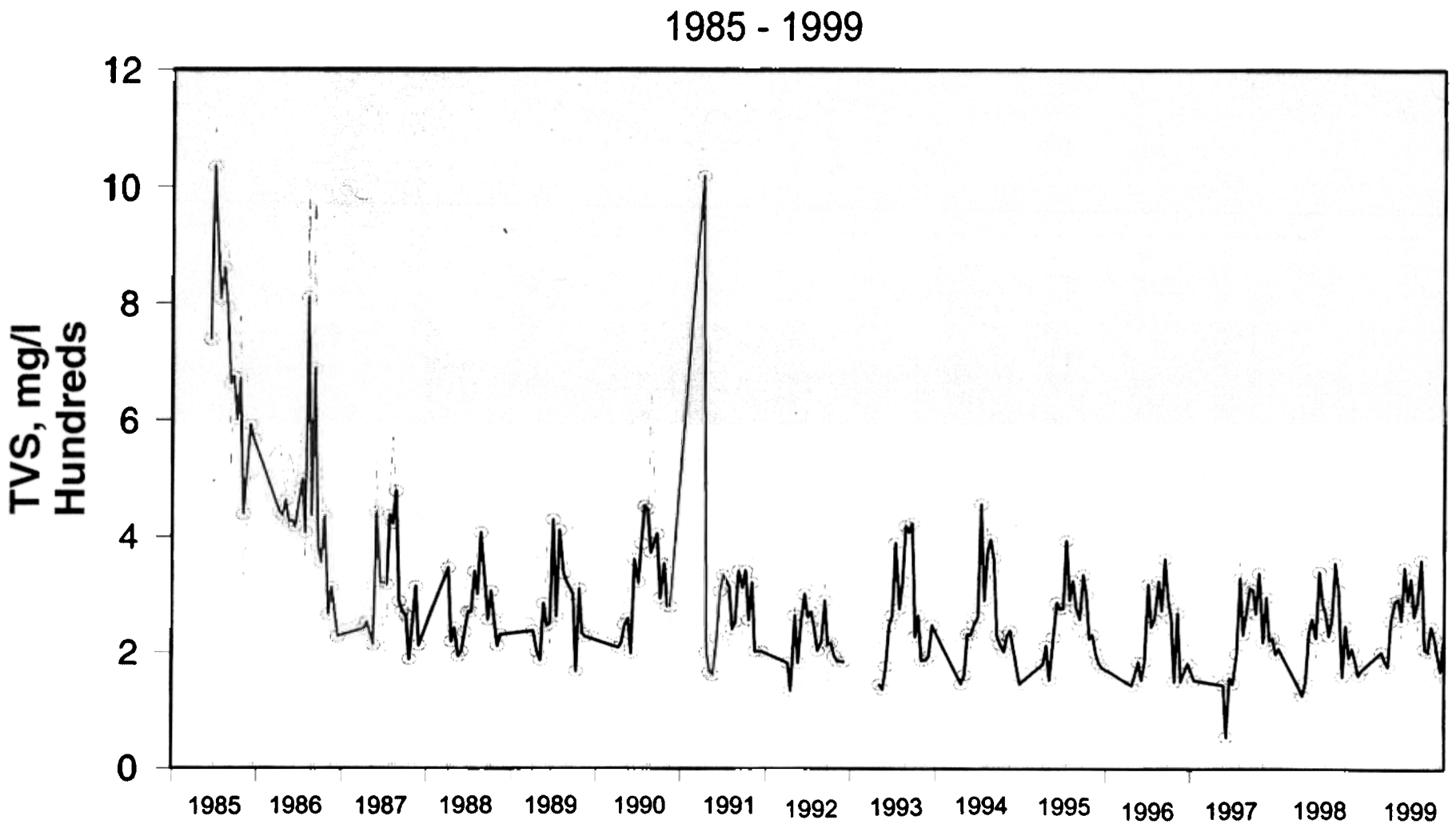
Onondaga Lake - Trophic Status Indices



Onondaga Lake - Total Suspended Solids

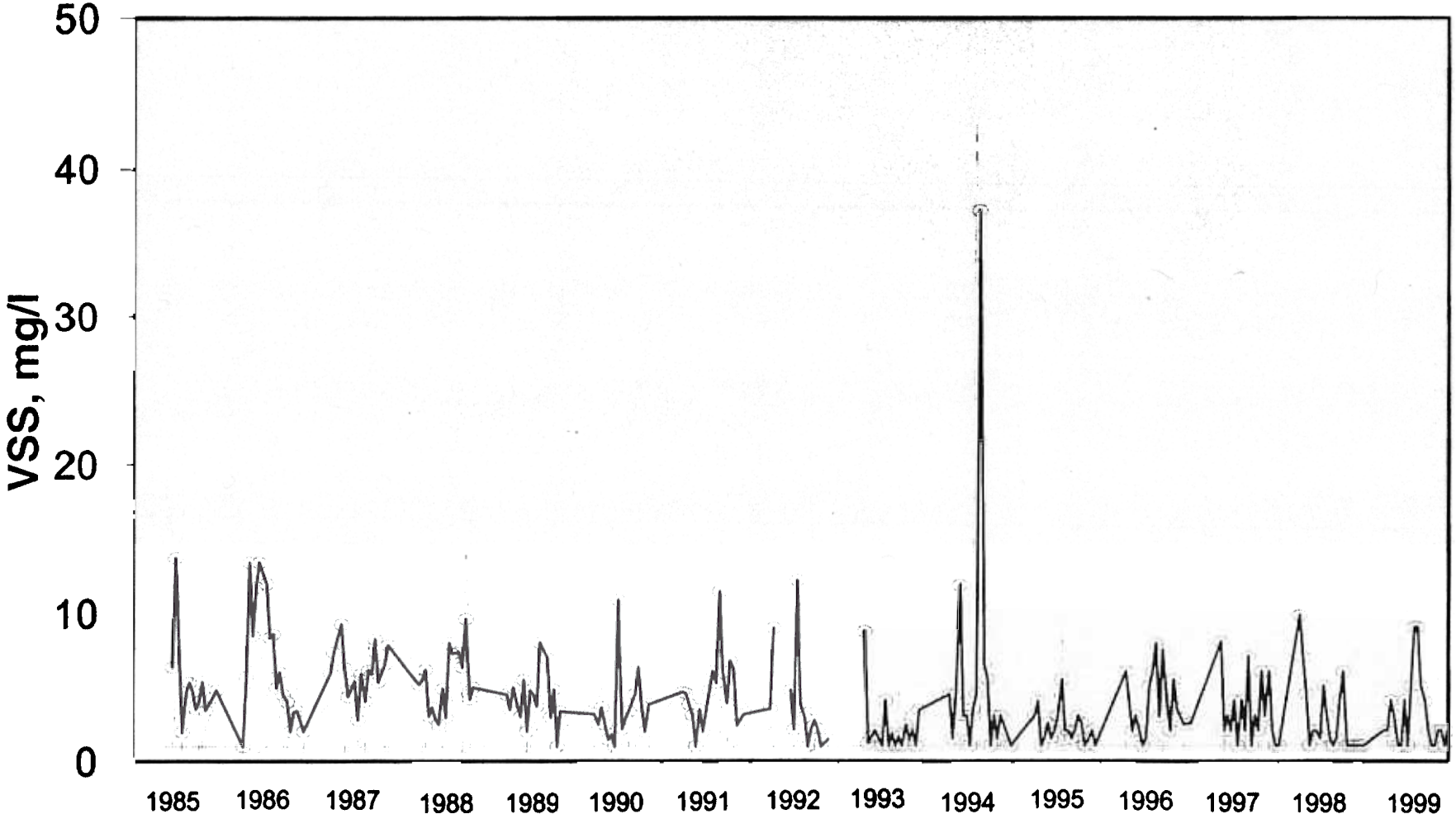


Onondaga Lake - Total Volatile Solids



Onondaga Lake Volatile Suspended Solid

1985 - 1999



Note: Parameters below detection limits assumed equal to detection limit values

Epilimnion Hypolimnion Limit of Detection

A.3
Analytical Limits of Detection, 1985 to 1999

Limits of Detection - Onondaga Lake Data 1985-1999

PARAMETER, mg/l	1999	1998	1997	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	1986	1985
BOD 5	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
ALK-T	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TOC	0.1	0.1	0.1	1	1	1	1	1	1	1	1	1	1	1	1
TOC-F	0.1	0.1	0.1	1	1	1	1	1	1	1	1	1	1	1	1
TIC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TKN-F	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.2
NH3-N	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
NO3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NO2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.01	0.01	0.01	0.01	0.01
	001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	**1**	**1**	**1**	**1**	**1**	**1**	1	1	1	1	1	1	1	
	1		1	1		**1**									
	0.0005*	0.0005*	0.0005*	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.002	0.002	0.002	0.002	0.002
	0.0004*	0.0005*	0.0005*	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.01	0.01	0.01	0.01	0.01
	0.0005*	0.0005*	0.0005*	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.002	0.002	0.002	0.002	0.002
	0.0004*	0.0005*	0.0005*	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.002	0.002	0.005	0.005	0.005
Hg	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Pb-GFA	0.0005*	0.0005*	0.0005*	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.02	0.02	0.02	0.02
Fe	0.02	0.04	0.04	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mg	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mn	0.002	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Ni	0.002*	0.0038*	0.0038*	0.0025	0.0025	0.0025	0.0025	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
PHENOL	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
PHEO-A	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
CHLOR-A	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
TCOLI		2	2	2	2	2	2	2	2	2	2	2	2	2	2
ECOLI-MF	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
FSTREP			2	2	2	2	2	2	2	2	2	2	2	2	2
OP	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.005	0.005	0.005	0.005
TDP							0.001								
TIP-SOLUBLE			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.005	0.005	0.005	0.005
TIP			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.005	0.005	0.005	0.005
TIP-F			0.001	0.001	0.001	0.001	0.001								

*** Indicates Method has a lower level of detection due to sample concentration.**

A.4
Volume-Averaged Database

1999 DATABASE OF SOUT

Onondaga Lake 1999 Annual Report
All SOUTH lake station sampling results, volume-averaged when appropriate.
Volume-averaged parameters use the actual LT value rather than 1/2 the LT value.

			Quarterly										Quarterly		Quarterly			
EPILIMNION		3/29	4/6	4/20	5/4	5/12	5/18	5/26	6/1	6/9	6/14	6/23	6/29	7/7	7/13	7/21	7/27	8/4
ALK-T	mg/l	179	181	178	168		176		179		158		152		146		91	
As	µg/l		2										2		2			
BOD5	mg/l	2	2	3	3		2		2		3		2		2		4	
Ca	mg/l	141	143	137	136		162		155		143		152		150		133	
Cd	µg/l		0.5										0.4		0.4			
Chloride	mg/l	459	450	458	443		477		489		497		516		488		486	
CHLOR-A	mg/m³	7.5	15.0	45.9	16.6	1.1	2.1	2.1	1.6	34.2	34.7	8.0	2.7	16.0	32.0	22.9	72.1	39.0
CHLOR-A [4]	mg/m³	7.5	12.3	33.6	17.1	0.5	1.6	1.6	1.1	41.1	30.4	8.0		17.1	33.1	33.1	72.6	37.4
CN-T	µg/l		2										2		2			
COND	mmho/cm	2057	2018	2031	2022		2097		2157		2213		2285		2270		2256	
Cr	µg/l		0.6										0.6		0.5			
Cu	µg/l		1.3										0.4		1.0			
DO-Field	mg/l	11.97	12.94	15.34	15.59		9.41		8.78		8.53		4.49		6.96		5.99	
ECOCCI	cell/100 ml	8	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
FCOLI	cell/100 ml	5	5	5	5	5	5	5	5	10	5	5	5	5	35	5	5	5
Fe	mg/l	0.156	0.112	0.042	0.053		0.043		0.076		0.065		0.171		0.085		0.083	
K	mg/l		4.90										5.53		5.31			
Mg	mg/l	22.0	21.7	21.8	22.8		23.0		23.0		24.2		24.8		23.8		24.0	
Mn	mg/l	0.044	0.012	0.005	0.005		0.005		0.019		0.002		0.002		0.051		0.002	
Na	mg/l	235	234	237	234		236		238		242		246		252		250	
NH3-N [1]	mg/l	1.44	1.43	1.24	1.19		1.61		2.20		1.67		1.72		1.27		0.60	
NH3-N [2]	mg/l	1.44																
	µg/l		22.5										3.6		5.2			
	mg/l	0.07	0.06	0.06	0.06		0.06		0.09		0.12		0.11		0.14		0.16	
NO3	mg/l	1.32	1.33	1.24	1.08		1.09		1.04		1.23		1.01		1.77		1.86	
ORG-N [1]	mg/l	0.61	0.62	0.71	0.72		0.75		0.48		1.07		0.49		0.59		1.10	
ORG-N [2]	mg/l	0.65																
Pb	µg/l		3.7										4.8		5.2			
PHENOL	µg/l		14										10		10			
Pheophytin-a [3]	mg/m³	1.87	0.37	0.20	1.76	1.17	2.00	0.20	0.64	0.20	0.20	1.71	0.69	2.30	1.23	2.83	3.60	3.26
Pheophytin-a [4]	mg/m³	1.12	0.80	0.20	0.20	1.33	2.00	1.01	1.17	0.20	0.96	1.33		1.98	0.20	4.27	3.63	4.86
pH	std units	7.90	8.05	8.36	8.44		7.84		8.02		7.94		7.64		8.01		7.90	
Se	µg/l		2										2		2			
Secchi	meters	1.7	1.1	1.5	1.9	7.2	7.9	5	4.8	1.6	1.2	2.3	4.2	2.0	1.2	0.9	0.5	0.6
SIO2	mg/l	3.60	3.59	0.76	0.37		1.02		1.39		1.30		1.02		1.34		1.20	
SO4	mg/l	158	172	169	175		193		185		200		194		193		178	
SRP (OP)	mg/l	0.043	0.032	0.001	0.001		0.024		0.022		0.018		0.019		0.035		0.002	
TDS	mg/l	1231	1220	1226	1203		1252		1351		1318		1430		1398		1343	
TEMP	°C	3.73	5.52	7.67	12.67		14.06		17.24		19.48		21.13		21.53		23.68	
TIC	mg/l	45.0	39.8	43.8	41.8		47.5		44.9		39.3		37.1		33.7		27.0	
TKN [1]	mg/l	2.09	2.04	1.95	1.91		2.37		2.68		2.74		2.20		1.87		1.70	
TKN-F [1]	mg/l	1.94	2.47								2.45		2.06		1.56		1.12	
TKN-F [2]	mg/l										2.32		1.96		1.33		0.78	
TOC	mg/l	4.22	4.22	4.63	4.60		4.37		4.39		4.20		3.95		4.30		4.63	
TOC-F	mg/l	3.94	3.84	4.22	4.02		4.29		4.14		3.75		3.64		3.85		3.79	
TP	mg/l	0.097	0.081	0.058	0.047		0.056		0.067		0.078		0.062		0.086		0.050	
TS	mg/l	1293	1251	1272	1376		1400		1430		1454		1506		1487		1489	
	mg/l	2	2	6	4		1		1		5		1		6		10	
	mg/l	204	187	178	257		290		293		258		348		292		329	
	mg/l	2	2	4	3		1		1		4		1		5		9	
Zn	µg/l		7.5										15.5		8.3			

Quarterly

EPILIMNION	8/10	8/19	8/24	9/1	9/7	9/15	9/21	9/23	9/30	10/5	10/19	10/27	10/28	11/3	11/16	11/30	12/14
ALK-T	98		96		98		106			125	143	148		149	145	142	150
As							2									2	
BOD5	4		3		2		2			2	2			3	6	6	6
Ca	128		136		138		131			130	140			128	143	135	150
Cd							0.4									0.4	
Chloride	539		541		501		526			527	532	617		565	583	546	539
CHLOR-A	32.0	33.6	16.0	16.6	21.9	13.4	16.0	18.2	12.7	13.9	10.1	8.0		5.3	8.5	8.5	5.3
CHLOR-A [4]	40.1	56.1	24.0	16.6	21.9	18.2	15.0	20.8	12.8	17.6	9.6			6.4	6.9	10.1	5.3
CN-T							2									2	
COND	2273		2325		2335		2229			2286	2299	2338	2337	2355	2350	2298	2335
Cr							0.5									0.7	
Cu							1.4									1.7	
DO-Field	6.58		6.90		7.43		8.04			7.18	5.55	6.66	6.72	6.97	9.64	9.48	9.02
ECOCCI	5	5	5	5	5	10	5	5	20	15	5			10	20	118	17
FCOLI	20	5	30	5	5	10	95	40	5	50	150			130	300	200	1200
Fe	0.125		0.063		0.059		0.038			0.045	0.047			0.055	0.062	0.094	0.066
K							5.45									5.68	
Mg	24.6		24.6		24.7		24.2			24.5	24.0			24.8	25.0	25.0	25.2
Mn	0.002		0.002		0.002		0.015			0.012	0.051			0.074	0.041	0.044	0.015
Na	261		259		260		270			272	265			278	287	274	276
NH3-N [1]	0.59		0.54		0.38		0.29			0.73	1.28	1.31		1.38	1.30	0.95	0.96
NH3-N [2]																	
Ni							6.9									5.1	
NO2	0.14		0.12		0.11		0.09			0.09	0.09	0.11		0.14	0.34	0.48	0.07
NO3	1.96		1.74		1.85		1.52			1.45	0.99	0.96		0.88	1.13	1.24	1.82
ORG-N [1]	1.02		0.63		0.69		0.69			0.73	0.58	0.72		0.72	0.54	0.60	0.44
ORG-N [2]																	
Pb							3.2									5.7	
PHENOL							10									10	
Pheophytin-a [3]	7.21	5.23	3.42	4.00	3.52	2.72	2.67	2.78	2.62	2.94	2.56	1.71		2.88	3.04	1.92	1.76
Pheophytin-a [4]	10.41	5.98	4.38	2.51	2.78	2.03	2.24	3.47	2.51	1.07	3.10			1.82	3.52	1.82	1.76
pH	7.93		7.99		8.05		7.86			7.71	7.57	7.71	7.57	7.73	7.78	7.68	7.56
Se							2									2	
Secchi	0.7	1.0	1.2		1.6	1.8	1.8	1.7	1.9	1.8	1.9	2.2		1.6	1.9	1.8	2.7
SIO2	0.99		1.25		0.58		1.17			1.58	2.12	2.24		2.31	2.54	2.63	3.05
SO4	199		196		199		182			199	198			205	202	196	177
SRP (OP)	0.010		0.005		0.001		0.001			0.015	0.097	0.129	0.128	0.134	0.122	0.122	0.116
	1309		1439		1444		1388			1334	1336	1333		1360	1368	1334	1380
	21.59		21.72		22.08		19.26			16.28	13.66	12.12	11.85	11.83	8.59	7.81	5.93
	20.9		26.2		27.4		22.4			33.0	36.7			37.1	40.5	39.9	
TKN [1]	1.61		1.17		1.07		0.98			1.46	1.86	2.03		2.09	1.85	1.55	1.41
TKN-F [1]	0.94		0.84		0.81		0.68			1.20	1.78			1.86	1.64	1.46	1.29
TKN-F [2]	0.57		0.52		0.48		0.75			1.11	1.81			1.83	1.78	1.59	1.41
TOC	4.72		4.49		4.24		4.88			4.23	4.34			3.86	5.97	4.88	4.19
TOC-F	4.48		4.00		3.96		4.45			4.00	4.09			3.74	5.82	4.47	4.04
TP	0.075		0.045		0.032		0.037			0.067	0.135	0.171	0.174	0.178	0.173	0.159	0.156
TS	1430		1514		1546		1423			1416	1445			1478	1429	1403	1445
TSS	10		5		4		2			1	1			3	3	2	2
TVS	265		288		361		209			205	246			229	198	169	222
VSS	9		5		4		2			1	1			2	2	1	2
Zn							10.0									3.4	

	3/29/99-12/14/99		5/18/99-9/15/99	
EPILIMNION	Ice-Free Mean	Ice-Free Season Median	Growing Season Mean	Growing Season Median
ALK-T	146	148	133	146
As	2	2	2	2
BOD5	3	3	3	2
Ca	143	139	144	143
Cd	0.4	0.4	0.4	0.4
Chloride	488	516	504	497
CHLOR-A	21.5	15.0	22.3	19.2
CHLOR-A (4)	24.1	17.1	26.7	24.0
CN-T	2	2	2	2
COND	2180	2279	2246	2270
Cr	0.6	0.6	0.6	0.6
Cu	0.9	1.3	0.7	0.7
DO-Field	9.30	7.74	7.23	6.96
ECOGCI	5	5	5	5
FCOLI	8	5	9	5
Fe	0.087	0.064	0.085	0.076
K	5.37	5.45	5.42	5.42
Mg	23.9	24.2	24.1	24.2
Mn	0.020	0.012	0.010	0.002
Na	255	256	249	250
NH3-N (1)	1.15	1.27	1.18	1.27
NH3-N (2)	1.44	1.44		
NI	8.7	5.2	4.4	4.4
NO2	0.13	0.11	0.12	0.12
NO3	1.36	1.24	1.51	1.74
ORG-N (1)	0.69	0.69	0.76	0.69
ORG-N (2)	0.65	0.65		
Pb	4.5	4.8	5.0	5.0
PHENOL	11	10	10	10
Pheophytin-a (3)	2.25	2.15	2.45	2.30
Pheophytin-a (4)	2.41	1.98	2.92	2.03
pH	7.87	7.88	7.92	7.94
Se	2	2	2	2
Secchi	2.2	1.8	2.3	1.6
SIO2	1.72	1.34	1.12	1.20
SO4	189	194	193	194
SRP (OP)	0.049	0.023	0.015	0.018
TDS	1333	1336	1365	1351
TEMP	14.52	13.86	20.28	21.53
TIC	36.0	37.1	33.8	33.7
TKN (1)	1.84	1.87	1.93	1.87
TKN-F (1)	1.51	1.51	1.40	1.12
TKN-F (2)	1.30	1.37	1.14	0.78
TOC	4.47	4.36	4.37	4.37
TOC-F	4.13	4.01	3.99	3.96
TP	0.095	0.076	0.061	0.062
TS	1424	1430	1473	1487
TSS	4	3	5	5
TVS	251	251	303	292
VSS	3	2	5	4
Zn	8.9	8.3	11.9	11.9

1999 DATABASE OF SOUTH DEEP LAKE SAMPLING RESULTS

Onondaga Lake 1999 Annual Report
All SOUTH lake station sampling results, volume-averaged when appropriate.
Volume-averaged parameters use the actual LT value rather than 1/2 the LT value.

			Quarterly						Quarterly					Quarterly						Quarterly		
HYPOLIMNION		3/29	4/6	4/20	5/4	5/18	6/1	6/14	6/29	7/13	7/27	8/10	8/24	9/7	9/21	10/5	10/19	10/27	10/28	11/3	11/16	11/30	12/14
ALK-T	mg/l	182	181	177	177	179	184	186	193	199	194	200	208	196	213	188	193	146	147		145	147	
			2						2	2					2							2	
BOD5		2	2	2	2	2	2	2	2	2	3	5	5	6	6	6	3			3	6	6	6
		150	140	138	144	150	146	142	135	151	148	139	146	149	138	134	146			140	146	139	
	µg/l		0.5						0.4	0.4					0.4							0.4	
Chlorid	mg/l	479	469	466	450	471	480	490	493	482	484	523	529	539	545	540	568	642		545	573	546	
	µg/l		2						2	2					2							2	
COND	µmho/cm	2154.04	2142	2036	2030	2056	2079	2134	2156	2202	2217	2227	2245	2319	2329.2	2364	2324	2347	2333	2361	2352	2303	2330
Cr	µg/l		1.0						0.5	0.5					0.5							1.0	
Cu	µg/l		1.4						0.4	0.7					0.4							1.9	
DO-Field	mg/l	10.85	11.35	15.01	11.85	6.95	4.60	3.28	0.69	0.00	0.05	0.00	0.07	0.06	0.07	0.00	4.44	6.48*	6.78	6.99	9.58	9.46	8.97
Fe	mg/l	0.099	0.119	0.046	0.044	0.040	0.047	0.079	0.048	0.072	0.117	0.113	0.265	0.134	0.120	0.112	0.134			0.058	0.063	0.107	
K	mg/l		5.03						4.78	4.74					4.55							5.46	
Mg	mg/l	22.5	21.3	21.5	21.8	22.5	22.5	22.8	22.2	22.5	23.1	23.9	23.6	23.9	24.0	24.5	25.0			25.5	25.0	25.0	
	mg/l	0.055	0.025	0.005	0.008	0.087	0.210	0.100	0.156	0.409	0.321	0.326	0.372	0.328	0.409	0.356	0.819			0.074	0.047	0.078	
	mg/l	246	246	236	237	226	236	241	241	248	250	257	255	282	277	276	286			282	284	268	
	mg/l	1.61	1.65	1.16	1.3298	1.75	1.92	2.02	2.62	2.9862	3.41	3.48	3.53	3.62	3.87	3.88	1.77	1.39		1.40	1.37	0.97	0.94
	mg/l	1.59																					
			21.8						2.6	4.2					4.7							4.0	
		0.08	0.07	0.06	0.06	0.05	0.05	0.06	0.04	0.03	0.06	0.01	0.01	0.01	0.02	0.03	0.01	0.11		0.14	0.34	0.56	
	mg/l	1.32	1.34	1.25	1.11	1.00	0.78	0.78	0.39	0.08	0.03	0.01	0.03	0.02	0.01	0.24	0.02	0.94		0.89	1.13	1.11	
	mg/l	0.061	0.065	0.001	0.025	0.118	0.184	0.223	0.337	0.367	0.387	0.412	0.414	0.393	0.414	0.443	0.197	0.128	0.127	0.135	0.122	0.123	0.116
	mg/l	0.57	0.55	0.61	0.45	0.61	0.55	0.55		0.10	0.15	0.45	0.42	0.54	0.43	0.71	0.58	0.59		0.72	0.46	0.53	0.48
	mg/l	0.55																					
	µg/l		3.2						3.5	5.4					3.4							5.2	
	std units	7.89	7.90	8.30	8.05	7.60	7.63	7.54	7.37	7.35	7.36	7.28	7.33	7.33	7.27	7.19	7.52	7.71	7.64	7.73	7.82	7.71	7.59
	µg/l		10						10	10					10							10	
	mg/l										1.3	2.7	2.5	3.1	6.5	4.9	4.4*						
	µg/l		2						2	2					2							2	
	mg/l	3.66	3.84	1.06	1.29	2.13	2.61	2.40	3.37	4.15	4.21	4.27	5.31	4.82	5.54	5.01	2.65	2.32		2.35	2.55	2.56	2.94
	mg/l	162	168	157	159	170	154	183	179	186	146	165	161	166	172	158	200			228	148	202	
	mg/l	1255	1284	1246	1224	1285	1303	1322	1347	1346	1332	1325	1364	1481	1409	1356	1381	1329		1358	1373	1349	1389
	oC	2.97	3.93	7.39	8.60	8.25	8.92	9.51	9.80	10.61	10.84	10.95	11.01	11.08	11.42	12.30	13.38	12.12	11.80	11.81	8.55	7.80	5.94
	mg/l	46.1	47.5	44.9	45.3	49.9	48.6	42.5	48.8	48.2	52.9	46.0	49.9	64.3	32.0	56.7	39.2			37.7	40.3	40.1	
	mg/l	2.17	2.19	1.76	1.78	2.36	2.48	2.57	2.99	3.05	3.57	3.94	3.95	4.17	4.30	4.59	2.35	1.98		2.11	1.82	1.50	1.42
	mg/l	2.14											3.14								1.67		
	mg/l	1.87	1.92					2.48	2.80	2.88	3.42	3.60	3.89	3.84	3.98	4.18	2.20			1.88	1.73	1.46	1.37
	mg/l							2.63	2.58	2.98	3.15	3.43	3.45	3.36	4.07	3.81	4.32			1.90		1.62	
	mg/l	4.29	4.18	4.75	4.24	4.17	4.12	4.04	3.56	4.10	3.59	4.17	4.82	3.86	4.88	4.03	4.37			3.98	6.84	4.15	
	mg/l	4.14	4.02	4.32	3.97	4.12	3.94	3.52	3.42	3.62	3.30	3.93	4.64	3.56	4.45	3.89	4.26			3.65	6.23	4.05	
	mg/l	0.109	0.101	0.049	0.062	0.164	0.220	0.263	0.375	0.447	0.405	0.504	0.467	0.428	0.500	0.524	0.227	0.169	0.179	0.186	0.176	0.159	
		1333	1357	1287	1354	1386	1403	1386.5	1405	1478	1492	1521	1427	1573	1469	1404	1475			1513	1439	1389	1470
		2	1	6	3	1	1	3	1	3	1	1	2	4	2	1	3			3	3	3	1
	mg/l	181	214	188	291	275	330	228	289	302	327	301	239	342	208	174	238			248	199	148	244
	mg/l	1	1	4	2	1	1	2	1	2	1	1	2	3	2	1	2			2	2	1	1
Zn	µg/l		6.6						9.1	7.4												7.7	

Data are volume-averaged when appropriate. Calculations use the laboratory limit of detection when an observation is below that limit.

(1) value is volume-weighted from discrete depth samples.

(2) value represents a composite sample observation.

Blanks: parameter not monitored; no data available.

* Data for 18 m only

1999 DATABASE OF SOUTH DEEP LAKE SAMPLING RESULTS

		3/29/99-12/14/99		5/18/99-9/21/99	
HYPOLIMNION		Ice-Free Mean	Ice-Free Season Median	Growing Season Mean	Growing Season Median
ALK-T	mg/l	182	185	195	195
As	µg/l	2	2	2	2
BOD5	mg/l	4	3	4	3
	mg/l	143	144	144	146
Cd	µg/l	0.4	0.4	0.4	0.4
Chloride	mg/l	516	508	504	492
CN-T	µg/l	2	2	2	2
	µmho/cm	2229	2236	2196	2209
Cr	µg/l	0.7	0.5	0.5	0.5
Cu	µg/l	1.0	0.7	0.5	0.4
DO-Field	mg/l	5.29	4.60	1.58	0.07
Fe	mg/l	0.096	0.099	0.103	0.096
K	mg/l	4.91	4.78	4.69	4.74
Mg	mg/l	23.3	23.1	23.1	23.0
Mn	mg/l	0.220	0.156	0.272	0.324
Na	mg/l	257	250	251	249
NH3-N (2)	mg/l	2.22	1.77	2.92	3.20
NH3-N (3)	mg/l	1.59	1.59		
Ni	µg/l	7.5	4.2	3.8	4.2
NO2	mg/l	0.090	0.06	0.03	0.04
NO3	mg/l	0.62	0.78	0.31	0.06
OP (SRP)	mg/l	0.218	0.160	0.325	0.377
	mg/l	0.50	0.55	0.42	0.45
	mg/l	0.55	0.55		
	µg/l	4.1	3.5	4.1	3.5
	std units	7.60	7.60	7.41	7.35
	µg/l	10	10	10	10
	mg/l	3.6	3.1	3.2	2.7
	µg/l	2	2	2	2
SiO2	mg/l	3.29	2.94	3.88	4.18
SO4	mg/l	172	166	168	168
TDS	mg/l	1336	1346	1351	1339
TEMP	oC	9.50	10.21	10.24	10.73
TIC	mg/l	46.4	46.1	48.3	48.7
TKN (1)	mg/l	2.72	2.36	3.34	3.31
TKN (2)	mg/l	2.32	2.14	3.14	3.14
TKN-F (1)	mg/l	2.72	2.64	3.36	3.51
TKN-F (2)	mg/l	3.11	3.26	3.21	3.26
TOC	mg/l	4.31	4.16	4.13	4.11
TOC-F	mg/l	4.05	3.99	3.85	3.77
TP	mg/l	0.267	0.203	0.377	0.417
TS	mg/l	1428	1416	1454	1448
TSS	mg/l	2	2	2	2
TVS	mg/l	248	241	284	295
VSS	mg/l	2	2	2	2
Zn	µg/l	6.7	7.4	6.4	7.4

1999 DATABASE OF NORTH DEEP LAKE SAMPLING RESULTS

Onondaga Lake 1999 Annual Report
All NORTH lake station sampling results, volume-averaged when appropriate.
Volume-averaged parameters use the actual LT value rather than 1/2 the LT value.

		Quarterly	Quarterly	Quarterly	Quarterly	4/6/99-11/30/99		7/13/99-9/21/99	
EPILIMNION		4/6	7/13	9/21	11/30	Ice-Free Mean	Ice-Free Season Median	Growing Season Mean	Growing Season Median
ALK-T	mg/l	178	144	106	145	143	145	125	125
As	µg/l	2	2	2	2	2	2	2	2
BOD5	mg/l	2	2	2	7	3	2	2	2
Ca	mg/l	136	151	122	140	137	138	137	137
Cd	µg/l	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
CHLOR-A	mg/m^3	23.52	20.82	26.16	8.01	19.63	22.17	23.49	23.49
Chloride	mg/l	451	507	532	552	511	520	520	520
CN-T	µg/l	2	2	2	2	2	2	2	2
COND	mmho/cm	2027	2257	2265	2333	2221	2261	2261	2261
Cr	µg/l	1.0	0.5	0.5	0.5	0.6	0.5	0.5	0.5
Cu	µg/l	2.6	1.1	0.7	1.7	1.5	1.4	0.9	0.9
DO-Field	mg/l	13.87	6.87	8.82	9.44	9.75	9.13	7.84	7.84
ECOCCI	cell/100 ml	20	5	5	45	19	13	5	5
FCOLI	cell/100 ml	5	5	55	62	32	30	30	30
Fe	mg/l	0.192	0.063	0.057	0.063	0.094	0.063	0.060	0.060
K	mg/l	4.82	5.23	5.34	5.73	5.28	5.29	5.29	5.29
Mg	mg/l	21.6	23.7	24.0	25.5	23.7	23.9	23.9	23.9
Mn	mg/l	0.009	0.002	0.012	0.043	0.017	0.011	0.007	0.007
Na	mg/l	229	247	270	281	257	259	259	259
NH3-N (1)	mg/l	1.38	1.36	0.25	1.00	1.00	1.18	0.81	0.81
Ni	µg/l	31.8	5.20	6.10	4.20	11.83	5.65	5.65	5.65
NO2	mg/l	0.06	0.13	0.09	0.47	0.19	0.11	0.11	0.11
NO3	mg/l	1.30	1.60	1.43	1.15	1.37	1.37	1.52	1.52
OP (SRP)	mg/l	0.023	0.038	0.001	0.127	0.047	0.031	0.020	0.020
ORG-N (1)	mg/l	0.61	0.49	0.69	0.47	0.56	0.55	0.59	0.59
Pb	µg/l	3.4	5.4	3.4	3.3	3.9	3.4	4.4	4.4
pH	std units	8.13	7.98	7.96	7.77	7.96	7.97	7.97	7.97
PHENOL	µg/l	10	10	10	10	10	10	10	10
Se	µg/l	2	2	2	2	2	2	2	2
Secchi	meters	1.7	1.8	1.8	1.9	1.8	1.8	1.8	1.8
SIO2	mg/l	3.35	1.51	1.06	2.63	2.14	2.07	1.29	1.29
SO4	mg/l	143	196	205	209	188	201	201	201
TDS	mg/l	1237	1398	1429	1342	1351	1370	1413	1413
TEMP	°C	5.90	21.04	19.62	7.78	13.58	13.70	20.33	20.33
TIC	mg/l	47.0	37.6	21.8	38.8	36.3	38.2	29.7	29.7
TKN	mg/l	1.99	1.85	0.94	1.48	1.56	1.66	1.39	1.39
TKN-F	mg/l	1.81	1.67	0.68	1.40	1.39	1.54	1.17	1.17
TKN-F (2)	mg/l		1.43	0.72	1.46	1.20	1.43	1.08	1.08
TOC	mg/l	4.42	4.80	4.99	4.87	4.77	4.83	4.89	4.89
TOC-F	mg/l	4.13	4.50	4.72	4.56	4.48	4.53	4.61	4.61
TP	mg/l	0.081	0.082	0.034	0.162	0.090	0.082	0.058	0.058
TS	mg/l	1297	1541	1481	1420	1435	1451	1511	1511
TSS	mg/l	3	4	3	3	3	3	4	4
TVS	mg/l	242	292	285	157	244	263	288	288
VSS	mg/l	3	3	3	1	3	3	3	3
Zn	µg/l	5.9	6.9	4.2	3.4	5.1	5.1	5.6	5.6

Data are volume-averaged when appropriate. Calculations use the laboratory limit of detection when an observation is below that limit.

(1) value is volume-weighted from discrete depth samples.

(2) value represents a composite sample observation.

Blanks: parameter not monitored; no data available.

*DRAFT

1999 DATABASE OF NORTH DEEP LAKE SAMPLING RESULTS

Quarterly	Quarterly	Quarterly	Quarterly	4/06/99-12/14/99	4/06/99-12/14/99	
[redacted]					Growing Season Mean	Growing Season Median
					198	198
					2	2
					4	4
					144	144
					0.4	0.4
					524	524
					2	2
					2302	2302
					0.6	0.6
					0.6	0.6
					0.00	0.00
					0.077	0.077
					4.66	4.66
					23.4	23.4
					0.343	0.343
					273	273
					3.17	3.17
					5.1	5.1
					0.02	0.02
					0.08	0.08
					0.347	0.347
					0.36	0.36
					4.2	4.2
					7.47	7.47
					12	12
					2.8	2.8
					2	2
					4.21	4.21
					173	173
					1406	1406
					11.64	11.64
					44.9	44.9
					3.52	3.52
					3.28	3.28
					3.28	3.28
					4.59	4.59
					4.24	4.24
					0.393	0.393
					1485	1485
					2	2
					251	251
					2	2
					4.0	4.0

Data are volume-averaged when appropriate. Calculations use the laboratory limit of detection when an observation is below that limit.

(1) value is volume-weighted from discrete depth samples.

(2) value represents a composite sample observation.

Blanks: parameter not monitored; no data available.

*Metals not included

DRAFT

A.5
Comparison of North and South Basin Data

COMPARISON OF NORTH AND SOUTH DATA

April 6, 1999

PARAMETER	UNITS	EPILIMNION SOUTH	EPILIMNION NORTH	HYPOLIMNION SOUTH	HYPOLIMNION NORTH
Secchi Disc Depth	m	1.1	1.70	NA	NA
pH	Std. Units	8.05	8.13	7.9	8.06
Temperature	C	5.52	5.90	3.93	4.79
Specific conductance	umho/cm	2018	2027	2142	2106
Dissolved Oxygen	mg/l	12.94	13.87	11.35	12.14
5-day BOD	mg/l	2	2	2	2
Total Alkalinity	mg/l	181	178	181	178
Total Organic Carbon	mg/l	4.2	4.42	4.18	4.38
TOC-Filtered	mg/l	3.84	4.13	4.02	4.1
Total Inorganic Carbon	mg/l	40.0	47.0	47.5	45.7
Total Kjeldhal Nitrogen	mg/l	2.04	1.99	2.19	2.17
TKN-Filtered	mg/l	2.47	1.81	1.92	1.77
TKN-Particulate	mg/l	-0.43	0.18	0.27	0.4
Organic Nitrogen	mg/l	0.62	0.61	0.55	0.64
Ammonia-N	mg/l	1.43	1.38	1.65	1.53
Nitrite-N	mg/l	0.06	0.06	0.07	0.06
Nitrate-N	mg/l	1.33	1.30	1.34	1.31
Arsenic	mg/l	2	2	2	2
Cyanide	ug/l	2	2	2	2
Total Phosphorus	mg/l	0.081	0.081	0.101	0.092
Soluble Reactive Phosphorus	mg/l	0.032	0.023	0.065	0.051
Silica	mg/l	3.59	3.35	3.84	3.49
Calcium	mg/l	143	136	140	135
Sodium	mg/l	234	229	246	236
Sulfate	mg/l	172	143	168	146
Sulfides	mg/l	NA	NA	NA	NA
Chloride	mg/l	450	451	469	457
Total Solids	mg/l	1251	1297	1357	1321
Total Volatile Solids	mg/l	187	242	214	218
Total Suspended Solids	mg/l	2	3	1	3
Volatile Suspended Solids	mg/l	2	3	1	2
Total Dissolved Solids	mg/l	1220	1237	1284	1260
Zinc	mg/l	0.0075	0.0059	0.0066	0.005
Copper	mg/l	0.0013	0.0026	0.0014	0.0012
Chrominum	mg/l	0.0006	0.001	0.001	0.0005
Cadmium	mg/l	0.0005	0.0005	0.0005	0.0005
Mercury	mg/l	NA	NA	NA	NA
Lead	mg/l	0.0037	0.0034	0.0032	0.0037
Iron	mg/l	0.112	0.192	0.119	0.095
Magnesium	mg/l	21.7	21.6	21.3	21.9
Manganese	mg/l	0.012	0.009	0.025	0.02
Nickel	mg/l	0.0225	0.0318	0.0218	0.0228
Phenol	ug/l	14	10	10	10
Phaeophytin-*a* (1)	mg/m^3	0.37	0.43	NA	NA
Phaeophytin-*a* (2)	mg/m^3	0.80	1.92	NA	NA
Chlorophyll-a (1)	mg/m^3	15	23	NA	NA
Chlorophyll-a (2)	mg/m^3	12	NA	NA	NA
Fecal Coliforms	cells/100ml	5	5	NA	NA

Data are volume-weighted when appropriate.

Calculations use the laboratory limit of detection when an observation is below that limit.

NA: Not Analyzed

(1) value represents a composite sample observation.

(2) sample taken from the photic zone.

COMPARISON OF NORTH AND SOUTH DATA

July 13, 1999

PARAMETER	UNITS	EPILIMNION		HYPOLIMNION	
		SOUTH	NORTH	SOUTH	NORTH
Secchi Disc Depth	m	1.2	1.8	NA	NA
pH	Std. Units	8.01	7.98	7.35	7.29
Temperature	C	21.53	21.04	10.61	10.24
Specific conductance	umho/cm	2270	2257	2202	2198
Dissolved Oxygen	mg/l	6.96	6.87	0.00	0.00
5-day BOD	mg/l	2	2	2	2
Total Alkalinity	mg/l	146	144	199	197
Total Organic Carbon	mg/l	4.3	4.8	4.1	4.1
TOC-Filtered	mg/l	3.85	4.50	3.62	3.82
Total Inorganic Carbon	mg/l	33.7	37.6	48.2	51.1
Total Kjeldhal Nitrogen	mg/l	1.87	1.85	3.05	2.99
TKN-Filtered	mg/l	1.56	1.67	2.88	2.82
TKN-Particulate	mg/l	0.31	0.18	0.17	0.17
Organic Nitrogen	mg/l	0.59	0.49	0.10	0.11
Ammonia-N	mg/l	1.27	1.36	2.99	2.88
Nitrite-N	mg/l	0.14	0.13	0.03	0.02
Nitrate-N	mg/l	1.77	1.60	0.08	0.14
Arsenic	mg/l	2	2	2	2
Cyanide	ug/l	2	2	2	2
Total Phosphorus	mg/l	0.086	0.082	0.447	0.414
Soluble Reactive Phosphorus	mg/l	0.035	0.038	0.367	0.353
Silica	mg/l	1.34	1.51	4.15	3.67
Calcium	mg/l	150	151	151	151
Sodium	mg/l	252	247	248	251
Sulfate	mg/l	193	196	186	172
Sulfides	mg/l	NA	NA	NA	1.1
Chloride	mg/l	488	507	482	483
Total Solids	mg/l	1487	1541	1478	1461
Total Volatile Solids	mg/l	292	292	302	285
Total Suspended Solids	mg/l	6	4	3	2
Volatile Suspended Solids	mg/l	5	3	2	2
Total Dissolved Solids	mg/l	1398	1398	1346	1394
Zinc	mg/l	0.0083	0.0069	0.0074	0.0057
Copper	mg/l	0.0010	0.0011	0.0007	0.0007
Chrominum	mg/l	0.0005	0.0005	0.0005	0.0005
Cadmium	mg/l	0.0004	0.0004	0.0004	0.0004
Mercury	mg/l	ND	ND	ND	ND
Lead	mg/l	0.0052	0.0054	0.0054	0.0050
Iron	mg/l	0.085	0.063	0.072	0.030
Magnesium	mg/l	23.8	23.7	22.5	22.8
Manganese	mg/l	0.051	0.002	0.409	0.318
Nickel	mg/l	0.0052	0.0052	0.0042	0.0043
Phenol	ug/l	10	10	10	10
Phaeophytin-*a* (1)	mg/m^3	1.23	1.23	NA	NA
Phaeophytin-*a* (2)	mg/m^3	0.20	NA	NA	NA
Chlorophyll-a (1)	mg/m^3	32.0	20.8	NA	NA
Chlorophyll-a (2)	mg/m^3	33.1			
Fecal Coliforms	cells/100ml	35	5	NA	NA

Data are volume-weighted when appropriate.

Calculations use the laboratory limit of detection when an observation is below that limit.

NA: Not Analyzed

(1) value represents a composite sample observation.

(2) sample taken from the photic zone.

COMPARISON OF NORTH AND SOUTH DATA

September 21, 1999

PARAMETER	UNITS	EPILIMNION		HYPOLIMNION	
		SOUTH	NORTH	SOUTH	NORTH
Secchi Disc Depth	m	1.8	1.8	NA	NA
pH	Std. Units	7.86	7.96	7.27	7.65
Temperature	C	19.26	19.62	11.42	13.04
Specific conductance	umho/cm	2229	2265	2329	2407
Dissolved Oxygen	mg/l	8.04	8.82	0.07	0.00
5-day BOD	mg/l	2	2	6	5
Total Alkalinity	mg/l	106	106	213	199
Total Organic Carbon	mg/l	4.88	4.99	4.88	5.08
TOC-Filtered	mg/l	4.45	4.72	4.45	4.66
Total Inorganic Carbon	mg/l	22.4	21.8	32	38.6
Total Kjeldhal Nitrogen	mg/l	0.98	0.94	4.30	4.06
TKN-Filtered	mg/l	0.68	0.68	3.98	3.73
TKN-Particulate	mg/l	0.30	0.26	0.32	0.33
Organic Nitrogen	mg/l	0.69	0.69	0.43	0.61
Ammonia-N	mg/l	0.29	0.25	3.87	3.45
Nitrite-N	mg/l	0.09	0.09	0.02	0.02
Nitrate-N	mg/l	1.52	1.43	0.01	0.01
Arsenic	mg/l	2	2	2	NA
Cyanide	ug/l	2	2	2	2
Total Phosphorus	mg/l	0.037	0.034	0.500	0.372
Soluble Reactive Phosphorus	mg/l	0.001	0.001	0.414	0.342
Silica	mg/l	1.17	1.06	5.54	4.74
Calcium	mg/l	131	122	138	136
Sodium	mg/l	270	270	277	294
Sulfate	mg/l	182	205	172	174
Sulfides	mg/l	NA	NA	6.4	4.5
Chloride	mg/l	526	532	545	564
Total Solids	mg/l	1423	1481	1469	1510
Total Volatile Solids	mg/l	209	285	208	218
Total Suspended Solids	mg/l	2	3	2	2
Volatile Suspended Solids	mg/l	2	3	2	2
Total Dissolved Solids	mg/l	1388	1429	1409	1417
Zinc	mg/l	0.0100	0.0042	0.0027	0.0022
Copper	mg/l	0.0014	0.0007	0.0004	0.0004
Chrominum	mg/l	0.0005	0.0005	0.0005	0.0006
Cadmium	mg/l	0.0004	0.0004	0.0004	0.0004
Mercury	mg/l	NA	NA	NA	NA
Lead	mg/l	0.0032	0.0034	0.0034	0.0034
Iron	mg/l	0.038	0.057	0.120	0.125
Magnesium	mg/l	24.2	24.0	24.0	24.0
Manganese	mg/l	0.015	0.012	0.409	0.369
Nickel	mg/l	0.0069	0.0061	0.0047	0.0058
Phenol	ug/l	10	10	10	10
Phaeophytin-*a* (1)	mg/m^3	2.24	2.24	NA	NA
Phaeophytin-*a* (2)	mg/m^3	2.67	NA	NA	NA
Chlorophyll-a (1)	mg/m^3	16.0	26.2	NA	NA
Chlorophyll-a (2)	mg/m^3	15.0	NA	NA	NA
Fecal Coliforms	cells/100ml	95	55	NA	NA

Data are volume-weighted when appropriate.

Calculations use the laboratory limit of detection when an observation is below that limit.

NA: Not Analyzed

(1) value represents a composite sample observation.

(2) sample taken from the photic zone.

COMPARISON OF NORTH AND SOUTH DATA

November 30, 1999

PARAMETER	UNITS	EPILIMNION SOUTH	EPILIMNION NORTH	HYPOLIMNION SOUTH	HYPOLIMNION NORTH
Secchi Disc Depth	m	1.8	1.9	NA	NA
pH	Std. Units	7.68	7.77	7.71	7.77
Temperature	C	7.81	7.78	7.8	7.73
Specific conductance	umho/cm	2298	2333	2303	2327
Dissolved Oxygen	mg/l	9.48	9.44	9.46	9.31
5-day BOD	mg/l	6	7	6	7
Total Alkalinity	mg/l	142	145	147	145
Total Organic Carbon	mg/l	4.88	4.87	4.15	4.90
TOC-Filtered	mg/l	4.47	4.56	4.05	4.51
Total Inorganic Carbon	mg/l	39.9	38.8	40.1	37.4
Total Kjeldhal Nitrogen[1]	mg/l	1.55	1.48	1.50	1.52
TKN-Filtered [1]	mg/l	1.46	1.4	1.46	1.35
TKN-Filtered [2]	mg/l	1.59	1.46	1.62	1.38
TKN-Particulate[1]	mg/l	0.09	0.08	0.04	0.17
Organic Nitrogen	mg/l	0.60	0.47	0.53	0.58
Ammonia-N	mg/l	0.95	1.00	0.97	0.94
Nitrite-N	mg/l	0.48	0.47	0.56	0.47
Nitrate-N	mg/l	1.24	1.15	1.11	1.18
Arsenic	mg/l	2	2	2	2
Cyanide	ug/l	2	2	2	2
Total Phosphorus	mg/l	0.159	0.162	0.159	0.163
Soluble Reactive Phosphorus	mg/l	0.122	0.127	0.123	0.126
Silica	mg/l	2.63	2.63	2.56	2.56
Calcium	mg/l	135	140	139	140
Sodium	mg/l	274	281	268	277
Sulfate	mg/l	196	209	202	208
Sulfides	mg/l	NA	NA	NA	NA
Chloride	mg/l	546	552	546	551
Total Solids	mg/l	1403	1420	1389	1430
Total Volatile Solids	mg/l	169	157	148	153
Total Suspended Solids	mg/l	2	3	3	3
Volatile Suspended Solids	mg/l	1	1	1	1
Total Dissolved Solids	mg/l	1334	1342	1349	1336
Zinc	mg/l	0.0034	0.0034	0.0077	0.0046
Copper	mg/l	0.0017	0.0017	0.0019	0.0014
Chrominum	mg/l	0.0007	0.0005	0.001	0.0005
Cadmium	mg/l	0.0004	0.0004	0.0004	0.0004
Mercury	mg/l	NA	NA	NA	NA
Lead	mg/l	0.0057	0.0033	0.0052	0.0039
Iron	mg/l	0.094	0.063	0.107	0.060
Magnesium	mg/l	25.0	25.5	25.0	25.0
Manganese	mg/l	0.044	0.043	0.078	0.040
Nickel	mg/l	0.0051	0.0042	0.0040	0.0042
Phenol	ug/l	10	10	10	10
Phaeophytin-*a* [1]	mg/m^3	1.82	2.46	NA	NA
Phaeophytin-*a* [2]	mg/m^3	1.92	NA	NA	NA
Chlorophyll-a [1]	mg/m^3	8.5	8.01	NA	NA
Chlorophyll-a [2]	mg/m^3	10.1	NA	NA	NA
Fecal Coliforms	cells/100ml	72	44	NA	NA

Data are volume-weighted when appropriate.

Calculations use the laboratory limit of detection when an observation is below that limit.

NA: Not Analyzed

[1] value represents a composite sample observation.

[2] sample taken from the photic zone.