Onondaga County Department of
WATER
ENVIRONMENT
PROTECTION

Onondaga Lake Ambient Monitoring Program

2007 Annual Report
FINAL
Revised April 2009

Onondaga County, New York
Joanne M. Mahoney, County Executive

ONONDAGA LAKE AMBIENT MONITORING PROGRAM

2007 ANNUAL REPORT

Chapters 1-10 AND APPENDICES 1-13

ONONDAGA COUNTY, NEW YORK

FINAL
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2007 AMP ANNUAL REPORT SUMMARY

Program Description

Onondaga County Department of Water Environment Protection (OCDWEP) conducts an annual program to evaluate the water quality conditions of Onondaga Lake, the lake tributaries, and a portion of the Seneca River. This program is one element of the Amended Consent Judgment (ACJ) signed in 1998, which requires Onondaga County to complete the analysis, design and construction of improvements to the wastewater collection and treatment system. In addition, reductions in the nonpoint sources of nutrients and sediment, such as urban stormwater and runoff from agricultural areas, are required. The Ambient Monitoring Program (AMP) is in place to measure the effectiveness of these reductions in pollutant inputs in bringing about better water quality conditions in Onondaga Lake and adjacent waters.

The AMP is designed to identify sources of materials (nutrients, sediment, bacteria, and chemicals) to the lake, evaluate in-lake water quality conditions, and examine the interactions between Onondaga Lake and the Seneca River. Compliance with water quality standards and trend analysis are two central elements. In addition to the water quality monitoring effort, the AMP examines the health of the entire lake ecosystem by sampling fish, phytoplankton, zooplankton, benthic invertebrates, aquatic plants, and zebra mussels.

A rigorous Quality Assurance/Quality Control program is in place. The annual AMP workplan is subject to New York State Department of Environmental Conservation (NYSDEC) review and approval each year. Samples are collected by trained technicians and analyzed in a state-certified laboratory. Internal and external audits are conducted, blanks and duplicates are evaluated, and the results are presented in the annual AMP report. Technical experts serving on the Onondaga Lake Technical Advisory Committee review the data and interpretive reports and make recommendations.

Technological advances allow the County to monitor water quality on a near-real-time basis. A water quality buoy with an array of probes that measure physical and chemical characteristics of the lake water is deployed on the lake at its deepest point. Data from the buoy provide a window into the temporal changes in lake water quality. At the lake's outlet, acoustic Doppler devices installed by the U.S. Geological Survey provide data needed to understand water exchange between the lake and the Seneca River.

Each year, OCDWEP tests over 20,000 water samples and examines several thousand biological samples. The County has invested in creation of custom databases to facilitate analysis and reporting tasks. The 2007 water quality data were appended to the water quality database, which is a repository of tributary and lake data since 1968. In early 2008, the County and its consultants completed the integrated biological database which compiles results of the AMP fisheries, phytoplankton, zooplankton, macroinvertebrate and zebra mussel monitoring efforts.

Results

Onondaga Lake water quality continues to improve in response to reduction in nutrient loading. The 2007 lake conditions were consistent with improved conditions observed in recent years following implementation of upgrades to the treatment plant. Phosphorus input to the lake continued to decrease in 2007; in response, lake phosphorus and algal abundance were also low. Dissolved oxygen content of the lake has increased to the point where water quality standards are now routinely met in the upper waters during fall mixing. Algal blooms are diminishing and cyanobacteria (blue-greens) represent a minor component of the algal community. Zebra mussels have expanded substantially in the lake; the additional grazing pressure may be contributing to the reduction in algal biomass and improved water clarity. Clearer water has allowed the beds of aquatic plants to expand; this has increased the amount of nesting and nursery habitat for the warmwater fish community.

Improvements in Wastewater Treatment

Improvements to the county's wastewater collection and treatment system are primarily responsible for the improved water quality conditions in the lake. Significant investment in wastewater treatment technology has achieved far lower discharges of wastewater-related pollutants, particularly ammonia and phosphorus.

Onondaga Lake exhibited high ammonia concentrations for decades. Monitoring results from 1970 to 2002 documented that ammonia levels in the lake waters were above New York State's ambient water quality standards designed to protect aquatic life. Metro effluent was the largest source of ammonia to the lake, averaging about 90% of the total annual input. Recent improvements to Metro were designed to reduce ammonia levels in the treated effluent and bring the lake's water quality into compliance with state standards.

The final stage of the Metro improvements for ammonia treatment came on-line in early 2004. The Biological Aerated Filter (BAF) system has resulted in year-round nitrification (conversion of ammonia to nitrate) in wastewater. Prior to this final stage, various improvements to the treatment system had resulted in substantial reductions, particularly in the summer ammonia levels.

Average annual Metro (Outfall 001) ammonia load

Years	*metric tons*	*percent of gauged total input*
1990 - 1997	1210	90%
1998 - 2003	522	85%
2004 - 2007	82	48%

Enhanced phosphorus removal from wastewater is another objective of the Metro improvements currently underway. A High Rate Flocculated Settling (HRFS) physical-chemical treatment system (known as ACTIFLO) came on-line in 2005 to reduce effluent total phosphorus (TP) concentration. This stage of phosphorus treatment is designed to meet a 12-month rolling average TP limit of 0.12 mg/l. Evaluation of compliance with this limit began in April 2006, following 12 months of operation. In 2007, Metro effluent TP concentration met the 0.12 mg/l limit.

Average annual Metro (Outfall 001) TP load

Years	*metric tons*	*percent of gauged total input*
1990 - 1997	53	56%
1998 - 2004	34	54%
2005 - 2007	13	39%

In 2007, Metro contributed about 33% of the total external phosphorus load to Onondaga Lake through outfall 001 (28%) and outfall 002 (5%). The remainder of the phosphorus load comes from runoff from urban areas, farm fields, construction, forestry practices and other nonpoint sources throughout the 285-square mile watershed.

Water Quality Monitoring Results

Phosphorus concentrations in the lake are declining as loading reductions are achieved at the wastewater treatment plant and in the nonpoint source loads. In 2007, the summer average total phosphorus concentration was approximately 25 µg/l in the lake's upper waters.

Chlorophyll-*a* concentration averaged 9.63 µg/l during the summer of 2007; the peak of 28.84 µg/l was measured on September 11, 2007. Low algal levels were measured during the summer recreational period; less than 10% exceeded 15 µg/l (a threshold of perceived impairment for recreational use). In 2007, cyanobacteria were essentially absent from the algal community. Nuisance algal blooms (exceeding 30 µg/l) have not been measured since 2004, presumably in response to reductions in nutrient loads.

Dissolved oxygen (DO) levels continued to show improvement in response to reduced productivity in the lake. The DO concentrations in upper waters during fall mixing met regulatory standards; the minimum concentration measured in 2007 during fall mixing was greater than 8 mg/l. The volume-days of anoxia (a summary metric that includes both the volume and duration of oxygen depletion in the lower waters) was the lowest ever measured In addition, detectable DO and nitrate concentrations persisted in the lower waters longer during the stratified period. Phosphorus release from sediments was greatly diminished in 2007 compared with previous years in response to the improved redox conditions in the lower waters.

Water clarity is variable within and between years; it is affected by algal blooms, particles washing in from the tributaries, and resuspension of bottom sediments. The abundance of grazing organisms, such as zooplankton and zebra mussels, affect water clarity as well. In 2007, the average water clarity at the South Deep station was 2.1 m, based on weekly measurements between June 1 and September 30. Nearshore data were in compliance with the swimming safety guidance value of 1.2 m.

Ammonia and nitrite nitrogen concentrations are declining in response to enhanced treatment at the wastewater treatment plant. In 2007, the annual average concentrations of ammonia and nitrite in the lake's upper waters were 0.16 mg/l and 0.04 mg/l, respectively. The upper waters of the lake are in full compliance with the New York State ambient water quality standard for both ammonia and nitrite. Onondaga Lake was removed from the State 303(d) list of impaired waters for ammonia, in recognition that the lake is in compliance.

Bacteria concentrations were monitored at a network of nearshore stations as well as at South Deep (the primary water quality monitoring site). In 2007, concentrations within the Class B portion of Onondaga Lake met the New York State ambient water quality standard for fecal coliform bacteria, a metric which is meant to assess suitability for water contact recreation. The 2007 data show that bacteria levels in the lake's southern basin, near the CSOs and major streams, are occasionally elevated after storms of sufficient intensity and duration to cause the combined sewer system to overflow. This finding highlights the need for continued progress with the CSO abatement projects, as well as the need for improved storm water management to reduce nonpoint source pollution from urban areas. Additional data analysis, coupling bacteria results to rainfall, is recommended.

Biological Monitoring Results

Zooplankton grazing is a significant factor affecting water clarity. A reduction in population of the larger zooplankton taxa was evident in late summer 2002 when alewives became an important component of the lake's fish community. These larger zooplankton, which are efficient grazers of phytoplankton, are the preferred food source of the alewife.

Consequently, abundant alewives lead to few large zooplankton, which in turn leads to more phytoplankton and the loss of clear water. Alewives remained abundant in the lake in 2007, and their effects were seen throughout the food web. Although these organisms are an important factor affecting water clarity, the population dynamics are not controllable.

Fish are one of the most visible components of the ecosystem. Results of the 2007 fish program indicate that the community continues to be dominated by warmwater species. Popular gamefish such as largemouth and smallmouth bass are common, and tend to be more abundant in the northern basin. An increasing trend in the numbers of both smallmouth and largemouth bass is evident.

The greater abundance in the northern basin is consistent with the distribution of aquatic plants, and macroinvertebrates, demonstrating that the northern basin provides better habitat quality. Other gamefish, such as walleye and northern pike, are present but are far less common than bass. Panfish, such as yellow perch, pumpkinseed, and bluegill, are abundant in nearshore areas.

Of the 26 fish species captured in Onondaga Lake in 2007, 11 (42%) showed evidence of successful reproduction. The young-of-the-year community was dominated by two species: largemouth bass, with 48% of the catch and *Lepomis*, which represented 47%.

Alewife abundance was evaluated using hydroacoustics, gill nets, and electrofishing. Estimated density was about 30% lower than measured in 2005 and 2006. The strong year classes of 2002 and 2004 remain dominant. Reductions in alewife, mediated through grazing by zooplankton, should lead to improved water clarity.

The New York State Department of Health (NYSDOH) produces an annual report detailing health advisories for the consumption of fish and game in New York. The May 2007 report “2007-2008 Health Advisories: Chemicals in Sportfish and Game”, advises that the following fish taken from Onondaga Lake should not be consumed due to elevated mercury concentrations: largemouth and smallmouth bass over 15 inches in length, and walleye. It is also recommended to eat no more than one meal per month of all other species taken from Onondaga Lake.

Macrophytes (rooted aquatic plants and algae) have expanded throughout most of the littoral zone. The community remains dominated by a few species. Year-to-year variability in coverage is documented by the AMP’s annual aerial photographs; this variability is typical of other regional lakes. Much of the littoral zone has plant coverage within the ideal range for largemouth bass propagation

An **Index of Biotic Integrity (IBI)** has been proposed for use in coastal wetlands and nearshore areas of the Great Lakes (Seilheimer and Chow-Fraser 2006). This proposed index was evaluated for its applicability to Onondaga Lake, and the results are promising. The spatial pattern and temporal trend of the IBI correlate well with other metrics of habitat quality and biological response in Onondaga Lake.

Seneca River Monitoring Results

Onondaga County completed a focused water quality monitoring effort at selected stations along the Seneca-Oneida-Oswego River system in 2007. High-frequency measurements using sondes detected periods where DO concentrations fell below ambient water quality standards. The river’s water quality conditions continue to be influenced by zebra mussels.

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LIST OF ACRONYMS

AMP	Ambient Monitoring Program
ACJ	Amended Consent Judgment
ASLF	Atlantic States Legal Foundation
AWQS	Ambient Water Quality Standards
BAF	Biological Aerated Filter
BAP	Biological Assessment Profiles
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CBUD	Continuous Backflow Upwelling Dual Filters (Phosphorus Filtration Stage III)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFU	Colony Forming Units
CSO	Combined Sewer Overflows
DAIP	Data Analysis and Interpretation Plan
DO	Dissolved Oxygen
DVT	Data Visualization Tool
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HRFS	High Rate Flocculated Settling
ISD	Impact Source Determination
LA	Load Allocation
METRO	Metropolitan Syracuse Wastewater Treatment Plant
MOS	Margin of Safety
MRL	Minimum Reporting Level
N	Nitrogen
NYCRR	Official Compilation of the Rules and Regulations of the State of New York
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priority List
NYSDEC	New York State Department of Environmental Conservation
OCDWEP	Onondaga County Department of Water Environment Protection
OLP	Onondaga Lake Partnership
OLTAC	Onondaga Lake Technical Advisory Committee
OLWQM	Onondaga Lake Water Quality Model
PWL	Priority Waterbodies List
QEA	Quantitative Environmental Analysis, LLC
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RFP	Request For Proposal
RSE	Relative Standard Error
SPDES	State Pollution Discharge Elimination System
SRP	Soluble Reactive Phosphorus
SSO	Sanitary Sewer Overflow
TKN	Total Kjeldahl Nitrogen

LIST OF ACRONYMS
(continued)

TMDL	Total Maximum Daily Load
TOGS	Technical and Operational Guidance Series
TP	Total Phosphorus
TRWQM	Three Rivers Water Quality Model
TSS	Total Suspended Solids
UFI	Upstate Freshwater Institute
USGS	United States Geological Survey
WFI	Wetland Fish Index
WLA	Wasteload Allocation

PART ONE:

CHAPTER 1: OVERVIEW OF THE AMBIENT MONITORING PROGRAM

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CHAPTER 1. OVERVIEW OF THE AMBIENT MONITORING PROGRAM (AMP)

1.1 REGULATORY CONTEXT OF THE ONONDAGA COUNTY AMP

The 2007 Onondaga County Department of Water Environment Protection's (OCDWEP) Ambient Monitoring Program (AMP) represents the 38th consecutive year of Onondaga County's lake monitoring effort. The program began in 1970 as a baseline evaluation of the "state of the lake." Over the years, the program has evolved into an annual monitoring effort designed to track water quality conditions of the lake and its response to pollution abatement efforts.

In 1998, the County's existing lake monitoring program was modified to comply with the requirements of an Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation. The ACJ settled a suit between the parties regarding performance of the Onondaga County wastewater collection and treatment system. By signing the ACJ, Onondaga County committed to a 15-year program to design and implement three elements:

1) Improvements to the wastewater and stormwater collection systems to abate Combined Sewer Overflows (CSOs).
2) Improvements to the Metropolitan Syracuse Wastewater Treatment Plant (Metro) to reduce the concentration of ammonia N, phosphorus, BOD, solids, and bacteria in treated effluent prior to discharge.
3) A comprehensive monitoring program of Onondaga Lake, the lake tributaries, and the Seneca River to track their response to the pollution abatement actions.

The ACJ included specific monitoring requirements for the lake, the tributaries, and the river to track their response to the pollution abatement actions. To meet these requirements, the existing lake monitoring program was modified and expanded. This process of evaluation and modification was a collaborative effort of six entities:

Onondaga County
Onondaga Lake Technical Advisory Committee (OLTAC)
U.S. Geological Survey (USGS)
New York State Department of Environmental Conservation (NYSDEC)
Environmental Protection Agency (EPA)
Atlantic States Legal Foundation (ASLF)

The monitoring program was restructured around a series of hypotheses related to the effectiveness of the County's improvements to the wastewater collection and treatment system. The revised lake monitoring program, now known as the Ambient Monitoring Program, was initiated in August 1998.

1.2 PROGRAM SUMMARY

The AMP is designed to provide data and information necessary to evaluate the effectiveness of improvements to the County's wastewater collection and treatment system. The findings of the AMP, and the implications of these findings on the water quality and ecological status of the lake and watershed, are reviewed by engineers and scientists affiliated with OLTAC, USGS, NYSDEC, EPA, ASLF, and the Onondaga Lake Partnership. The overall objectives and structure of the AMP are summarized in **Table 1-1**.

1.2.1 Program Summary

Improvements to Metro and the CSOs are being implemented in phases, with final completion dates in the year 2012. 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 and special elements. Annual elements are designed to evaluate compliance and establish trends, and special elements are timed to follow ACJ-related milestones. Consequently, each year the AMP is slightly different. The structure of the 2007 monitoring program with respect to the ACJ-required objectives is summarized in **Table 1-2.**

Table 1-1. Objectives and structure of the Ambient Monitoring Program.

AMP Program Objective	Monitoring and Assessment	Comments
Quantify external loading.	Monitor streams and point sources for flow, nutrients, solids, indicator bacteria, metals, and salts. Calculate load.	Regular (biweekly) tributary sampling supplemented with storm and high flow event monitoring.
Assess compliance and trends in lake water quality..	Physical characteristics: temperature, light penetration, water clarity, turbidity Chemical characteristics: nutrients, salts, dissolved oxygen, ammonia, pH, metals. Biological characteristics: chlorophyll-*a* and phaeophytin, phytoplankton, zooplankton, indicator bacteria. *Additional biological parameters are summarized below*. Trophic status: phosphorus, chlorophyll-*a*, Secchi disk transparency, dissolved oxygen, phytoplankton community	Profiles through water column, supplemented by buoy with sondes at fixed depths. Water quality monitoring buoy at deepest location (profile sampling). Biweekly monitoring (open water season), monthly winter sampling, as possible. Water clarity and indicator bacteria monitoring at nearshore stations: suitability for water contact recreation.
Determine tributary water quality, biota, and habitat conditions.	Water quality: Annual program for flow, nutrients, solids, bacteria, metals, salts, oxygen-demanding material, and carbon fractions. Habitat and biota: Every 2 years starting in 2000: monitor stream macroinvertebrate community. Stream mapping: based on the Natural Resources Conservation Service Visual Assessment Protocol 1998 (baseline assessment in 2000 and 2002, to be repeated in 2008 and 2012). Additional evaluation of stream segments possible following improvements and/or major hydrologic events.	Stream mapping and habitat assessment (including macroinvertebrates) limited to the three CSO-affected tributaries. Water quality monitoring occurs in all tributaries and inflows.
Assess the biological community in Onondaga Lake.	Fish community: annual assessment of nests, larval fishes, juveniles, adults using multiple sampling gears and techniques. Macrophytes: annual aerial photography for percent cover of littoral zone (limited ground truthing). Detailed field survey every 5 years starting in 2000. Littoral macroinvertebrates: every 5 years, community structure and abundance. Zebra mussels: habitat mapping and sampling at reference locations (lake and river)	Focus on metrics of community structure, food web dynamics. Biological sampling of littoral zone, sediment texture analysis. TRWQM and OLWQM Support (Zebra Mussels)

Table 1-2. Elements of the 2007 AMP in relation to ACJ-required monitoring objectives.

ACJ Statement of Required Program Objective:	**2007 Program Elements**	**Data Used To**	**Location in 2007 Report**
Quantify external loading of phosphorus, nitrogen, suspended solids, indicator bacteria, and salts. Assess the reduction in loading achieved by the CSO improvements. Design program to evaluate the relative contribution of point and nonpoint sources of pollution to the lake.	(Annual program) Tributary monitoring: biweekly, and high flows – Includes locations upstream and downstream of CSOs, urban and rural segments of subwatersheds.	Estimate annual external loading to Onondaga Lake	• 2007 Progress Report[1] • Chapter 2 – Metro and CSOs • Chapter 3 – Nutrients and Trophic State • Chapter 4 – Other Parameters Status and Trends • Appendix 7 Mass Balance Report
Assess the tributaries' physical habitat and macroinvertebrate community.	(Periodically) • Stream mapping using NRCS Visual Stream Assessment Protocol in CSO-subwatersheds: Onondaga Creek, Ley Creek and Harbor Brook	Quantify baseline conditions and provide basis to measure change.	Baseline surveys conducted in 2000 and 2002; most recent published in 2002 AMP report. Post-improvements surveys scheduled for 2008 and 2012; may be modified based on CSO construction or major hydrologic event.
	(Every 2 years, even years) • Macroinvertebrate surveys of CSO-affected subwatersheds	Quantify baseline conditions and provide basis to measure change	Most recent survey conducted in 2006 and published in 2006 AMP report; next survey scheduled for 2008.
Gather data on an adequate temporal and spatial scale to assess compliance with ambient water quality standards.	(Annual programs) • Lake monitoring program: South Deep Station and nine nearshore stations • Tributary monitoring program • Seneca River monitoring program	Assess compliance with numerical and narrative standards Calibrate and verify models	• 2007 Progress Report[1] • Chapter 7 – Progress Toward Compliance

[1] The 2007 Progress Report is a separate document for public outreach.

Table 1-2. Elements of the 2007 AMP in relation to ACJ-required monitoring objectives (continued).

ACJ Statement of Required Program Objective:	**2007 Program Elements**	**Data Used To**	**Location in 2007 Report**
Evaluate changes in the water quality and trophic state of Onondaga Lake in response to reductions in external loading achieved by the improvements to Metro and the CSOs.	(Annual programs) • Lake monitoring • Tributary monitoring • River monitoring	Assess conditions in relation to inputs and trends Calibrate USGS watershed model of land use and nutrient export (using AMP tributary data) Construct conceptual model and mass-balance model Calculate "fish space metrics" to track changes in available habitat for cold water, cool water and warm water fish Develop and calibrate Onondaga Lake model	• 2007 Progress Report[1] • Chapter 2 – Metro and CSOs • Chapter 3 – Nutrients and Trophic State • Chapter 4 – Other Parameters Status and Trends • Appendix 10 – South and North Comparison • Appendix 11 – Licor Data Analysis

Table 1-2. Elements of the 2007 AMP in relation to ACJ-required monitoring objectives (continued).

ACJ Statement of Required Program Objective:	**2007 Program Elements**	**Data Used To**	**Location in 2007 Report**
Expand the chemical monitoring program to include other indices of ecological integrity: biological data, contaminant burden, and physical habitat.	(Annual biological program unless noted otherwise) • Fish: nesting, larvae, juveniles, and adult communities • Lower trophic levels: phytoplankton and zooplankton • macrophytes: annual aerial surveys with ground-truthing; full field surveys in 2000, 2005 and 2010 • macroalgae: visual surveys in nearshore areas • littoral macroinvertebrates: surveys in 2000, 2005 and 2010 Fish flesh contaminant levels, monitored and reported by NYSDEC	Assess current trophic state, abundance and diversity of species, importance of exotic species, reproductive success Test for trends or shifts in data Compare Onondaga Lake with Oneida Lake (zooplankton community) and other regional lakes (fish community)	• Chapter 3 – Nutrients and Trophic State • Chapter 4 – Other Parameters Status and Trends • Chapter 5 – Biological Community • Appendix 3 – Lower Trophic Levels • Appendix 4 – Macrophyte and Macroalgae • Appendix 6 – Dreissenid Mussel Survey • Appendix 8 – Fish Monitoring
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.	Annual program and supplemental investigations, NYSDEC review and approvals Meetings with OLTAC and work groups	Support conceptual and empirical (mass-balance) model; AMP data will be used to calibrate and verify new lake model (begun in 2005)	Not included in 2007 AMP report

Table 1-2. Elements of the 2007 AMP in relation to ACJ-required monitoring objectives (continued).

ACJ Statement of Required Program Objective:	**2007 Program Elements**	**Data Used To**	**Location in 2007 Report**
Define ambient water quality conditions in the Seneca River between Cross Lake and the Three Rivers junction.	(Annual program) Surveys at Seneca River Buoy 316 (target low flow conditions)	Assess current conditions, data set for model validation Assess compliance with ambient water quality standards	• Chapter 6 – Seneca River Conditions • Appendix 9 – 2007 Seneca River Conditions
Evaluate and quantify the assimilative capacity of the Seneca River and quantify effects of zebra mussels. Quantitative Environmental Analysis, LLC. *Final Phase 2 Report Three Rivers Water Quality Model.* Prepared for: Onondaga County Department of Water Environment Protection Syracuse, NY, Onondaga Lake Cleanup Corp., Syracuse, NY. Job Number: ONOsen: 227. August 2005.	River modeling work group and peer review (Annual program) Surveys during low flow conditions in the fall (depends on hydrologic conditions)	Assess current conditions, data set for model verification	• Chapter 6 – Seneca River Conditions • Appendix 6 – Dreissenid Mussel Survey • Appendix 9 – 2007 Seneca River Conditions *TRWQM applications to estimate assimilative capacity will be reported separately*
	Periodic zebra mussel assessment (surveys completed in spring and summer 2007)	Assess current conditions, compile data for model verification	• Appendix 6 – Dreissenid Mussel Survey • Appendix 9 – 2007 Seneca River Conditions

1.2.2 Data Analysis and Interpretation Plan

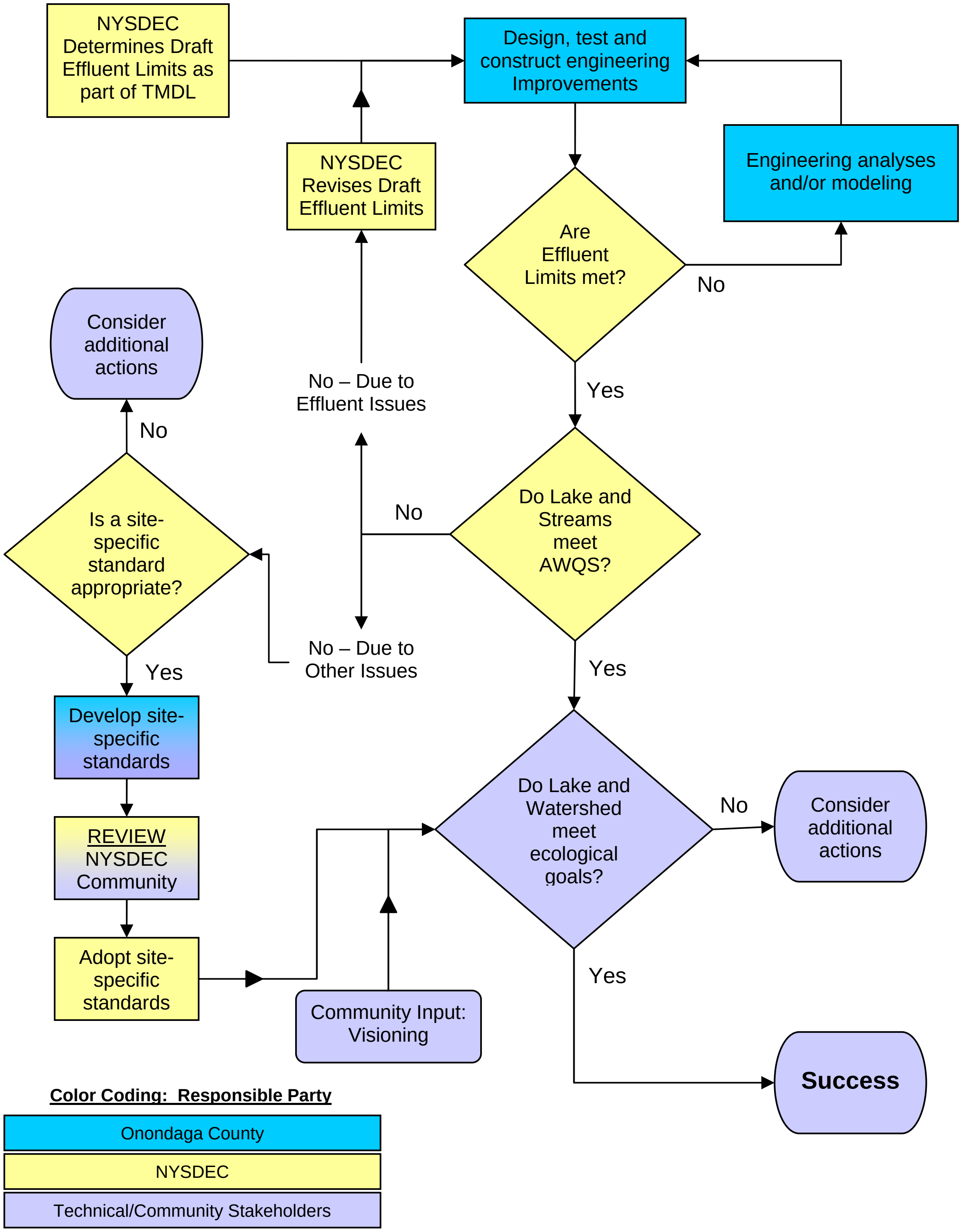
The AMP generates thousands of observations each year. It is challenging to organize and communicate these data in a way that retains integrity of the scientific information and makes it useful for all stakeholders. In addition, program managers must assure that the ACJ requirements are met. A Data Analysis and Interpretation Plan (DAIP) was developed to guide program managers through the extensive AMP dataset. The document was prepared at the request of NYSDEC and is updated annually. The complete DAIP is included in this Annual Report as **Appendix 5**. Key features of the DAIP are summarized in this chapter in order to provide a context for interpreting the data summaries and discussion presented in subsequent report chapters.

The AMP is the primary source of data to support engineering and regulatory evaluations of water quality conditions. AMP data are used to:

- Evaluate whether the engineering improvements of the wastewater collection and treatment system enable the County to meet effluent limits.
- Evaluate whether the controls on wastewater are sufficient to bring the lake, streams and river into compliance with applicable standards.
- Determine if additional measures are required to bring the surface waters into compliance with applicable regulations, standards, guidance values, and criteria.
- Provide information on whether the lake and its watershed meet community goals for a rehabilitated ecosystem.

Figure 1-1 presents a flow chart of decision-makers and responsibilities.

Figure 1-1. Flow chart of decisions and responsibilities.



The AMP will provide the data and information needed to support model development and TMDL allocation. Ultimately, these tools will support decisions regarding the level of treatment and location of the discharge of the Metro treatment plant. Milestone dates for these decisions are memorialized in the ACJ.

1.2.3 Overall Approach: Monitoring and Modeling

Onondaga County and the other stakeholders rely on an integrated program of monitoring and modeling to determine whether the planned improvements to the wastewater collection and treatment infrastructure are effective in meeting regulatory discharge limits. These discharge limits, in turn, are set by state regulators in the context of the assimilative capacity of the receiving waters. That is, what are the limits on discharge that will attain the designated use of Onondaga Lake, the lake tributaries, and the Seneca River?

Monitoring is used to measure conditions over the 15-year period of phased improvements. Monitoring data can describe current conditions, but mathematical water quality models are necessary to project future conditions under a range of management scenarios and environmental conditions. The NYSDEC will require mathematical models to complete their required Total Maximum Daily Load (TMDL) allocation.

Modeling is used to describe the interrelationships between physical, chemical, and biological characteristics of the lake and watershed. Models are valuable tools for interpreting data and elucidating underlying mechanisms. Once verified, models can be used to project future conditions.

Several types of water quality models of Onondaga Lake, the lake watershed, and the Three Rivers system have been completed or initiated. Ultimately, models of the watershed, lake, and Seneca River will be linked.

The USGS developed a model of the Onondaga Lake watershed that simulates the export of water and materials (including nutrients and sediment) from the landscape to the tributary subwatersheds, and ultimately to the lake. The USGS model used the loads measured by the AMP to initiate calibration of the export coefficients (unit loss of materials) for representative land use and vegetative cover conditions. This model was subject to an internal peer review by USGS staff. Input from the USGS model will be used in the Onondaga Lake model, which will be linked to the Three Rivers Water Quality Model (TRWQM).

The TRWQM went through a rigorous peer review by a panel of experts from various academic institutions and government agencies; the review was completed in April 2003. The Onondaga Lake Water Quality Model (OLWQM), which began in mid-2005, is also peer-reviewed by another team of experts at critical stages during development and testing.

The interrelationship between the management questions, monitoring and modeling, and the spatial and temporal designation of compliance is summarized in **Table 1-3.**

Table 1-3. Summary of management questions and decision analysis.

Management Question	**Decision Analysis Components and Regulatory References**	**Spatial and Temporal Scale of Assessment**	**Tools for Assessment**
Can ambient water quality standards be achieved with continued Metro discharge to Onondaga Lake? **Decision date: February 1, 2009**	Dissolved Oxygen: 6 NYCRR Sec. 703.3 Ammonia: 6 NYCRR Sec. 703.5 Turbidity: 6 NYCRR Sec. 703.2 Floatables: 6 NYCRR Sec. 703.2 Phosphorus: 6 NYCRR Sec. 703.2 TOGS 1.1.1 Water Quality Standards & Guidelines Nitrogen: 6 NYCRR Sec. 703.2 Bacteria: 6 NYCRR Sec. 703.4	Dissolved Oxygen: Upper waters, fall mixing, South Deep Ammonia and nitrite: Upper waters; South Deep, year-round Bacteria: Class B portions of lake	Monitoring: AMP data Modeling CSOs: use SWMM to confirm: system-wide annual average capture of at least 85% of combined sewage volume. Modeling Lake: Onondaga Lake model (development began in 2005)
Must Metro effluent meet the Stage III phosphorus and ammonia limits for discharge to Onondaga Lake or the Seneca River in order for the receiving water to achieve compliance with ambient water quality standards? **Decision date: February 1, 2009**	Phosphorus: 6 NYCRR Sec. 703.2 (*possibly modified by site-specific guidance value)* Trophic state indicators: frequency, intensity and duration of algal blooms Ammonia: TOGS 1.1.1 Water Quality Standards & Guidelines (*latest revision to NYS standards*) NYSDEC revised TMDL for phosphorus and ammonia: **January 1, 2009**	Phosphorus and other trophic state parameters: Summer average, upper waters, South Deep (per NYSDEC guidance). Dissolved Oxygen: Upper waters, fall mixing, South Deep Ammonia: Upper waters, South Deep, year-round	*For lake discharge:* • AMP data: Ammonia: effects of Stage III limits, met in 2004 TP: effects of Stage II limits, met in 2006 • Use lake model to project compliance under critical conditions *For Seneca River discharge*: TRWQM
Are additional measures needed to ensure compliance with dissolved oxygen standards during fall mixing? **Decision date: December 1, 2012**	Feasibility analysis of hypolimnetic oxygenation (ENSR 2004). *Status: on hold*	Focus of compliance for dissolved oxygen: fall mixing, upper waters	• AMP data: profiles and buoy • Mass-balance model • Onondaga Lake model

1.2.4 Hypotheses

The elements of the monitoring program were distilled into a series of testable hypotheses. This work product was used as a basis for evaluating the AMP design, allowing the project team, OLTAC, and the reviewers from NYSDEC and EPA to determine whether the correct parameters were being measured.

There are three types of hypotheses to be tested using data generated by the AMP:

- Improvements at the Metro Treatment Plant and CSO remediation enable Onondaga County to achieve compliance with the effluent limits required by the State Pollution Discharge Elimination System (SPDES) permit.
- Reduction of nutrient loading from the Metro Treatment Plant and surrounding watershed result in ambient water quality standards being met in Onondaga Lake and the tributaries.
- Reduction of nutrient loading from the Metro Treatment Plant and surrounding watershed result in statistically significant trends in the monitoring data, showing improvement in water quality and biological metrics.

Details of the hypotheses for elements of the monitoring program, by measured parameter, are presented in the DAIP and "Progress towards Improvement" tables (**Appendix 5**).

1.2.5 Metrics

A series of metrics have been developed to organize and report the extensive AMP dataset. As defined by EPA, metrics are attributes of the physical, chemical and/or biological ecosystem that respond to human disturbance. For the Onondaga Lake watershed, metrics are designed to indicate progress towards compliance with applicable standards and guidelines, and progress towards attaining a desired use.

Selected metrics may relate directly to an impairment of the lake or watershed; relate to a resource of interest; or correspond to a published standard that, in turn, reflects the requirements of public health or the aquatic biota. Candidate metrics can be measured and interpreted with relative ease to answer basic questions such as "Is the lake getting better?" and "Is it safe for my family to swim here?"

Metrics selected to interpret and report on the AMP data are listed in **Table 1-4.** Note that the metrics are grouped into categories that address human uses and ecosystem function:

- water contact recreation;
- aesthetics;
- aquatic life protection; and
- sustainable recreational fishery

Metrics for water contact recreation are straightforward. New York State Department of Health and EPA have standards and guidance values for indicator bacteria and water clarity that are designed to be protective of human health and safety. Selecting metrics for aesthetics is slightly more judgmental, as they relate to perceived attributes such as water color and clarity, odors, and the visible extent of weed and algal growth. Water quality conditions needed to support aquatic life are fairly well defined in federal criteria and state standards. Onondaga County AMP metrics are designed to track water quality and habitat conditions during critical periods for reproduction and survival of young animals.

Table 1-4. Summary of metrics: measuring progress towards improvement in Onondaga Lake.

Desired Use	Metrics	Measured By
Water contact recreation	Indicator bacteria	Fecal coliform bacteria abundance measured at stations within the Class B segment of Onondaga Lake (includes nearshore and North Deep stations)
	Water clarity	Secchi disk transparency at nearshore stations
Aesthetics	Water clarity	Secchi disk transparency at South Deep
	Bloom frequency and magnitude	Percent of chlorophyll-*a* measurements greater than 15 µg/l (USEPA threshold for public perception as impaired for recreational use)
		Percent of chlorophyll-*a* measurements greater than 30 µg/l (threshold for public perception of nuisance bloom).
	Algal community structure	Percent of algal community represented by cyanobacteria (blue-green taxa)
	Macroalgae proliferation	Percent cover of littoral zone, measured at nine nearshore stations June 1 – September 30 annually
Aquatic life protection	Ammonia N	Percent of measurements in compliance with standards.
	Nitrite N	Percent of measurements in compliance with standards.
	Dissolved oxygen	DO at fall mixing. Duration of DO concentrations < 4 mg/l (data source: measurements at 15-minute intervals from probe on buoy)
Aquatic life protection (cont'd).	Integrated metrics	"Fish space" metrics, volume-days with suitable conditions of DO and temperature for cold water and cool water fish communities *(Note: this metric does not account for other requirements such as habitat and forage base)*
	Species assemblage	Percent intolerant or moderately intolerant of pollution

Table 1-4. Summary of metrics: measuring progress towards improvement in Onondaga Lake (continued).

Desired Use	Metrics	Measured By
Sustainable recreational fishery	Number of species with documented reproduction and recruitment[1]	Nesting surveys, larval sampling (Miller tows), young-of-year sampling (littoral and pelagic) adult survey (electrofishing, gill netting), hydroacoustical survey.
	Habitat quality	Percent cover of macrophytes: scaled to optimal level for largemouth bass (40 – 60% cover is target).

[1]Sampling captures young-of-the-year (YOY) fish in the lake. It is assumed that the majority of these small fish originated in the lake, given their size and limited mobility of the early life stages. However, the presence of YOY fish that originated in the Seneca River or tributaries to Onondaga Lake cannot be ruled out.

1.3 ONONDAGA LAKE AND WATERSHED

1.3.1 Physical Features

Onondaga Lake is located immediately northwest of the City of Syracuse in Onondaga County, New York, USA (43°06'54" N, 76°14'34" W). The outlet of Onondaga Lake flows into the Seneca River, which joins with the Oneida River to become the Oswego River, which flows north on its route to Lake Ontario.

The Onondaga Lake drainage basin encompasses approximately 725 km^2 (285 square miles) and, with the exception of 2 km^2 in Cortland County, lies almost entirely in Onondaga County. The drainage basin includes six natural subbasins: Ninemile Creek (including Otisco Lake), Harbor Brook, Onondaga Creek, Ley Creek, Bloody Brook, and Sawmill Creek (**Figure 1-2**).

A bathymetric map (**Figure 1-3**) shows two minor depressions in a fairly uniform profile. The littoral zone is quite narrow. The Onondaga Lake shoreline is highly regular, with few bays. Onondaga Lake is relatively small[2]:

Length	4.6 miles	(7.6 kilometers)
Width	1 mile	(1.6 kilometers)
Surface Area	4.6 square miles	(11.9 square kilometers)
Volume	35 billion gallons	(132 million cubic meters)
Average Depth	35 feet	(10.9 meters)
Maximum Depth	63 feet	(19.2 meters)

The climate of the Onondaga Lake basin is continental humid, 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 temperature extremes but contributes high amounts of cloudiness and snowfall. The summer months are drier on average, but high year-to-year variation is typical (**Table 1-5**).

[2] Obtained from the Onondaga Lake Partnership web site: http://www.onlakepartners.org/p11.html

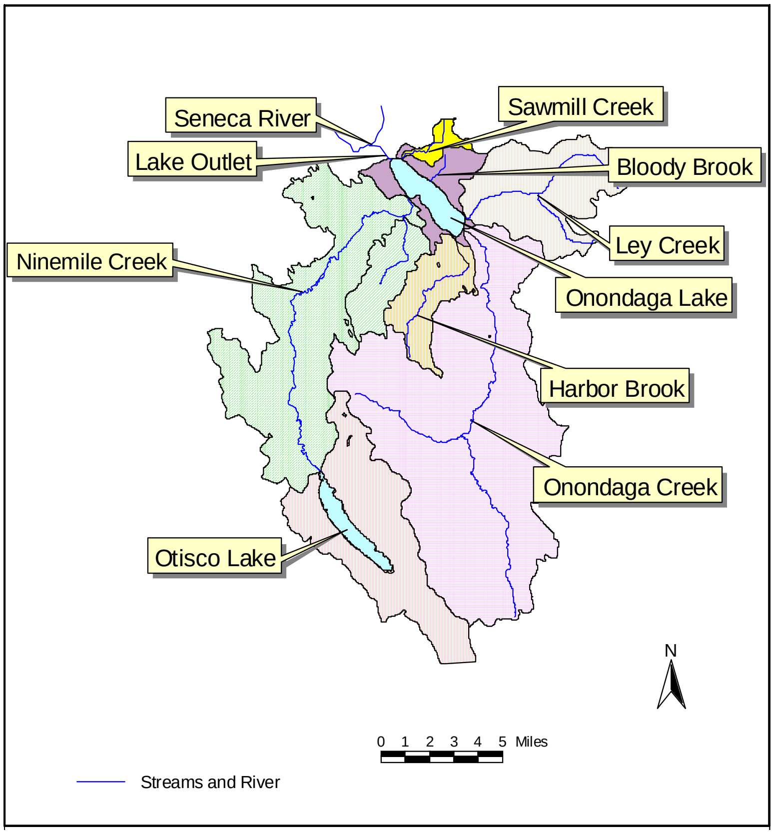


Figure 1-2. Onondaga Lake watershed and six natural sub-basins. (Note: No GIS layer is available for Bloody Brook. Area shown in solid purple includes Bloody Brook watershed and areas of direct drainage to Onondaga Lake.)

Table 1-5. Climate statistics for Onondaga Lake basin.

	Normals for Syracuse, NY	2007
Maximum monthly average temperature	70.9 ºF (July)	70.8 ºF (August)
Minimum monthly average temperature	22.7 ºF (January)	18.5 ºF (February)
Annual average temperature	47.4 ºF	48.1 ºF
Annual precipitation	40.05 inches	41.60 in (+1.55 in)
Snowfall	121.1 inches	140.2 in (+19.1 in)

Sources:
Normals for Syracuse NY (1971-2000): National Weather Service Binghamton Weather Forecast Office obtained 06/03/2008 (on-line linkage: http://www.erh.noaa.gov/bgm/climate/syr/syr_normals.shtml)
2007: NOWData - NOAA Online Weather Data obtained 04/01/2008 (on-line linkage: http://www.nws.noaa.gov/climate/xmacis.php?wfo=bgm).

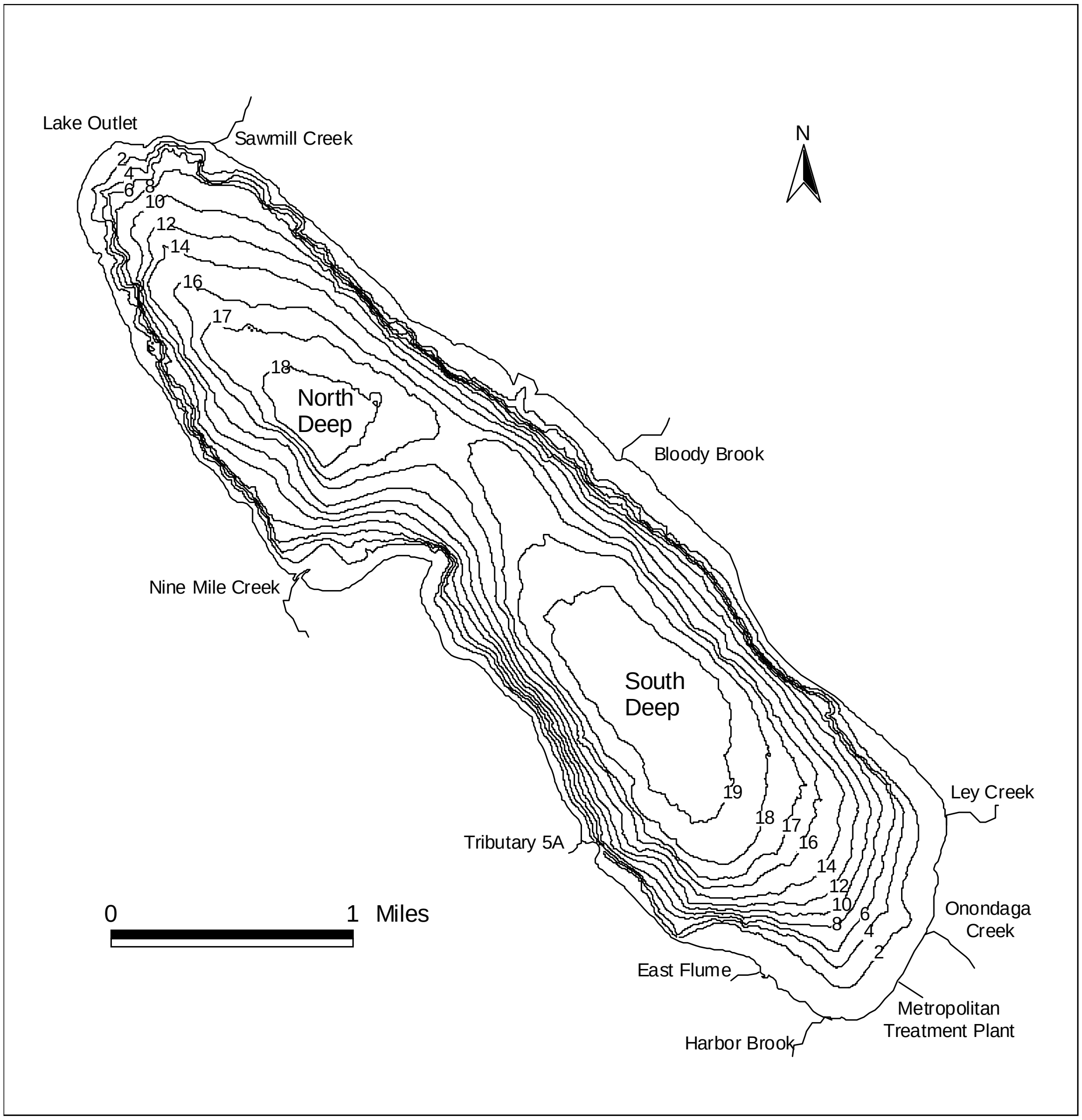


Figure 1-3. Bathymetric map of Onondaga Lake. (Note: Contour lines are in meters.)

1.3.2 Thermal Stratification

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 the 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 2007, Onondaga Lake waters stratified 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). Density differences during thermal stratification were strong enough to impede most wind-induced mixing between the epilimnion and hypolimnion.

By September 2007, Onondaga Lake ceased gaining heat and the waters began to cool. The cooling process was manifested in a steady deepening of the epilimnion and gradual decrease in its temperature. Less and less wind energy was required to entrain the metalimnetic waters. Heat loss continued through the fall. Eventually, the temperature of the upper water cooled to the temperature of the lower water layer, and there was no density impediment to wind mixing of the water column. In 2007 fall mixing occurred in late October (October 27th). Fall mixing typically occurs between October 15 and 31 each year, although occasionally specific meteorological conditions result in fall mixing occurring outside of this period.

1.3.3 Ice Cover

Development of thermal stratification in winter is variable, depending on the extent and persistence of ice cover. OCDWEP staff maintains an ice diary noting dates of ice cover and sketching the surface area of the lake covered. Observations are summarized in **Table 1-6.** There were 35 days of lakewide ice cover during the winter of 2007-2008.

Table 1-6. Onondaga Lake ice cover, 1987-2007.

Winter	Date Ice First Reported	Date Ice Last Reported	Approximate Days of Ice Cover, North Basin	Approximate Days of Ice Cover, Lakewide *(diary notes >90%)*
87-88	12/31/87	3/28/88	70 days	20 days
88-89	12/14/88	3/22/89	75 days	9 days
89-90	12/6/89	3/14/90	90 days	30 days
90-91	12/27/1990	3/4/91	54 days	6 days
91-92	12/19/1991	3/25/92	59 days	19 days
92-93	12/14/1992	4/9/93	76 days	13 days
93-94	12/23/1993	4/4/94	78 days	18 days
94-95	12/12/1994	3/16/95	53 days	5 days
95-96	12/13/1995	3/6/96	32 days	11 days
96-97	01/09/1997	2/27/97	47 days	19 days
97-98	12/31/1997	2/11/98	15 days	0 days
98-99	12/23/1998	3/29/99	62 days	12 days
99-00	01/17/2000	NA	42 days	28 days
00-01	12/26/2000	4/6/01	66+ days	54 days
01-02	01/08/2002	2/20/02	2 days	2 days
02-03	01/04/2003	3/26/03	42 days	40 days
03-04	01/09/2004	3/26/04	61 days	73 days

Table 1-6. Onondaga Lake ice cover, 1987-2007 (continued).

Winter	Date Ice First Reported	Date Ice Last Reported	Approximate Days of Ice Cover, North Basin	Approximate Days of Ice Cover, Lakewide *(diary notes >90%)*
04-05	01/20/2005	4/1/05	73 days	72 days
05-06	12/14/2005	3/13/06	23 days	14 days
06-07	01/22/2007	3/30/07	69 days	64 days
07-08	12/19/07	3/25/08	37 days	35 days

1.3.4 Water Residence Time

Onondaga Lake has a short water residence time. Using inflow data for the period 1988-2007, the lake's residence time is estimated at 0.27 years[3]. This simple calculation assumes that the water column of the lake is consistently well mixed. However, Onondaga Lake is dimictic, with two periods of complete mixing separated by periods of thermal stratification. During summer stratification periods, upper waters are replaced by tributary and effluent inflows (warmer and less dense), while the cooler, denser lower waters are not. The replacement rate of the upper waters during summer stratification is rapid. Based on a detailed analysis of the volume of the upper waters and tributary inflows over the three year period from 1987–1989, Effler and Whitehead (1996) concluded that the water in the lake's upper layer is replaced about three times between May and September of an average hydrologic year.

1.3.5 Tributary Inflows

Five natural tributaries, three effluent discharges, and the lake outlet were monitored in 2007. Data summarizing the nature of the tributaries and point source inflows to the Lake are summarized in **Table 1-7**. Discharges from the major tributaries and Metro are gauged; approximately 95% of the hydrologic input to the lake is measured and sampled throughout the year.

[3] Calculated using Onondaga Database spreadsheet Mass_Balance.xls, current as of April 2008.

Table 1-7. Summary of monitoring locations: tributaries and inflows, 2007.

Tributary/ Inflow Gauged and Monitored	Drainage Area (km^2)	Gauge Site(s)	Percent of Lake Water Budget
Ninemile Creek	298	Lakeland (Rt. 48)	33%
Onondaga Creek	285	• Rt. 20, Lafayette • Dorwin • Spencer	35%
Metro: *Outfalls 001 and 002*	Syracuse service area	Post treatment, at outfall to Lake	17%
Ley Creek	66.1	Park St.	7.4%
Harbor Brook	31.4	• Velasko Rd. • Hiawatha Blvd.	2.7%
East Flume *(includes Honeywell International complex)*	<3	At weir	0.13%
Tributary 5A (*includes Crucible Specialty Metals*)	<8	Downstream of facility outfall	0.11%
Direct precipitation and ungauged drainage area *(including Bloody Brook and Sawmill Creek)*	Lake surface area: 11.7 Direct drainage < 30	None	Approx. 5.3%
Total	**727 km^2**	**--**	**100%**

1.3.6 Land Cover

The Onondaga Lake watershed is highly urbanized compared with other lakes in the Seneca-Oneida-Oswego river basin. Approximately 28% of the watershed land cover is classified as developed, 51% as forest and scrub/shrub, and 9.5% as cultivated or grassland. A watershed land cover map is included as **Figure 1-4.**

The majority of the lake 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, shoreline fishing, and cultural entertainment. The lake is used for secondary water contact recreation activities such as boating.

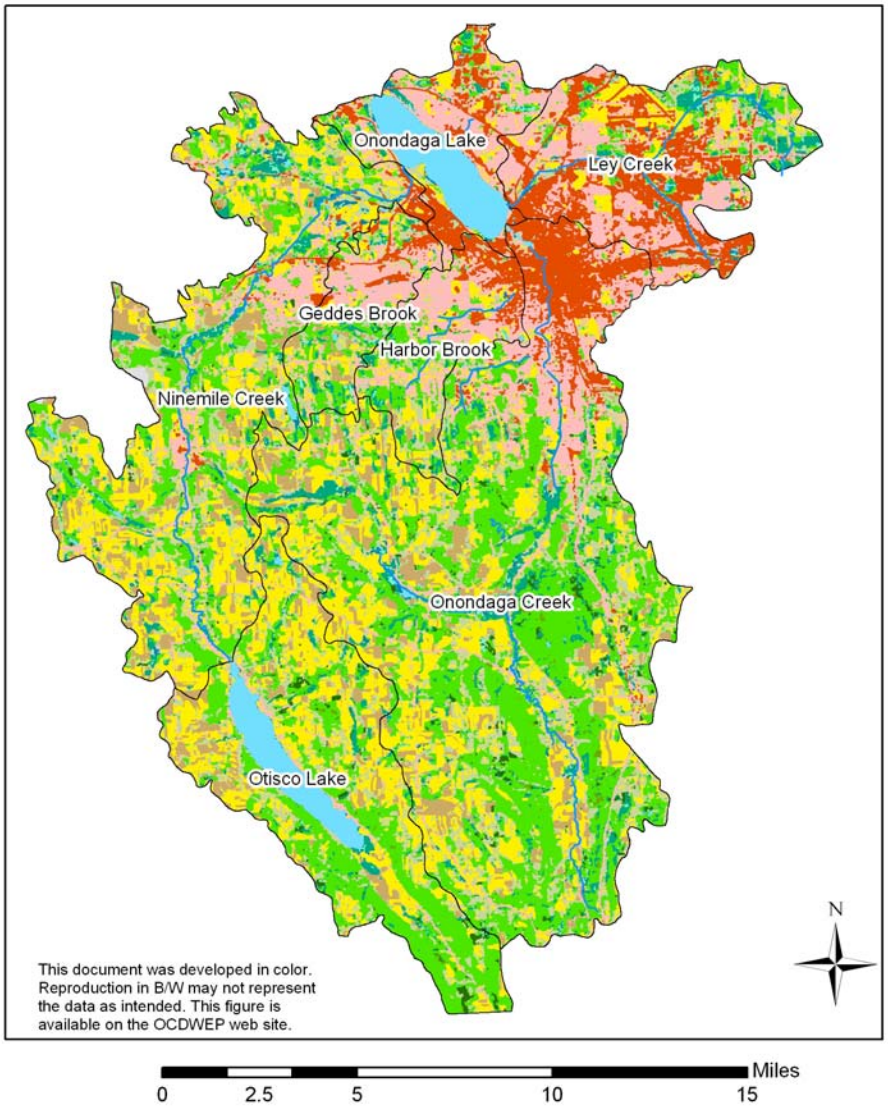


Figure 1-4

Onondaga Lake Watershed NOAA C-CAP Great Lakes 2001 Land Cover

Legend

- Minor Basins

Land Cover Classes

- Forest, Deciduous
- Forest, Evergreen
- Forest, Mixed
- Scrub/Shrub
- Developed, Low Intensity
- Developed, High Intensity
- Cultivated Land
- Grassland
- Wetland, Palustrine Emergent
- Wetland, Palustrine Scrub/Shrub
- Wetland, Palustrine Forested
- Lakes
- Bare Land

Land Cover by Major Basin Watershed (NOAA 2001)

	Acres	Percent
Forest (deciduous, evergreen, mixed)	45,482	32%
Scrub/Shrub	26,416	19%
Developed, low intensity	24,671	17%
Developed, high intensity	14,934	11%
Cultivated Land / Grassland	13,378	9.5%
Wetlands (palustrine)	11,070	8%
Lakes	5,369	3.8%
Bare Land	174	0.12%
Sum Total, with Lakes	141,495	100%

Data obtained from Don Jordan (Syracuse-Onondaga County Planning Agency). Land Cover data from NOAA Coastal Services Center/Coastal Change Analysis Program(C-CAP) published 9/11/2002.

1.3.7 Water Quality Classification and Designated Use

The 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).

Onondaga Lake is classified as B and C waters (**Figure 1-5**). The Class B segment encompasses the northern basin; the Class C segments include much of the southern basin and a small area around the mouth of Ninemile Creek. Both B and C waters must exhibit water quality conditions suitable for fish survival and propagation. Class B waters are to 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).

The main stems of the lake tributaries are classified mostly as C (suitable for fish propagation and secondary water contact recreation) but several small segments are Class B. The Seneca River segment in the vicinity of the Onondaga Lake outflow and downstream is Class B. As summarized in **Table 1-8**, several Class C stream segments within the subwatersheds are required to comply with Class C(T) water quality standards, meaning that dissolved oxygen and ammonia levels shall be suitable for salmonids. NYSDEC stocks several streams within the watershed with various species as summarized in **Table 1-9**.

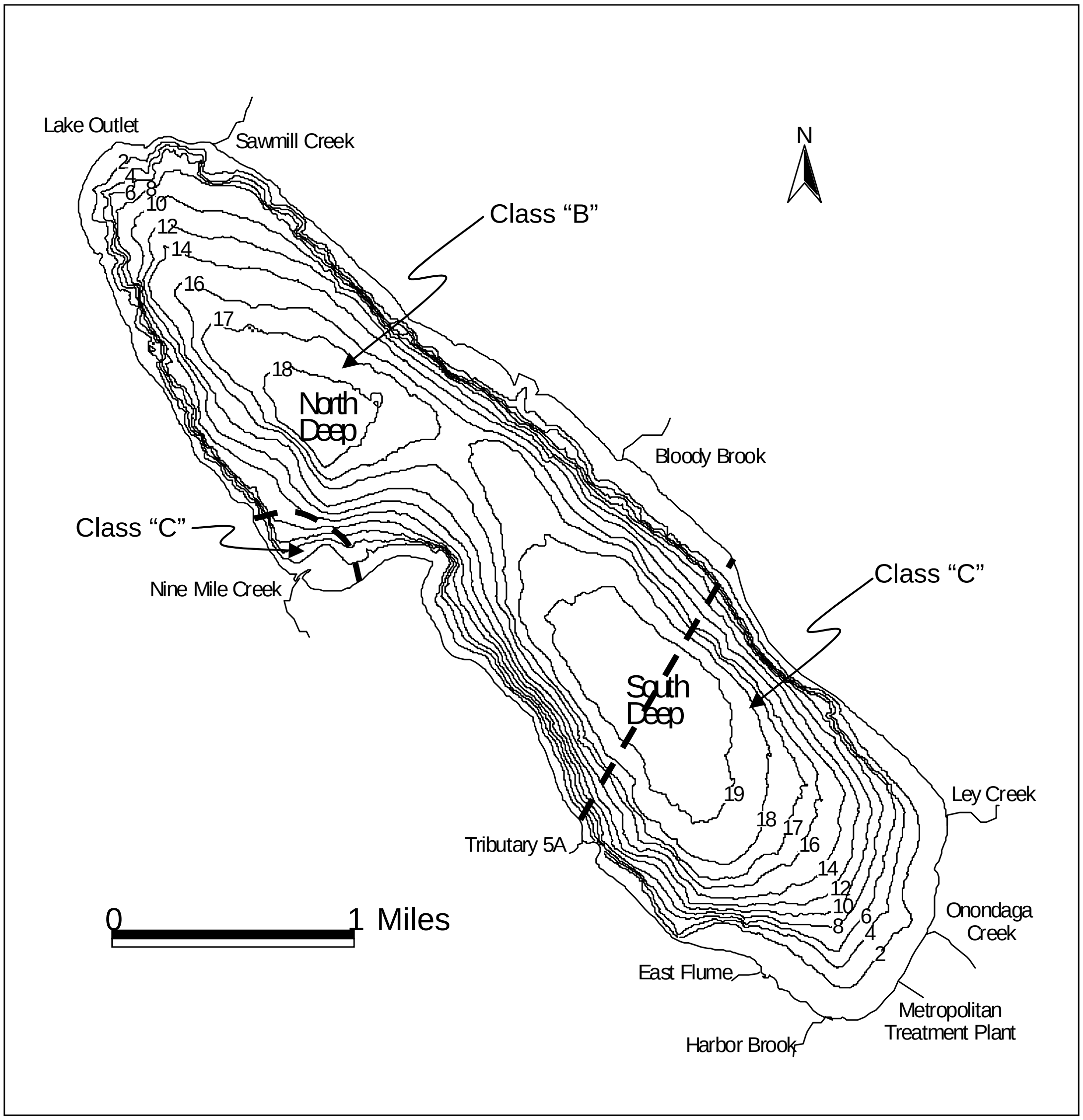


Figure 1-5. Regulatory classifications and bathymetry of Onondaga Lake. (Note: Contour lines are in meters.)

Table 1-8. Summary of regulatory classification of streams within Onondaga Lake watershed.

Stream	Description of Stream Segment	Regulatory Classification	Standards
Onondaga Creek	Enters Onondaga Lake at southeastern end. Mouth to upper end of Barge Canal terminal (0.85 miles)	C	C
	Upper end of Barge Canal terminal to Temple Street (1.7 miles)	C	C
	From Temple Street, Syracuse to Tributary 5B (4.4 miles)	B	B
	From Tributary 5B to Commissary Creek (1.9 miles)	C	C
	From Commissary Creek to source	C	C(T)
Ninemile Creek	Enters Onondaga Lake from south. From mouth to Allied Chemical Corp. water intake located on creek to point mid-way between Airport Rd and Rt. 173 bridge at Amboy (3.4 miles)	C	C
	From point mid-way between Airport Rd and Rt. 173 to outlet of Otisco Lake	C	C(T)
Harbor Brook	Enters Onondaga Lake at the southern most point of the lake and within the City of Syracuse. From mouth to upper end of underground section, at Gifford Street (approx. 1.9 miles)	C	C
	From upper end of underground section to City of Syracuse line (1.3 miles)	B	B
	From City of Syracuse City line to source	C	C(T)
Ley Creek	Enters Onondaga Lake 0.2 mile southeast of point where City of Syracuse line intersects east shore of lake. From mouth to Ley Creek sewage treatment plant outfall sewer	C	C
	From Ley Creek sewage treatment plant outfall sewer to South Branch. Tribs. 3-1A and 3-lB enter from north approximately 3.0 and 3.1 miles above mouth respectively	B	B
Bloody Brook	Enters Onondaga Lake 2.25 miles southeast of outlet. From mouth to trib. 1 of Bloody Brook (approximately 0.37 miles from mouth)	B	B
	From trib. 1 of Bloody Brook to source	C	C

Source: NYSDEC (classifications as of July 2004); on-line linkage http://www.dec.ny.gov/regs/4539.html#17588

Table 1-9. NYSDEC fish stocking in waters connected to Onondaga Lake, 2007.

Stream Segment	Species Stocked	Number Stocked
Ninemile Creek	Brook Trout Brown Trout	2,280 17,178
Geddes Brook	Brown Trout Rainbow Trout	675 304
Furnace Brook	Brook Trout	400
Harbor Brook	Brown Trout	200
Onondaga Creek	Brown Trout	2,340
West Branch Onondaga Creek	Brown Trout	280
Otisco Lake	Brown Trout Tiger muskellunge	2,500 7,500

Source: NYSDEC - Fish Stocking Lists 2007 Lists by County
http://www.dec.ny.gov/outdoor/30467.html

1.3.8 Priority Waterbodies Listing within the Watershed

New York State has an extensive program of monitoring and reporting to assess the extent to which designated uses for lakes and streams 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 periodically. Agencies and stakeholder groups including Environmental Management Councils, Soil and Water Conservation Districts, NYSDEC, watershed groups, and Water Quality Coordinating Committees provide input into the PWL. 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. This list is developed by NYSDEC and subject to a public comment period. A final list is forwarded to EPA for approval.

1.3.8.1 Priority Waterbodies List (PWL) Segments

Various stream and lake segments in the Onondaga Lake watershed are included on the PWL for the Seneca-Oneida-Oswego basin, which was updated in 2007. The Rotating Intensive Basin Surveys (RIBS) are the primary source of data for determining the status of water quality and habitat conditions, and use attainment. The DEC is sampling in the Seneca-Oneida-Oswego basin from 2006 -2008.

1.3.8.2 2008 303(d) list

The 2008 303(d) list includes the Seneca River, Onondaga Lake Outlet, Onondaga Lake (north and south ends), and several tributaries (**Table 1-10).**

Table 1-10. Draft 2008 Section 303(d) list for New York State (January 15, 2008).

Water body	Type	Class	Cause/Pollutant	Source
Individual water body segments with impairment requiring TMDL/other strategy:				
Seneca River (0701-0001)	River	C	D.O./Oxygen Demand	Agricultural
Multiple segment/categorical impaired waterbody segments (fish consumption):				
Onondaga Lake, northern end (0702-0003)	Lake	B	Dioxin Mercury PCBs	Contaminated sediment
Onondaga Lake, southern end (0702-0021)	Lake	C	Dioxin Mercury PCBs	Contaminated sediment
Waterbodies for which TMDL development may be deferred (requiring verification of impairment):				
Seneca River (0701-0008)	River	C	Pathogens	On-site WTS
Waterbodies for which TMDL development may be deferred (pending implementation/evaluation of other restoration measures):				
Onondaga Lake Outlet* (0702-0020)	River	B	D.O./Oxygen Demand	CSOs Municipal Urban
Onondaga Lake, northern end* (0702-0003)	Lake	B	Pathogens	CSOs Municipal Urban
Onondaga Lake, southern end* (0702-0021)	Lake	C	Pathogens	CSOs Municipal Urban
Minor tribs to Onondaga Lake* (0702-0022)	River	C	Pathogens Nutrients (phos, NH_3) Cyanide	CSOs Municipal Urban
Bloody Brook and tribs* (0702-0006)	River	C*	Pathogens	CSOs Municipal Urban
Ley Creek and tribs* (0702-0001)	River	C*	Pathogens Nutrients (phos, NH_3) Cyanide	CSOs Municipal Urban
Onondaga Creek, lower* (0702-0023)	River	C	Pathogens Nutrients (phos, NH_3) Unknown toxicity	CSOs Municipal Urban
Onondaga Creek, middle and tribs* (0702-0004)	River	B	Pathogens Nutrients (phos, NH_3) Unknown toxicity	CSOs Municipal Urban
Harbor Brook, lower and tribs* (0702-0002)	River	B	Pathogens Nutrients (phos, NH_3)	CSOs Municipal Urban
Ninemile Creek, lower and tribs* (0702-0005)	River	C	Pathogens Nutrients (phosphorus)	CSOs Municipal Urban
Geddes Brook and tribs* (0702-0007)	River	C	Pathogens Ammonia (NH_3)	CSOs Municipal Urban

Table 1-10. Draft 2008 Section 303(d) list for New York State (January 15, 2008) (continued).

Water body	Type	Class	Cause/Pollutant	Source
Other impaired waterbody segments not listed because a TMDL has already been established for the segment/pollutant.				
Onondaga Lake, northern end (0702-0003)	Lake	B	Phosphorus**	Municipal
Onondaga Lake, southern end (0702-0021)	Lake	C	Phosphorus**	Municipal

*Impairments to these waters are being addressed through the Onondaga Lake Amended Consent Judgment and the efforts of the Onondaga Lake Partnership.

**Onondaga Lake previously appeared on the list of "Other impaired waterbody segments not listed because development of a TMDL is not necessary" due to impairments from, and development of a TMDL for, ammonia. Subsequently the lake has been found to be meeting water quality standards for ammonia, so Onondaga Lake is considered to have been restored for ammonia. Phosphorus remains on the list.

1.4 REFERENCES

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CHAPTER 2: COUNTY EFFORTS 2007 – METRO AND CSOS

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CHAPTER 2. COUNTY EFFORTS 2007 – METRO AND CSOs

2.1 SUMMARY DESCRIPTION OF THE WASTEWATER TREATMENT FACILITY

The Syracuse Metropolitan Wastewater Treatment Plant (Metro) is an advanced facility providing wastewater treatment for 270,000 residents and many industrial and commercial customers in the city of Syracuse and other areas of Onondaga County. A tertiary treatment facility, Metro is designed and operated to remove solids, organic material, ammonia nitrogen, and phosphorus. Seasonal disinfection is required between April 1 and October 15; ultraviolet radiation is used to kill microorganisms.

The plant is designed to treat an average influent of 84.2 million gallons a day (mgd) of wastewater. Metro provides full secondary and tertiary treatment to flows up to 126 mgd; treated wastewater is discharged to the surface of Onondaga Lake through Metro Outfall 001. Flows greater than 126 mgd receive primary treatment and disinfection and are discharged to the lake through Bypass Outfall 002. On rare occasions of high rainfall and/or snowmelt, flows in the service area exceed Metro's hydraulic capacity of 240 mgd and bypass the plant with a direct discharge to Onondaga Lake.[1]

2.2 METRO PERFORMANCE 2007

2.2.1 Treatment Volume

Metro provided full treatment to an average flow of 63.4 mgd in 2007, which was discharged to the lake through Outfall 001. On an annual basis, this discharge summed to more than 23.2 billion gallons. An additional 384 million gallons were discharged through Bypass Outfall 002; the dates and events are shown in **Table 2-1**.

Table 2-1. Secondary Bypass Volumes (Outfall 002), 2007

Start Date	Duration (hours)	Million Gallons	Start Date	Duration (hours)	Million Gallons
1/5/07	12.6	10.25	4/23/07	5.5	7.06
1/7/07	6.5	3.04	4/25/07	7.8	3.20
1/13/07	3.1	0.29	4/27/07	1.1	0.42
1/15/07	17.4	10.75	5/25/07	1.1	0.46
3/2/07	16.0	14.48	6/4/07	5.5	4.22
3/3/07	0.1	0.01	6/19/07	6.4	11.95
3/13/07	24.0	16.88	6/27/07	1.5	7.20
3/14/07	24.0	39.54	7/8/07	1.5	1.30
3/15/07	24.0	20.09	7/11/07	3.3	3.38
3/16/07	13.1	2.72	7/19/07	4.3	4.14

[1] Onondaga County Department of Water Environment Protection web site: http://ongov.net/WEP/we1901.html

Table 2-1. Secondary Bypass Volumes (Outfall 002), 2007 (continued).

Start Date	Duration (hours)	Million Gallons	Start Date	Duration (hours)	Million Gallons
3/17/07	3.8	0.09	7/23/07	1.6	0.38
3/18/07	0.1	0.03	8/23/07	1.7	2.05
3/22/07	9.3	3.15	9/9/07	3.8	1.25
3/24/07	6.8	2.79	9/26/07	1.7	1.79
3/26/07	21.3	16.95	9/27/07	3.3	3.17
3/27/07	13.8	1.66	10/7/07	1.6	0.59
3/28/07	0.1	0.05	10/9/07	1.2	1.12
3/30/07	0.1	0.04	10/19/07	1.2	0.80
4/1/07	4.2	1.02	10/23/07	14.9	20.46
4/4/07	1.9	0.75	11/15/07	9.2	7.23
4/12/07	1.0	0.07	11/20/07	5.1	3.66
4/15/07	15.1	1.53	11/26/07	13.3	17.43
4/16/07	23.4	10.42	12/3/07	16.5	20.74
4/17/07	23.6	12.60	12/11/07	15.5	12.39
4/18/07	23.5	5.73	12/23/07	23.5	55.84
4/19/07	14.7	9.18	12/24/07	14.9	7.77
4/20/07	0.7	0.29	**TOTAL**	**471.2**	**384.4**

There were six occasions in 2007 when heavy rain or a combination of rain and snowmelt required inflowing wastewater to completely bypass the treatment plant. An estimated 24.4 million gallons were consequently discharged to Onondaga Lake without treatment, as summarized in **Table 2-2**.

Table 2-2. Headworks Bypasses (Outfall 001), 2007.

Start Date	Duration (hours)	Million Gallons
1/5/07	1.6	0.2
3/14/07	24.0	17.7
3/15/07	6.4	1.9
3/26/07	4.1	4.2
9/26/07	0.1	0.2
12/23/07	9.0	0.2
Total	***45.2***	***24.4***

2.2.2 SPDES Compliance

Discharges from the Metro treatment plant are regulated under the State Pollution Discharge Elimination System (SPDES). Compliance with the facility's permit limits in effect for 2007 is summarized in **Table 2-3**. Nine permit violations occurred during the year.

- One exceedance for fecal coliform bacteria (7-day average) occurred from July 22, 2007 through July 28, 2007; the weekly geometric mean of 530 cfu/100 ml exceeded the SPDES permit limit of 400 cfu/100 ml.
- One exceedance for ammonia (30-day average concentration) occurred during March 2007; the 30-day arithmetic mean limit of 3.4 mg/l exceeded the SPDES permit limit of 2.4 mg/l. This exceedance occurred as a result of operational problems for the BAF system.
- Five exceedances for total residual chlorine from Bypass Outfall 002 were reported in 2007.
- Two exceedances for settleable solids from Bypass Outfall 002 were reported in 2007.

Table 2-3. Metro SPDES limit exceedances 2007*.

Parameter	**SPDES Limit**	**Number of Exceedances**
Flow (12-month rolling average)	80 MGD	0
$CBOD_5$ (30-day average concentration)	21.0 mg/l	0
$CBOD_5$ (30-day average load)	14,011 lbs/day	0
$CBOD_5$ (7-day average concentration)	31.5 mg/l	0
$CBOD_5$ (7-day average load)	21,017 lbs/day	0
$CBOD_5$ Percent Removal	85%	0
Suspended Solids (30-day average concentration)	30 mg/l	0
Suspended Solids (30-day average load)	20,016 lbs/day	0
Suspended Solids (7 -day average concentration)	45 mg/l	0
Suspended Solids (7-day average load)	30,024 lbs/day	0
Suspended Solids Percent Removal	85%	0
Fecal coliform bacteria (30-day average)	200 cfu/100 ml	0
Fecal coliform bacteria (7-day average)	400 cfu/100 ml	1
pH	6.0-9.0 SU	0
Settleable Solids	0.3 ml/l	0
Ammonia-N (as NH_3) (30-day average concentration)	1.2 mg/l; 2.4 mg/l	1
Total Phosphorus (12-month rolling average)	0.12 mg/l	0
Cyanide	40.0 lbs/day	0
Bypass (Outfall 002) total residual chlorine	0.1 mg/l	5
Bypass (Outfall 002) settleable solids	0.8 mg/l	2
Cadmium	4.0 lbs/day	0
	Action Levels	
Lead	5.0 lbs/day	0
Zinc	40.0 lbs/day	0
Total		**9**

Notes:
* Exceedances based on effluent limits. As in previous years, the exceedance column does not reflect data reported as greater than (“>”) values on the Discharge Monitoring Reports. The County does not consider values required to be reported with a greater than symbol (“>”) as exceedances.

2.2.3 Ammonia Limits

Onondaga County is progressing through a 15-year program of improvements to the wastewater collection and treatment system as required by the Amended Consent Judgment signed in January 1998. Improvements to the Metro plant were required to enhance the removal of ammonia from wastewater. Staged effluent limits were established for ammonia under the ACJ (**Table 2-4**). The 2007 analytical results from Metro effluent are shown in **Figure 2-1** with the Stage 3 effluent limit.

Table 2-4. Metro effluent concentrations for Ammonia-N, 2007, with SPDES limits.

SPDES Limit	Effective Date	2007 Results (average)
Stage I :		
8,700 ppd (7/1-9/30)	January 1998	
13,100 ppd (10/1-6/30)		0.29 mg/l (6/1/07-10/31/07)
Stage 2:		
2 mg/l (6/1-10/31)	May 2004	
4 mg/l (11/1-5/31)		1.44 mg/l (11/1/06 –5/31/07)
Stage 3:	Dec. 2012 (Met Feb. 2004)	
1.2 mg/l (6/1-10/31)		
2.4 mg/l (11/1-5/31)		

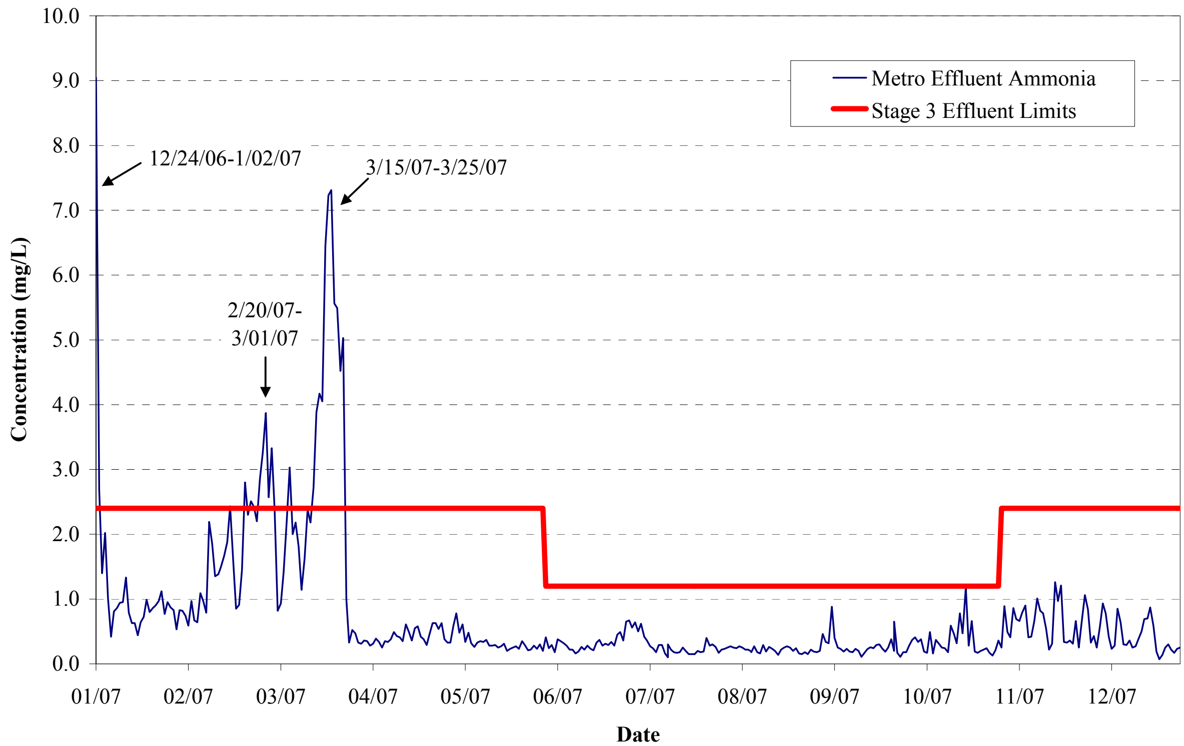

Figure 2-1. Metro effluent ammonia-N daily concentrations during 2007, with Stage 3 effluent limit.

2.2.4 Phosphorus Limits

In addition to ammonia, the County has been upgrading the Metro plant to remove phosphorus from the effluent discharged to the lake. The staged effluent limits and 2007 analytical results are shown in **Table 2-5** and **Figure 2-2**.

Table 2-5. Metro effluent concentrations for Total Phosphorus, 2007, with SPDES limits.

SPDES Limit	Effective Date	2007 Results (range)
Stage I : 400 pounds per day (12-month rolling average)	January 1998 – April 2006	0.113 mg/l – 0.125 mg/l (12-month rolling averages)
Stage 2: 0.12 mg/l (12-month rolling average)	April 2006 – December 2012	
Stage 3: 0.020 mg/l	December 2012	

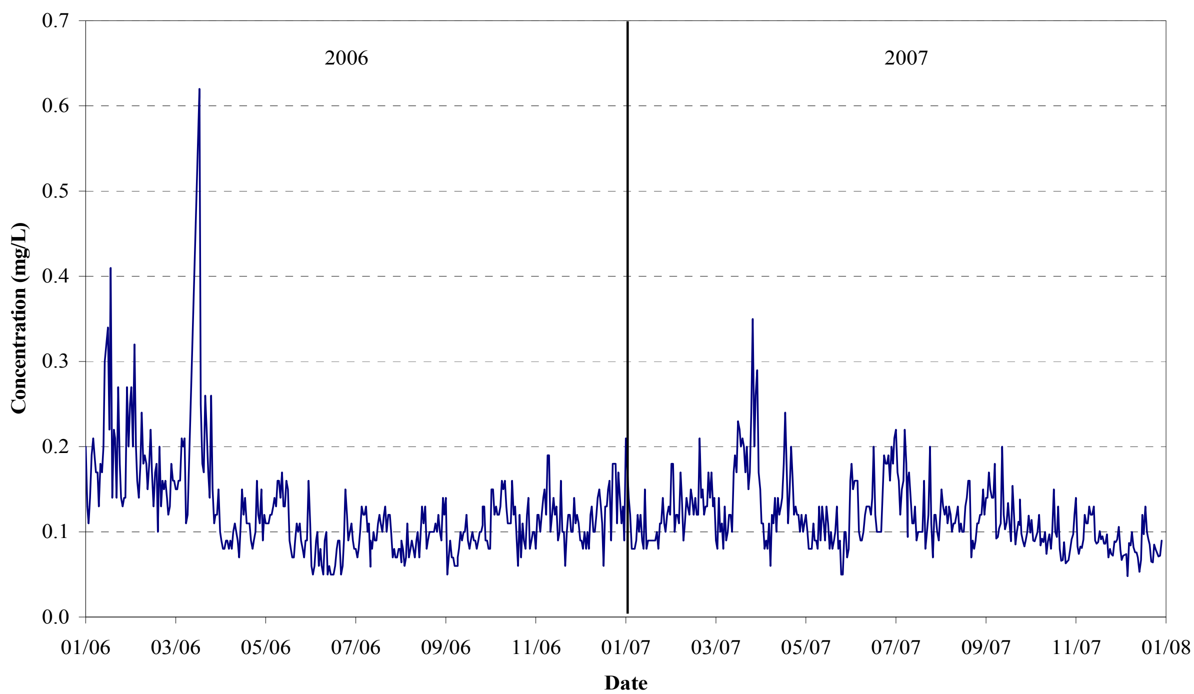

Figure 2-2. Metro effluent total phosphorus daily concentrations during 2006 and 2007.

2.3 COLLECTION SYSTEM: SANITARY SEWER AND COMBINED SEWER OVERFLOWS

2.3.1 Sanitary Sewer Overflows

OCDWEP tracks the occurrence of overflows from sanitary sewer collection system; overflows from both the combined and separate service areas are monitored and reported. A total of 15 events were recorded in 2007, as summarized in **Table 2-6**, with an estimated volume of 9.4 million gallons of sewage released to the Widewaters drainage area, Hamlin Marsh, Mud Creek, Onondaga Creek, Harbor Brook, Ninemile Creek, Ley Creek, Geddes Brook, Bloody Brook, Bear Trap Creek, Limestone Creek, Seneca River, or to the direct drainage in nearshore Onondaga Lake areas. Approximately 71% of the total volume of sanitary sewer overflows during 2007 occurred over March 14 and 15 at multiple locations. Another 20% of the total volume occurred on December 23 in multiple locations. Both events were associated with rapid snow melt and heavy rainfall.

Table 2-6. 2007 record of sanitary sewer overflows (SSO), Onondaga Basin.

Date	Estimated Volume (gallons)	Receiving Water
01/24/2007	15	Hamlin Marsh (Drainage swale to)
03/02/2007	31,800	Ley Creek
03/12/2007	1,350	Widewaters drainage area
03/14/2007	100,000	Ley Creek
	162,000	Hamlin Marsh (Storm sewer to)
	231,000	Mud Creek (Drainage swale to)
	275,625	Seneca River (Storm sewer to)
	444,000	Ley Creek (Storm sewer to)
	954,000	Limestone Creek
	1,008,000	Bloody Brook
	1,060,000	Ley Creek - Onondaga Lake
	1,650,000	Onondaga Lake
03/15/2007	87,000	Ley Creek (Storm sewer to)
	698,000	Limestone Creek
03/26/2007	15,000	Seneca River
	18,000	Bear Trap Creek (Storm drain to)
	18,000	Bloody Brook (Storm sewer to)
	18,300	Ley Creek (Storm sewer to)
	30,000	Seneca River (Storm sewer to)
	36,000	Geddes Brook (Storm sewer to)
	120,000	Onondaga Lake via Ley Creek
04/24/2007	1,400	Hamlin Marsh via Mud Creek
04/30/2007	5,000	Seneca River (Drainage swale to)
05/08/2007	50	Limestone Creek (Storm sewer to)
07/26/2007	500	Harbor Brook
08/17/2007	1,500	Onondaga Creek
08/19/2007	500	Hamlin Marsh (Drainage swale to)
08/21/2007	528,500	Harbor Brook

Table 2-6. 2007 record of sanitary sewer overflows (SSO), Onondaga Basin (continued).

Date	Estimated Volume (gallons)	Receiving Water
10/09/2007	2,025	Ley Creek (Storm drainage to)
12/23/2007	27,000	Mud Creek to Oneida River (Storm sewer to)
	78,000	Bloody Brook
	97,500	Seneca River (Drainage swale to)
	108,000	Ley Creek (Storm to)
	114,000	Ley Creek (Storm sewer to)
	126,000	Bloody Brook
	240,000	Geddes Brook (Storm sewer to)
	262,500	Onondaga Lake
	315,000	Seneca River (Storm drainage to)
	510,000	Onondaga Lake via Ley Creek

Total SSO releases in 2007 (gal)	**9,375,565**
Widewaters drainage area	1,350
Hamlin Marsh	163,915
Mud Creek	258,000
Bear Trap Creek (Ley Creek)	18,000
Geddes Brook	276,000
Bloody Brook	1,230,000
Limestone Creek	1,652,050
Ley Creek	1,965,125
Onondaga Creek	1,500
Harbor Brook	529,000
Seneca River	738,125
Onondaga Lake (direct drainage)	2,542,500

Source: Onondaga County Department of Water Environment Protection Sanitary Sewer Overflow Reports for 2007.

Ley Creek and Harbor Brook were each sampled once during 2007 at times that the sanitary sewers overflowed. These sample events occurred on March 14 (Ley Creek Park Street), and on August 21 (Harbor Brook at Velasko Road and Hiawatha Boulevard):

Tributary	SSO Date	SSO Volume	Water quality sampling date(s)
Ley Creek	3/14	1,604,000 gallons	2/27, 3/14 and 3/20
Harbor Brook	8/21	528,500 gallons	8/7, 8/21, 8/22, and 8/23

2.3.2 Combined Sewer Overflows

The quarterly submittals to NYSDEC detailing performance of the CSO control facilities were also reviewed for this Annual AMP report. Various remedial measures have been installed to capture CSOs or remove floatable solids prior to discharge. The Amended Consent Judgment specifies completion of a number of other projects to control CSOs discharging to Onondaga Creek and Harbor Brook. A program of sewer separation in some service areas continues. The CSO remedial projects presently underway are presented in **Table 2-7**; more details about County CSO projects are on the County web site (http://ongov.net/lake/)

Table 2-7. CSO remedial projects presently underway.

Tributary	Project	Facility Type	Status
Onondaga Creek	Midland CSO Abatement Facility	RTF	Under construction
	Clinton CSO Abatement Facility	RTF	Planning, design, and approvals are completed. Projected date of construction completion: 2012. Project is on-hold awaiting review of green and grey infrastructure alternatives.
	Onondaga Creek	FCF	Complete (skimmer boat, interim measure)
	Parkway-Rockland CSO Basin (050)	SS	Underway
Harbor Brook	Harbor Brook CSO Abatement Facility	RTF	Planning, design, and approvals are completed. Projected date of construction completion: 2012 Project is on-hold awaiting review of green and grey infrastructure alternatives.
	Harbor Brook	FCF	Complete (interim measures)

Facility Types:
FCF = Floatables Control Facility
RTF = Regional storage and treatment facility
SS = Sewer Separation

During 2007, there were several events highlighted in many of the quarterly reports (**Table 2-8**). These events resulted in higher flow volumes from rainfall runoff, snow melt, or both. Where snowmelt was a significant contributor, the reports indicate a lower correlation coefficient between precipitation and flow through the facility.

- March 14-16: Over this period a combination of rainfall and snowmelt was observed. Roughly four feet of snow pack melted during this period, accompanied by rainfall in the range of 0.5 to 0.7 inches.
- April 14-15: Over this period an inch of rain and hard packed snowmelt resulted in high flows through the facilities.

- June 19: A recorded rainfall of just under 2" in 3.5 hours with antecedent moisture conditions resulted in high flows through the facilities. Based on information obtained from the Northeast Regional Climate Center, this was characterized as being greater than a 5-year (3-hour accumulation period) return frequency storm.
- December 23: A period of moderate to heavy rainfall occurred coincident with the peak of snowmelt runoff.

Table 2-8. Summary of combined sewer overflow (CSO) Facility Reports, 2007.

Facility	Comments from reports
Newell St. Regional Treatment Facility (RTF)	Designed for 90% storm event (23 cfs). Presently in service as a vortex separator for CSO #067; will be taken out of service when Midland is complete. 18-inch underdrain to creek is monitored for flow. 2007 Discharges to Onondaga Creek: (see table below) *Pump failure during storm event on 5/10; pump was repaired.* *Faulty connection affected flow data during second half of Sept; repaired week of Oct 8.* *Pump failure during storm event on 12/23; pump was repaired.*
Burnet floatables control facility (FCF)	Uses bags to capture solids. Operators change bags at approximately 30%-40% capacity or as needed. Considered effective in reducing solids load during wet-weather flows. 2007 Discharges to Onondaga Creek (total captured = 10.09 tons): (see table below)
Teall Brook FCF	No permanent flow monitoring device installed at the facility; operational information is an hour meter reading which indicates the number of hours the bar screens have operated. The Copa bar screen is fully automatic, activating the raking mechanism when water levels rise. Considered effective in reducing solids load during wet-weather flows. 2007 Report Results (see table below)
Butternut FCF	Uses bags to capture solids. Operators change bags at approximately 30%-40% capacity or as needed. Considered effective in reducing solids load during wet-weather flows. 2007 Discharges to Onondaga Creek (total captured = 14.66 tons): (see table below) *In the third quarter, there was a flow meter probe problem; as a result, flow meter data was not included in the quarterly report. The probe was replaced on 10/10. The flow meter problem continued for the first two months of the fourth quarter.*

Newell St. RTF — 2007 Discharges to Onondaga Creek:

Quarter	# Overflows	Average Volume (gal)	Notes
01/01 – 03/31	9	43,981	none
04/01 – 06/30	7	29,256	pump failure
07/01 – 09/30	7	6,014	flow meter problem
10/01 – 12/31	8	24,459	pump failure

Burnet FCF — 2007 Discharges to Onondaga Creek (total captured = 10.09 tons):

Quarter	# Events	Average Volume (mgal)	Captured (tons)	Notes
01/01 – 03/31	32	4.95	1.64	none
04/01 – 06/30	28	2.03	2.32	none
07/01 – 09/30	26	1.89	3.21	none
10/01 – 12/31	37	2.52	2.92	none

Teall Brook FCF — 2007 Report Results:

Quarter	# Events	Hours of Operation	Station Cleaning	Notes
01/01 – 03/31	7	17	3 times	none
04/01 – 06/30	11	18	2 times	none
07/01 – 09/30	17	20	2 times	none
10/01 – 12/31	15	20	1 time	none

Butternut FCF — 2007 Discharges to Onondaga Creek (total captured = 14.66 tons):

Quarter	# Events	Average Volume (mgal)	Captured (tons)	Notes
01/01 – 03/31	27	6.38	2.18	none
04/01 – 06/30	23	5.84	4.31	none
07/01 – 09/30	--	--	4.28	flow meter problem
10/01 – 12/31	9	6.34	3.89	none

Table 2-8. Summary of combined sewer overflow (CSO) Facility Reports, 2007 (continued).

Facility	Comments from reports
Maltbie St. FCF	Uses bags to capture floating solids. Operators change bags at approximately 30%-40% capacity or as needed. Considered effective in reducing solids load during wet-weather flows.

2007 Discharges to Onondaga Creek (total captured = 3.812 tons):

Quarter	# Events	Average Volume (gal)	Captured (tons)	Notes
01/01 – 03/31	25	584,170	no changeout	none
04/01 – 06/30	17	234,200	0.662	blockage removed
07/01 – 09/30	27	194,758	1.69	blockage removed
10/01 – 12/31	24	333,578	1.46	none

Blockage was removed from sewer siphon 6/2 – 6/4, resulting in peak flow through the facility at the start of a storm event.
An obstruction was discovered and removed from the siphon connection at the main interceptor sewer, downstream of the regulator, during the third quarter.

Facility	Comments from reports
Harbor Brook FCF	Uses bags to capture floating solids. Operators change bags at approximately 30%-40% capacity or as needed. Facility has met the requirements of the performance evaluation period. The County is awaiting submission of record drawings to designate the project substantially complete. Considered effective in reducing solids load during wet-weather flows.

2007 Discharges to Harbor Brook (total captured = 3.936 tons):

Quarter	# Changeouts	Captured (tons)	Notes
01/01 – 03/31	1	0.819	none
04/01 – 06/30	3	1.03	facility damaged
07/01 – 09/30	2	0.657	none
10/01 – 12/31	3	1.43	none

The facility was damaged in the June 19 storm event (greater than 5-year return frequency storm); recommendations are being prepared for repair and modifications to protect from flash flood type events. The facility has remained in service through 2007.

Facility	Comments from reports
Erie Blvd Storage System (EBSS)	This system has a capacity of 5.5 mg; designed to retain discharge for a 90th percentile storm from 9 CSOs, and bleed back to Metro. In the event the maximum capacity of the EBSS and Main Intercepting Sewer was reached, further incoming CSO flows were discharged to Onondaga Creek to prevent flooding.

2007 Discharges to Onondaga Creek:

Quarter	Date	Overflow (mgal)	%CSO ; %SW	Notes
01/01 – 03/31	--	--	--	no releases
04/01 – 06/30	06/19	1.73	68% ; 32%	one release
07/01 – 09/30	--	--	--	no releases
10/01 – 12/31	--	--	--	no releases; damaged

% CSO ; %SW – estimated percent contribution of volume originating from Combined Sewer Overflows and urban stormwater. During periods of no releases, CSO contribution is less than 20%.
Jun 19 storm event was characterized as greater than 5-year return storm; storage mode was initiated at 9:00 PM. EBSS Storage capacity completely utilized by 9:43 PM.
After Dec 23 storm event, position indicator on Gate 4 failed due to water infiltration. Upon receipt of the cost estimate the repair will be completed by a contractor.

Table 2-8. Summary of combined sewer overflow (CSO) Facility Reports, 2007 (continued).

Facility	Comments from reports
Hiawatha RTF	Facility consists of Swirl Concentrator (SC), Storage Tank (ST) and Disinfection Tank (DT) process units, which are activated during rain events. Overflows discharged to Ley Creek Outfall.

2007 Discharges to Ley Creek:

Quarter	# Overflows	Volume (gal)	Time (hours)	Units Activated
01/01 – 03/31	0	--	--	SC, ST, DT
04/01 – 06/30	1	not reported	not reported	SC, DT
07/01 – 09/30	0	--	--	SC, ST
10/01 – 12/31	1	269,000	5	SC, ST, DT

One overflow occurred June 19 – the automatic disinfection system at the facility did not activate due to a persistent problem with a carrier pipe leak that disables the system.

One 5-hour overflow occurred Dec 23,while the disinfection system was out of service for repair during winter months. Total flow into facility measured 773,000 gallons; 504,000 CSO volume pumped back to the Metro STP.

2.4 ROUTE 20 AND SPENCER STREET IN-SITU MONITORING

In 2006, OCDWEP and USGS initiated a joint project to enhance data collection at two sites on Onondaga Creek:

- Route 20 in Lafayette, in the rural headwaters, and
- Spencer Street in Syracuse, in the urban area affected by CSO discharges.

A new gauging station was constructed at Route 20 in 2006, while an existing gauging station was upgraded at Spencer Street.

2.4.1 Route 20 Gauging Station

In-situ water quality monitoring and meteorological data collection capabilities were installed, including precipitation collection equipment outfitted with heating elements to measure snowfall precipitation water equivalents. The Route 20 sonde was installed at the monitoring site to record data on a continuous basis starting on 7/25/07. Prior to this date it was operational during the testing and sampling event periods only. It was removed from service for the winter on December 11, 2007. The sonde collects readings at 15-minute intervals for depth, water temperature, dissolved oxygen (percent saturation and concentration), specific conductivity, salinity, pH, oxidation-reduction potential, and turbidity.

The data will be used to evaluate loss of materials from the rural agricultural portion of the Onondaga Creek subwatershed.

2.4.2 Spencer Street Gauging Station

The Spencer Street Station is operational and accommodates real-time flow gauging, an automated sampler that can be activated by remote command, and a series of water quality probes. A YSI sonde measures and records dissolved oxygen concentration, turbidity, salinity, water temperature, pH, oxidation-reduction potential, and specific conductivity at 15-minute intervals. Also, a heated bucket rain gage is on-line, which will measure precipitation and will also allow the measurement of snowfall during the winter months.

2.4.3 Results

USGS flow and precipitation results for 2007 are shown in **Figure 2-3**. In-situ sonde results for turbidity, temperature and dissolved oxygen in 2007 are presented in **Figure 2-4**. A summary of the precipitation that occurred on and within three days of sampling for laboratory analysis is shown in **Table 2-9**. Analytical results for samples collected at the Route 20 (upstream) and Spencer Street (downstream) locations on Onondaga Creek in 2007 are presented in **Table 2-10**.

Table 2-9. Precipitation events corresponding to sampling events for laboratory analyses.

Analytical	Precipitation (inches)				
Sample Date	Spencer Gauge	Hancock Airport	3-day Period	Spencer Gauge	Hancock Airport
04/17/07	0.148	0.17	04/15-04/17	1.609	1.64
06/12/07	0	0	06/10-06/12	0	0
10/02/07	0	trace	09/30-10/02	0	trace
10/03/07	0	0	10/01-10/03	0	trace
10/30/07	0	0	10/28-10/30	0.004	trace
11/27/07	0.008	0.06	11/25-11/27	0.012	1.2

Note: Precipitation is shown for the date of sampling, and for the three-day period prior to and including the date of sampling. The three-day period was selected to provide a perspective on the moisture conditions occurring prior to the sampling event.

The analytical results with the 3-day sum of precipitation are shown in **Figures 2-5** and **2-6**. The highest concentrations of phosphorus (total, soluble reactive and dissolved), total suspended solids, and total Kjeldahl nitrogen at Route 20 station occurred on November 27. These results were higher at Route 20 than at the Spencer station. The three-day rain summary (11/25 through 11/27) at Hancock Airport was also greater than the precipitation measured at Spencer, which reflects the spatial variability of precipitation across the watershed. There was no precipitation data available for the Route 20 station. During periods of no rainfall, total phosphorus values are similar between the two stations; however, soluble reactive and total dissolved phosphorus exhibit greater variability between the stations. Total dissolved solids were higher during periods of no rainfall than during runoff events.

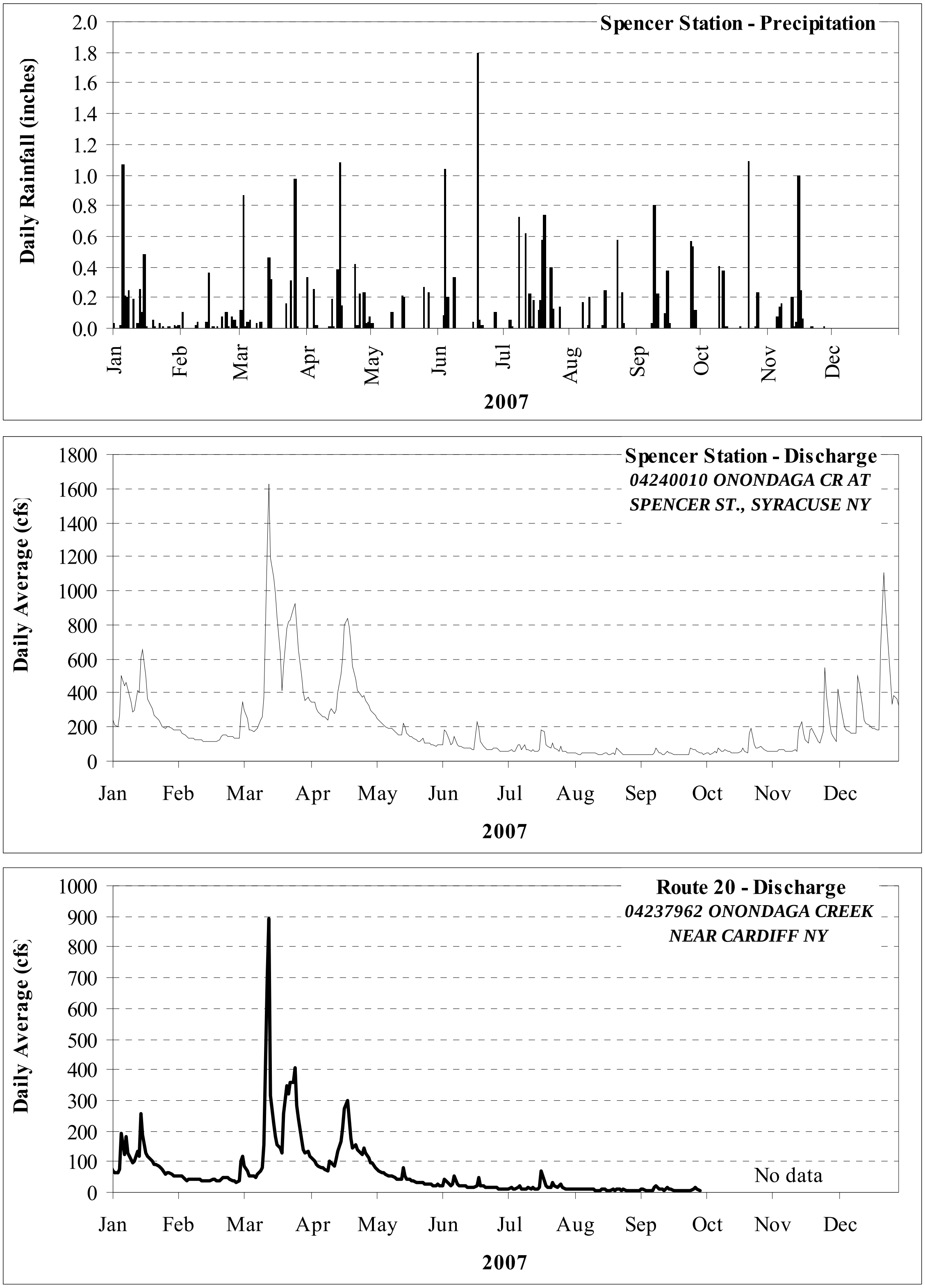

Figure 2-3. Precipitation and daily average flow in 2007 at Spencer Street (downstream) and Route 20 (upstream) stations on Onondaga Creek. Flow data from USGS at Route 20 were available through September 30, 2007.

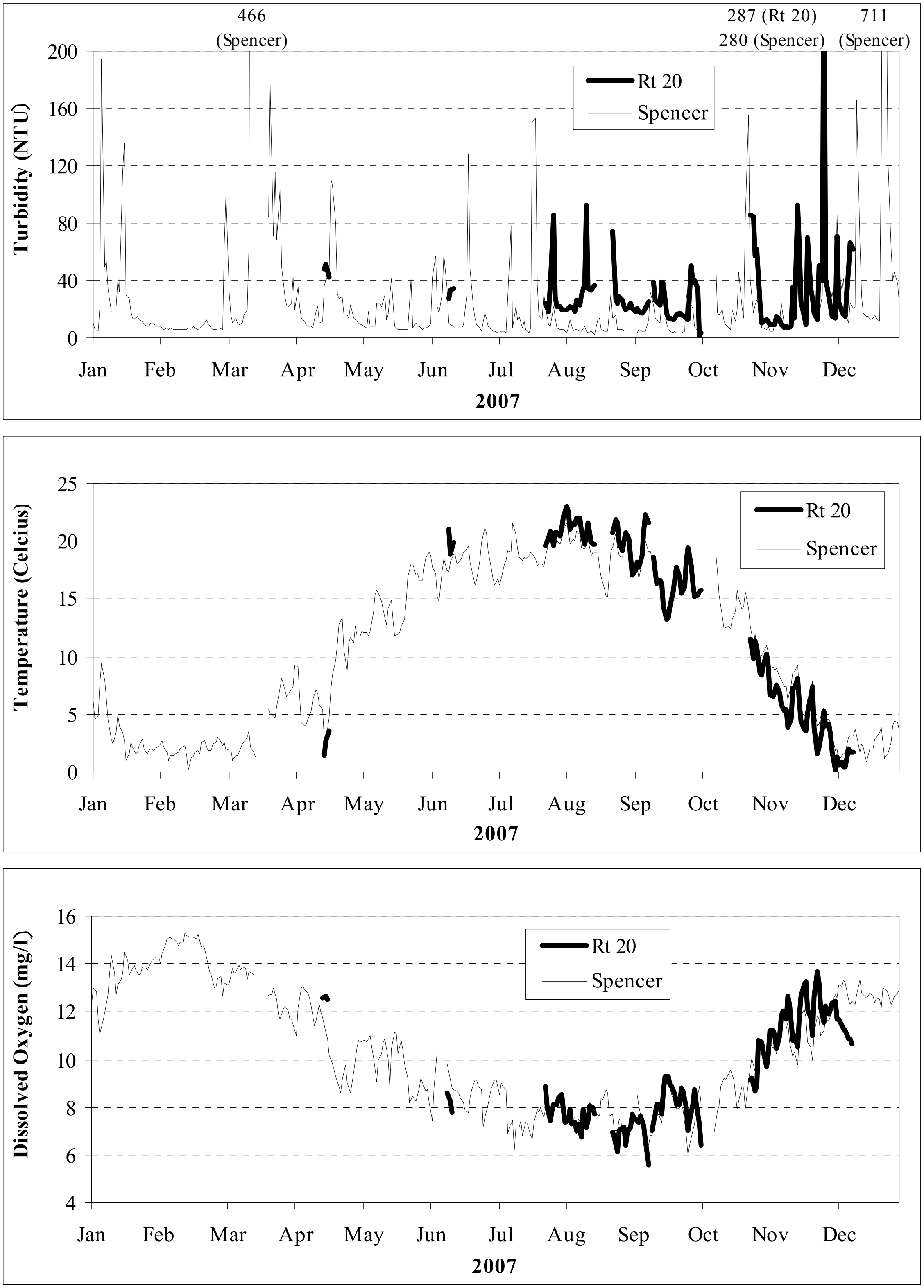

Figure 2-4. Daily average in-situ sonde results in 2007 for turbidity, temperature and dissolved oxygen at Spencer Street (downstream) and Route 20 (upstream) stations on Onondaga Creek. Daily averages calculated from 15-minute interval data.

Table 2-10. Comparison of 2007 data from upstream and downstream locations on Onondaga Creek.

Parameter	Sample Date	Onondaga Creek Route 20 Upstream	Onondaga Creek Spencer Downstream
Solids:			
Total dissolved solids	04/17/07	424	660
	06/12/07	1,080	1,164
	10/02/07	1,508	--
	10/03/07	--	1,536
	10/30/07	--	1,304
	11/27/07	386	942
Total suspended solids	04/17/07	35	12
	06/12/07	11	12
	10/02/07	<4	--
	10/03/07	--	<4
	10/30/07	--	7
	11/27/07	410	172
Phosphorus:			
Total phosphorus	04/17/07	0.071	0.044
	06/12/07	0.033	0.038
	10/02/07	0.022	--
	10/03/07	--	0.035
	10/30/07	--	0.012
	11/27/07	0.598	0.177
Soluble reactive phosphorus	04/17/07	0.003	0.008
	06/12/07	0.003	0.003
	10/02/07	0.002	0.014
	10/30/07	--	0.006
	11/27/07	0.022	0.008
Total dissolved phosphorus	04/17/07	0.013	0.015
	06/12/07	0.014	0.017
	10/02/07	<0.003	0.016
	10/30/07	--	0.004
	11/27/07	0.029	0.022
Nitrogen:			
Ammonia-N	04/17/07	<0.03	0.04
	06/12/07	0.06	0.03
	10/02/07	<0.03	--
	10/03/07	--	0.04
	10/30/07	--	0.034
	11/27/07	0.05	0.08
Total Kjeldahl Nitrogen	04/17/07	0.4	0.36
	06/12/07	0.29	0.31
	10/02/07	0.26	--
	10/03/07	--	0.38
	10/30/07	--	0.37
	11/27/07	1.33	1.04

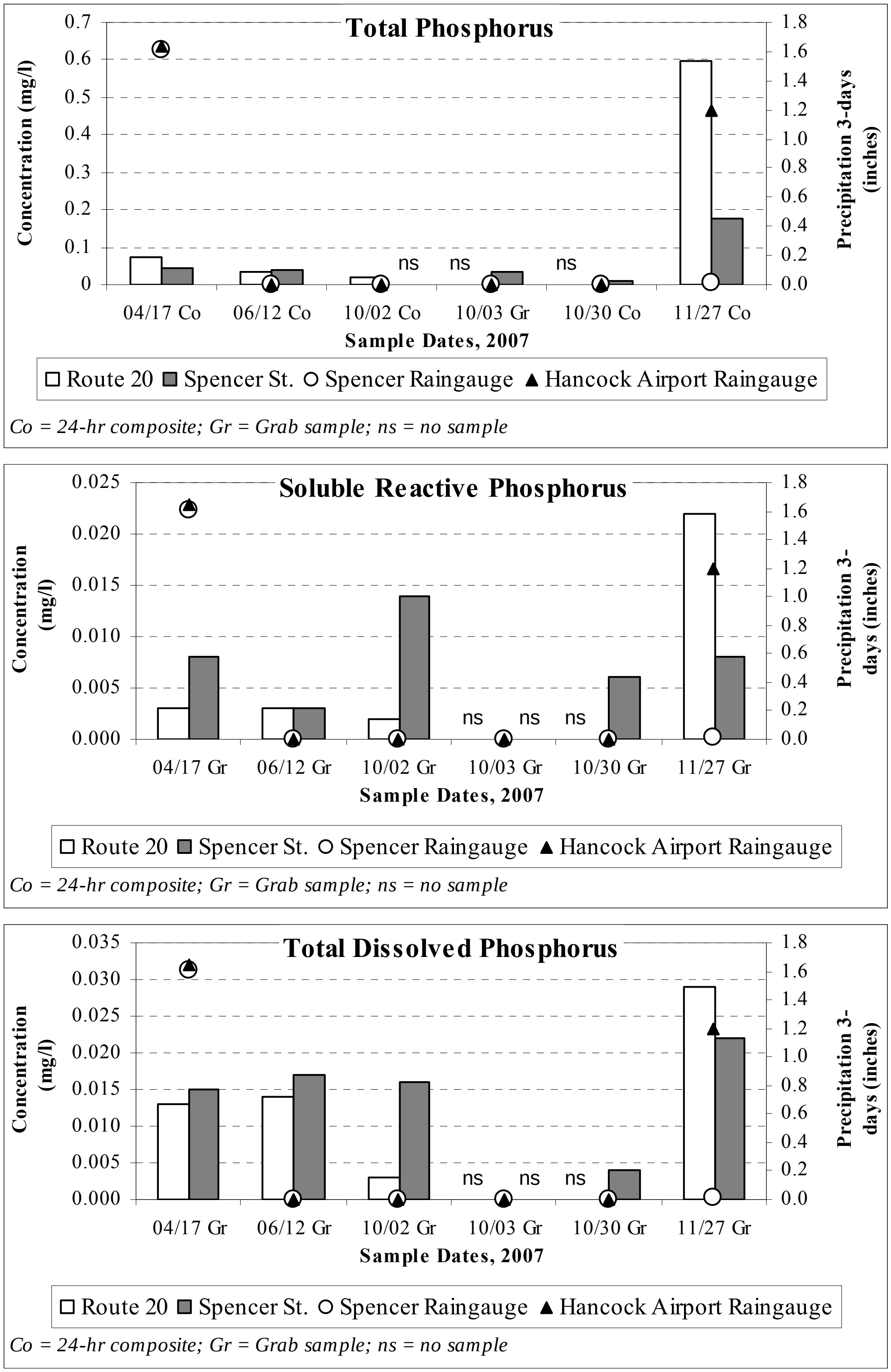

Figure 2-5. Analytical results for phosphorus, with the sum of precipitation over three-days up to and including the sample date.

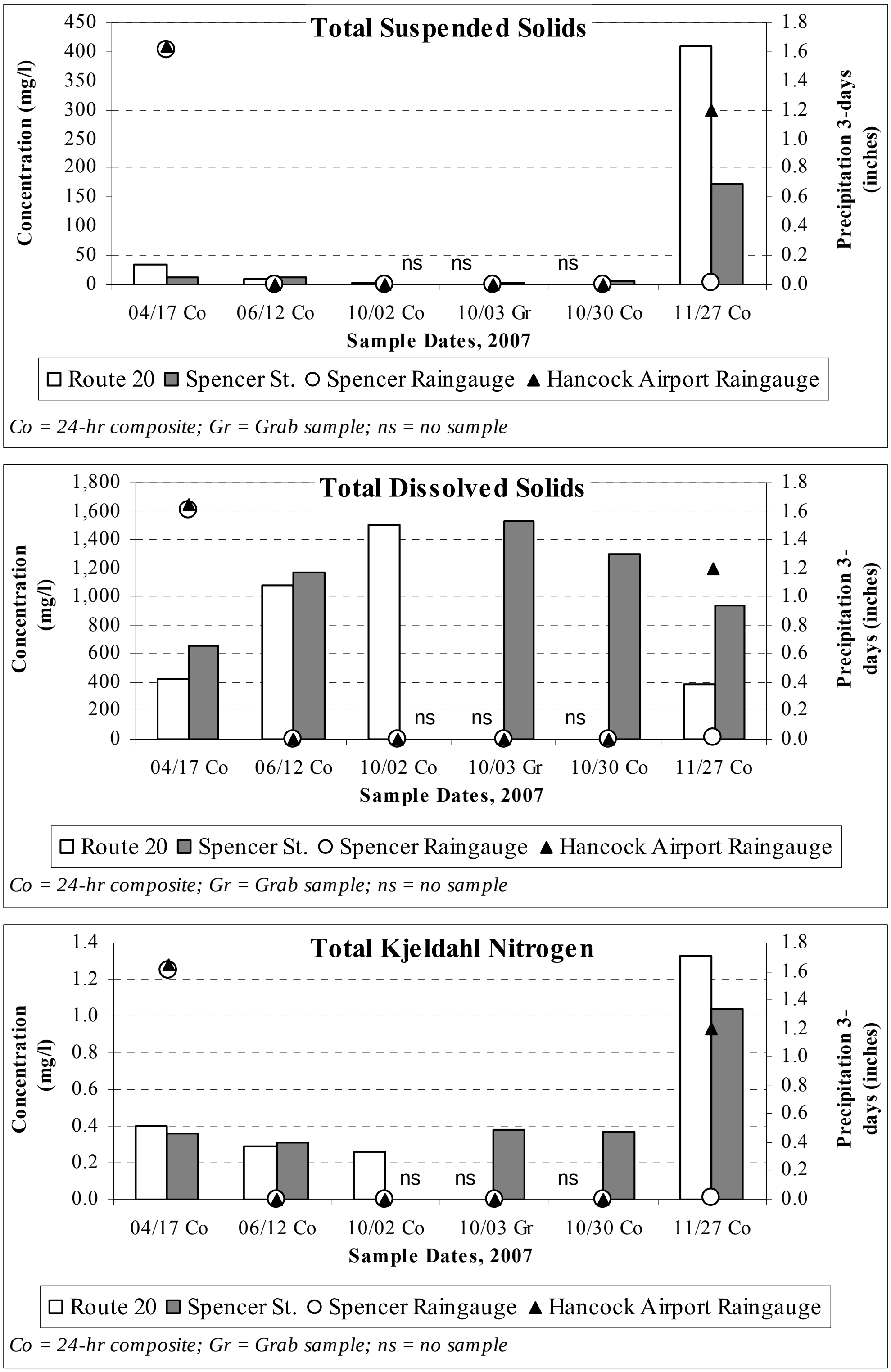

Figure 2-6. Analytical results for solids and Total Kjeldahl Nitrogen, with the sum of precipitation over three-days up to and including the sample date.

CHAPTER 3: NUTRIENTS AND TROPHIC STATE

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CHAPTER 3. NUTRIENTS AND TROPHIC STATE

The approved 2007 annual workplan (**Appendix 1**) for the Onondaga County Department of Environment Protection's Ambient Monitoring Program (AMP) included sampling, analysis and evaluation of many parameters. The rationale for the design of the AMP and the specific way the data are used to interpret compliance and trends are outlined in the Data Analysis and Interpretation Plan (DAIP – **Appendix 5**).

This chapter summarizes the 2007 results for the nutrients phosphorus and nitrogen, and discusses these results in context of reductions in external loading and lake response. Related parameters such as algae, water clarity, and dissolved oxygen are also discussed, as well as trophic state, nutrient ratios, and biochemical transformations in lower waters.

There are several appendices to the 2007 AMP report with additional details regarding sample collection and analysis:

- **Appendix 2** is a summary of the quality control review of the 2007 database.
- **Appendix 3** is a review of the lake's lower trophic levels (phytoplankton and zooplankton).
- **Appendix 4** presents the macrophyte 2007 aerial photograph interpretation.
- **Appendix 10** is a comparison of paired samples collected from the North and South basins
- **Appendix 11** is a compendium of light-related data

3.1 PRECIPITATION, TEMPERATURE, AND USGS TRIBUTARY FLOWS

Weather data for 2007 provide a hydrologic context for the 2007 AMP data. In 2007, annual precipitation measured at Syracuse Hancock Airport was above the 30-year average (**Table 3-1**). Monthly precipitation was generally over the 30-year average eight months of the year and below average the other four months (**Figure 3-1(a)**); generally, precipitation during the summer months was below normal. Annual air temperatures were close to the 30-year average; monthly average air temperatures were above normal six months of the year, and below normal the other six months (**Figure 3-1(b)**).

Table 3-1. NOAA Syracuse Hancock Airport precipitation and temperature data.

Measure	2007 (NOAA*)	30-year Average (1977-2006)	Notes
Precipitation (inches)			
Annual	41.6	38.25	3.35 above
Monthly extremes	0.86 (May)	3.16 (May)	2.47 below
	5.04 (December)	3.03 (December)	2.08 above
Temperature (°F)			
Annual	48.1	48.0	0.1 above
Monthly extremes	18.5 (February)	25.4	6.9 below
	58.0 (October)	50.3	7.7 above

*Obtained from **Northeast Regional Climate Center** March 11, 2007

Hydrographs of the major tributaries to Onondaga Lake are plotted in **Figure 3-2**. Sampling dates for the AMP tributary program are indicated on the hydrographs. The AMP is designed to sample the tributaries over a range of representative flow conditions, and targets a minimum of five samples collected during high flow events (defined as one standard deviation above the long-term monthly average flow[1]). In 2007, this minimum target was exceeded. There were 26 tributary sampling events completed in 2007 on Onondaga Creek, Harbor Brook, and Ninemile Creek; 25 events were completed on Ley Creek. An additional 26 sampling events occurred on Onondaga Creek as part of the Clinton Phase 1 Conveyance Project, and two events on Harbor Brook related to the Hillcrest pump station force main break. The numbers of high flow samples[2] collected in the tributaries were:

Tributary	*Number of high flow samples*	*Notes*
Onondaga Creek (Dorwin)	7	Plus 5 during the Clinton Phase 1 Conveyance Project
Ninemile Creek	9	--
Ley Creek	6	--
Harbor Brook (Hiawatha)	8	Plus 1 during the Hillcrest pump station force main break

[1] Long-term monthly average flow is defined as the 30-year period from 1977 to 2006.
[2]Samples flagged as "high flow" where stream flow for the sample date exceeds one standard deviation above long-term monthly average flow (1977-2006) at each sampling station. The USGS gaging station data used for this evaluation were obtained from the USGS web site for these four stations:

USGS 04240010 ONONDAGA CR AT SPENCER ST.
USGS 04240300 NINEMILE CREEK AT LAKELAND
USGS 04240120 LEY CREEK AT PARK STREET
USGS 04240105 HARBOR BK AT HIAWATHA BLVD.

Yearly variations in precipitation and lake inflow volume are summarized in **Chapter 8**. Over the 1990-2007 period, yearly runoff from the Onondaga Lake watershed varied from 12.21 to 29.53 inches and was strongly correlated with precipitation (r = 0.91). Precipitation gradually increased from approximately 31.5 to approximately 43.3 inches/yr while runoff increased from approximately 11.8 to approximately 23.6 inches/yr over the 1998-2007 period. This increase in precipitation complicates the interpretation of apparent trends in loading.

Any decreases in long-term-average loads or improvements in lake water quality resulting from the control program could have been partially masked by increases in non-point load attributed to rainfall. As a consequence, tests of AMP hypotheses regarding load reductions and lake improvements between 1998 and 2007 are weak and likely to be conservative; i.e. any improving trends might have been more pronounced had there not been an increasing trend in precipitation over this period.

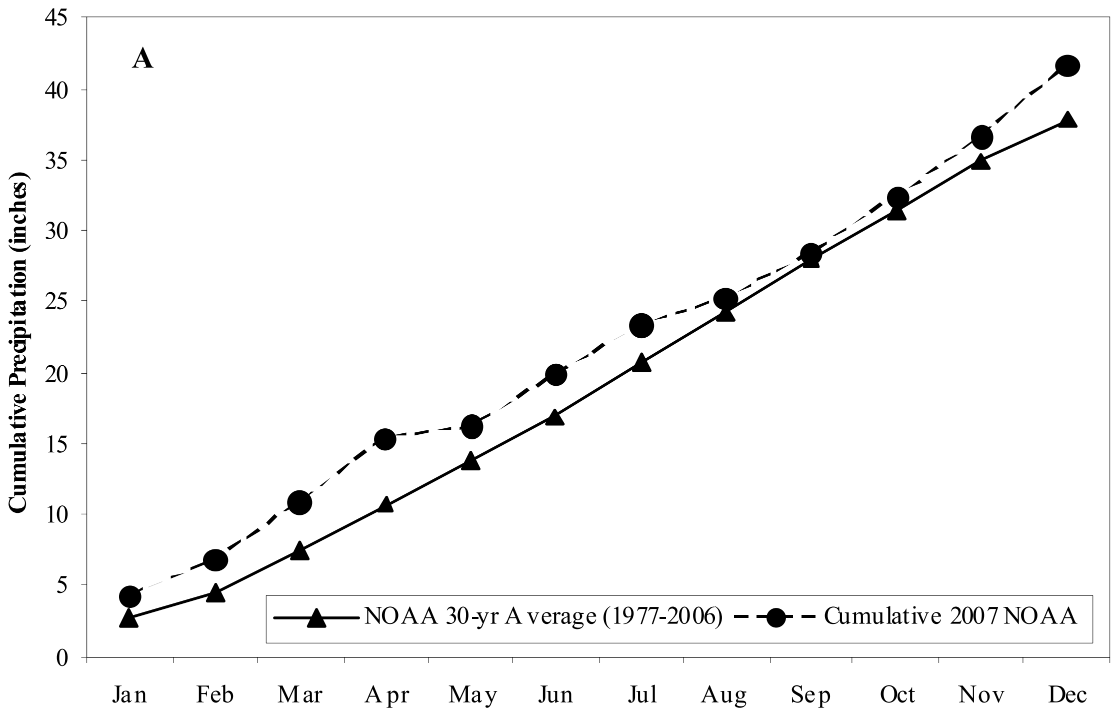

Figure 3-1a. Cumulative precipitation in 2007 compared with the historical average for Syracuse, NY.

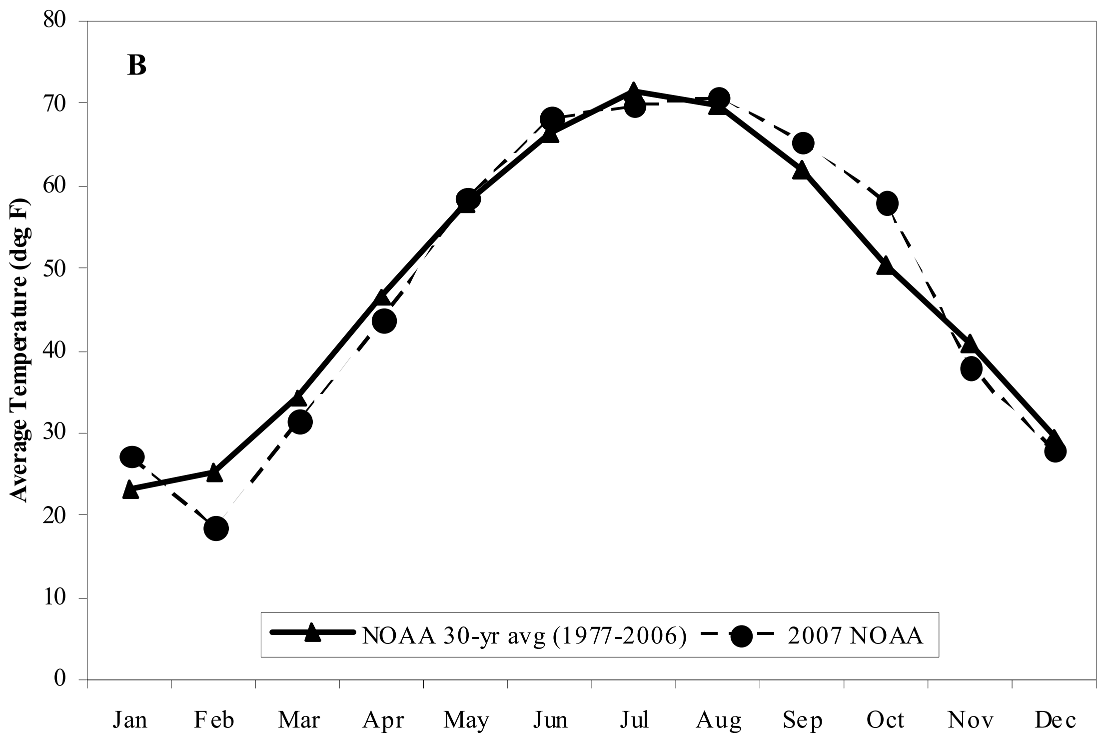

Figure 3-1b. Monthly average temperature in 2007 compared with the historical average for Syracuse, NY.

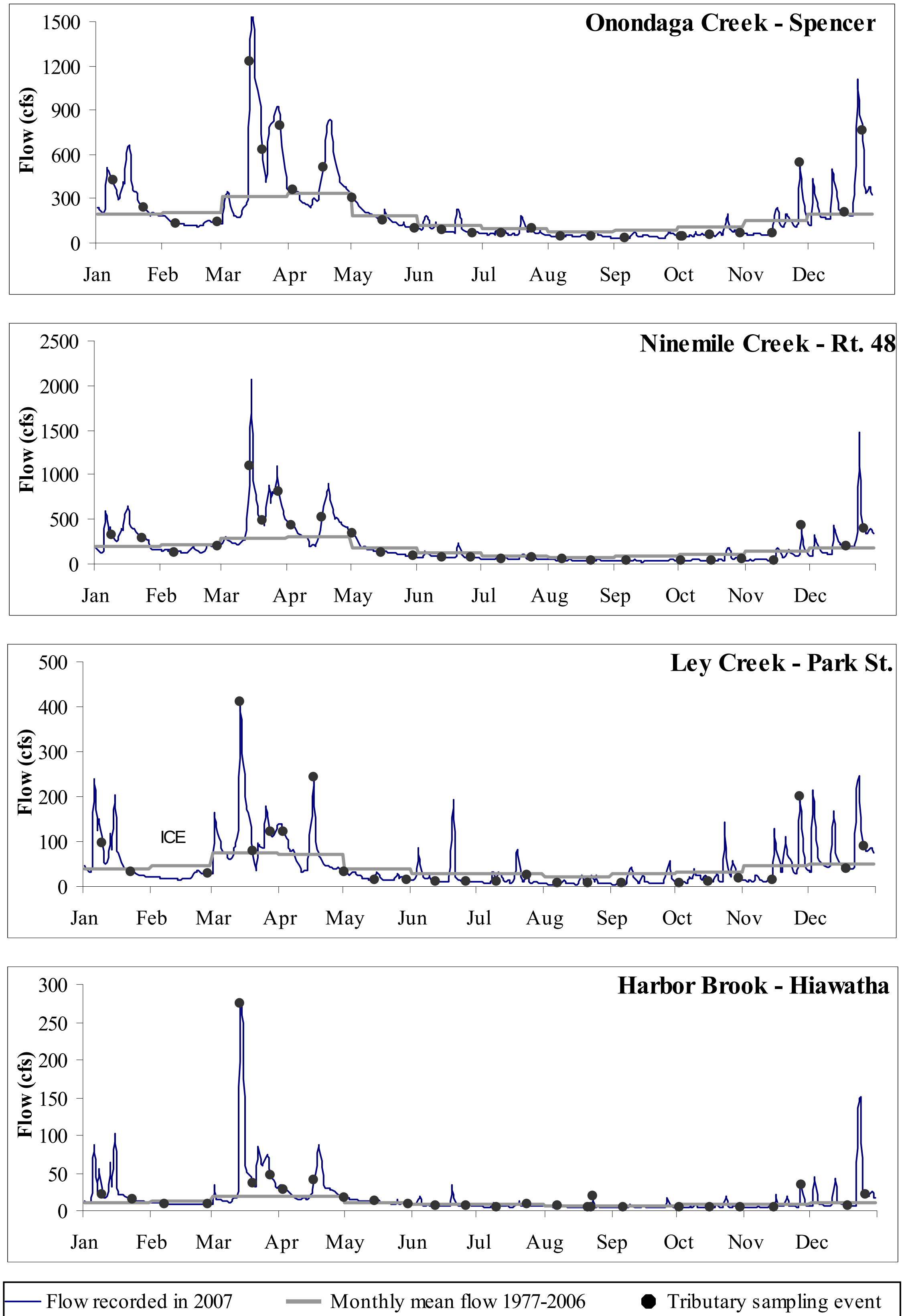

Figure 3-2. Observed tributary flows in 2007 compared with the long-term (1977-2006) average flow record. USGS final data received from OCDWEP 04/23/2008.

3.2 PHOSPHORUS

In Onondaga Lake, phosphorus is the limiting nutrient for algal growth. Elevated concentrations of phosphorus in lakes may cause excessive algal growth, which reduces water clarity and the amount of light available for rooted aquatic plants. When the algae die off, bacterial decomposition consumes oxygen present in the water, potentially reducing ambient concentrations of oxygen to levels that are stressful, or fatal, to the aquatic community. Because of its importance in lake ecology, phosphorus is a major focus of efforts to rehabilitate Onondaga Lake.

Amended Consent Judgment Goals for Phosphorus:

- Achieve compliance with the applicable ambient water quality standard in the upper waters considering all watershed sources of phosphorus.
- Achieve phosphorus reduction sufficient to reduce the frequency and duration of nuisance algal blooms and eliminate turbidity as impairment to desired uses of the lake for water contact recreation, aesthetics, aquatic life protection and fish reproduction.

Phosphorus in Onondaga Lake comes from both point and nonpoint sources. The Metro plant is the primary point source; watershed runoff is the primary nonpoint source. As described in Chapter 2 of this report, loading of phosphorus from the Metro facility has been reduced since implementation of treatment measures; most recently the high rate flocculated settling (HRFS) system implemented in 2005.

3.2.1 External Loading and Trends

During 2007, Metro Outfall 001 accounted for 28% of the total phosphorus loading to Onondaga Lake. This represents a substantial decrease from prior years. For the first time, Metro outfalls did not contribute the majority of phosphorus entering Onondaga Lake (**Figure 3-3**). The Bypass Outfall 002 accounted for about 5% of loading during 2007, which is close to the average annual contribution of about 4% for the 1998-2004 period. The Bypass Outfall 002 effluent is not treated for phosphorus removal.

Of the major natural tributaries to the lake, Onondaga Creek contributed the greatest amount of phosphorus to the lake in 2007, followed by Ninemile Creek, Ley Creek and Harbor Brook (**Table 3-2**). This pattern has not changed appreciably since the 1990s (**Figure 3-3**). The same order of importance has been observed during storm events in previous years. The consistency of this pattern implies that there have been no major changes in contributions from nonpoint sources over this period. As observed in the 2006 AMP report, this finding was notable in light of a shift in land cover within the subwatersheds between 1992 and 2001, where the increase in the percentage of land area classified as urban/developed ranged from 3% to 18%. At the same time, the decrease in area designated as agriculture ranged from 16% to 29% (**Table 3-3**).

Table 3-2. Summary of phosphorus loading and long-term comparison.

Tributary	2007 Loading Water (hm^3)	2007 Loading Total P (mt)	2007 Loading SRP (mt)	2007 Percent contribution by gauged inflow Water	Total P	SRP
Metro:						
Metro Outfall 001	88	10.4	0.39	18%	28%	7.7%
Metro Outfall 002	1.4	1.8	0.40	0.29%	4.9%	7.9%
Natural Tributaries:						
Onondaga Creek	183	11.6	1.7	37%	31%	33%
Ninemile Creek	170	9.2	1.6	34%	25%	32%
Ley Creek	39	2.6	0.41	7.8%	6.9%	8.0%
Harbor Brook	14	1.6	0.52	2.8%	4.3%	10%
Industrial Tributaries:						
East Flume	0.68	0.086	0.031	0.14%	0.23%	0.61%
Trib 5A	0.56	0.060	0.016	0.11%	0.16%	0.31%
Total Monitored	**496**	**37**	**5.10**	**100%**	**100%**	**100%**
Average 1990-2006:		**78**	**16**			
%Change 2007 from Average:		**-52%**	**-69%**			

Notes: mt = metric tons; hm3 = million cubic meters. Metro Outfall 001 calculated loads of TP are based on daily measurements. Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events). Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms.

Table 3-3. Land cover percent change by subwatershed, Onondaga Lake Watershed, 1992 and 2001. *Source: SOCPA*

Tributary	Land Cover Designation: Urban/Developed	Forest	Agriculture	Wetlands
Onondaga Lake (Nearshore)	+18%	-2%	-16%	--
Onondaga Cr	+7%	+12%	-22%	+3%
Ninemile Cr	+13%	+14%	-29%	+2%
Ley Cr	+17%	+1%	-16%	-3%
Harbor Brook	+14%	+8%	-25%	+3%
Otisco Lake	+3%	+24%	-29%	+1%
Range:	**+3% to +18%**	**-2% to 24%**	**-29% to -16%**	**-3% to +3%**

Note: "+" indicates percent increase from 1992 to 2001; "-" indicates percent decrease.

Between 1999 and 2002, total phosphorus loads remained relatively constant, ranging between 48 and 54 mt/year. A slight increase in total phosphorus loading occurred in 2004 (83 mt/yr) that was attributed to startup of the BAF ammonia removal system. Since HRFS system came on line in February 2005, the total phosphorus and soluble reactive phosphorus loadings from Metro have been reduced to levels below 20 mt/year. Overall, Metro and watershed loading were reduced in 2007 to 37 mt/year, a decrease of 52% over the 10-year average loading from 1990-2006. Flow-weighted concentrations are presented in **Appendix 12**.

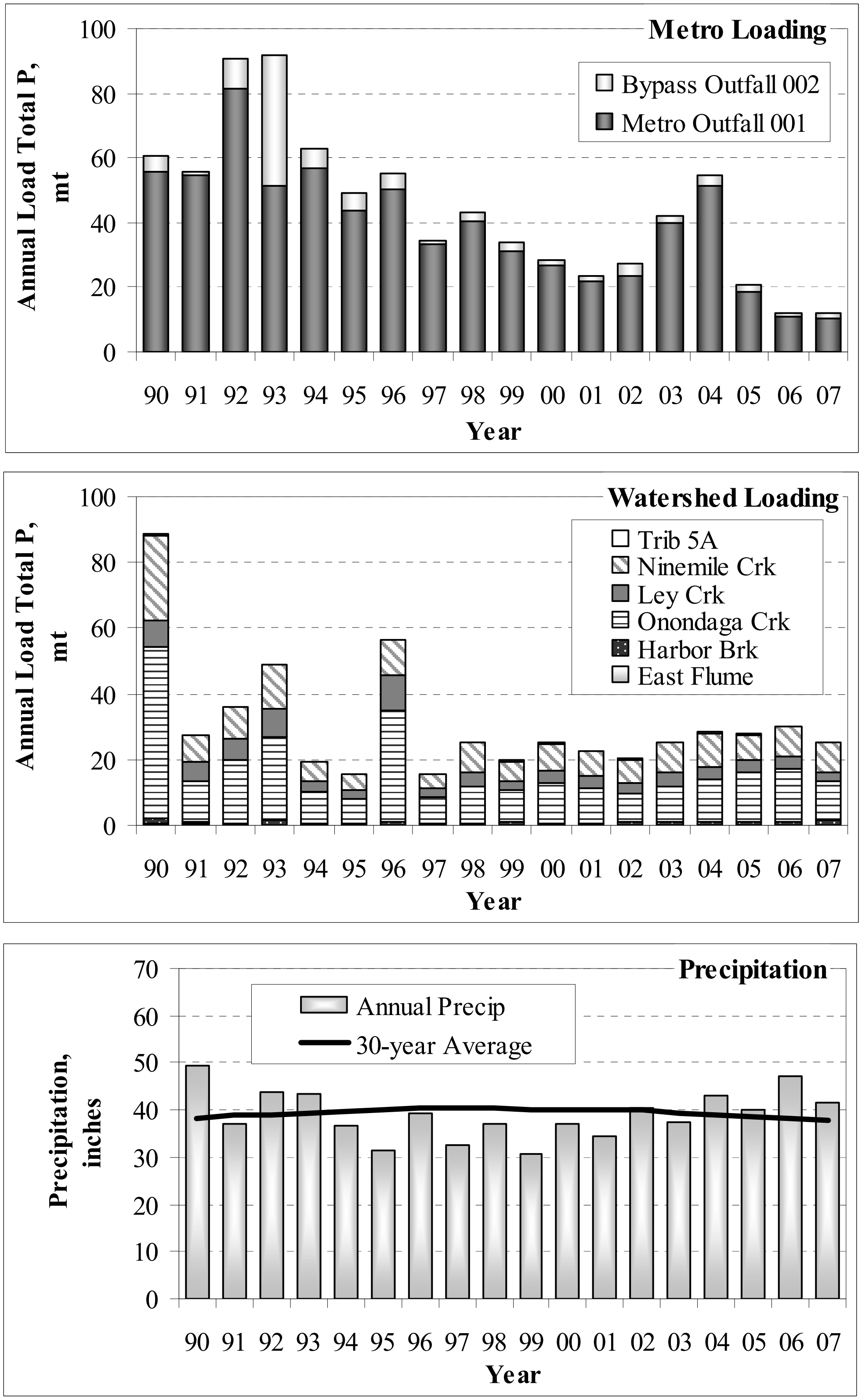

Figure 3-3. Total phosphorus loading over time from Metro and the watershed.
Note: 30-year average precipitation represents the 30-year period preceding each year; for example, the 30-year average precipitation for 1990 represents the period 1960-1989.

During wet years, more runoff flows to the lake from the large watershed. Note that with the recent improvements at the Metro plant, runoff from the watershed contributes the majority of phosphorus entering Onondaga Lake (**Figure 3-4**).

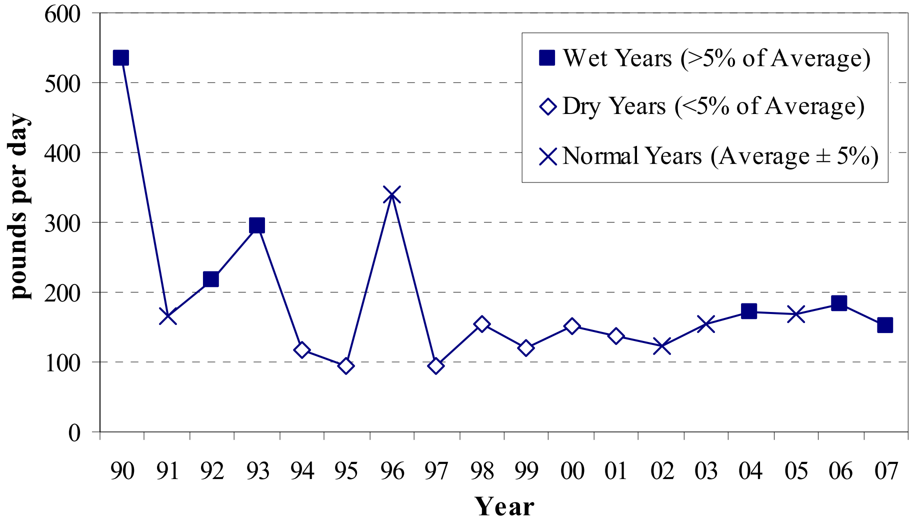

Figure 3-4. Phosphorus discharged to Onondaga Lake from non-Metro watershed sources.
Note: To evaluate wet and dry years, the 30-year rolling average precipitation was used. Therefore, 2006 is represented as a wet year, with precipitation greater than 5% of the 30-year average 1976-2005; and 2005 was a normal year relative to the previous 1975-2004 30-year average.

Data from the most recent ten-year period have typically been used to test AMP hypotheses regarding decreases in load or concentration resulting from implementation of control measures. As discussed in **Chapter 8**, the increase in precipitation over the 1998-2007 period significantly complicates causal interpretation of trends in the tributary loading data. Power for detecting trends is improved by considering a longer base period (1990-2007) that includes precipitation cycles. Rainfall and year are less correlated over this period ($r = 0.02$), as compared with 1998-2007 ($r = 0.78$). Because there is no net trend in precipitation during this period (1990-2007), conclusions regarding the presence or absence of trends are relatively insensitive to precipitation adjustment, although adjustment increases the power of the trend hypothesis test by decreasing variability in the time series. However, there are disadvantages of using a longer time frame: apparent trends may vary within the 18-year period; and improvements in the monitoring program over time could also affect the trend analysis.

With precipitation adjustment, results indicate slight (~1%/yr) decreasing trends in flow at Harbor Brook and Onondaga Creek sites and an 8%/yr decreasing trend in Tributary 5A flow. Reductions in phosphorus load and concentrations are indicated for most point and non-point sources and for the lake outflow. In contrast, increasing trends in phosphorus load and concentration are indicated for the lower portion of Harbor Brook (between the Velasko and Hiawatha monitoring sites).

The apparent trend in total non-point load (-1.012 ± 0.373 mt/yr) accounts for 20% of the trend in total inflow load (-4.880 ± 0.732 mt/yr), which primarily reflects reductions in Metro load over the 1990-2007 period. No trends in load are indicated for Ninemile Creek and the upper portion of Onondaga Creek. Further evaluation of nonpoint phosphorus loads for the 1998-2007 period, with and without adjustment for precipitation, is presented in **Chapter 8**.

3.2.2 Mass Balance Analysis

As a consequence of treatment improvements, annual total phosphorus concentrations in the Metro discharge varied from 0.12 to 0.54 mg/L in the 5-year mass balance period, but averaged 0.12 mg/L in both 2006 and 2007. Supplemental total phosphorus balances for 2006-2007 and 1998-2007 are presented in **Chapter 8 (Tables 8-6 and 8-7)**. The former is representative of point-source loads reflecting the Metro treatment level. The latter reflects a wider range of precipitation and runoff concentrations that would be representative of average non-point loads in the past 10 years. That period is used below as a baseline for evaluating load reduction scenarios using the phosphorus mass-balance. Total phosphorus balances for each period are summarized below:

TP Load (metric tons / yr)	1998-2007	2006-2007
Total Non-point	26.4	29.3
Industrial	0.4	0.2
Metro Discharge (Outfall 1)	27.5	10.7
Metro Bypass (Outfall 2)	2.3	1.5
Total	**56.8**	**42.0**

The 2006-2007 non-point load was above the 1998-2007 average because of high precipitation (**Chapter 8**). The 2006-2007 Metro discharge accounted for 30% of the total load, as compared with 52% in 1998-2007.

With non-point sources currently accounting for approximately 69% of the long-term average phosphorus load to the lake, implementation of non-point source controls will be important to achieving further load reductions and improvements in lake water quality.

3.2.3 Lake Concentration and Trends

Phosphorus loading to Onondaga Lake from Metro has been reduced from about 58 mt/yr in the 1990s to about 12 mt/yr in 2007. At the same time, phosphorus concentrations in the lake have been reduced from about 79 µg/L in the 1990s to 25 µg/l in 2007.

AMP Hypothesis To Be Tested:

Reduced phosphorus load from Metro reduces concentration of phosphorus in Onondaga Lake

Summer average phosphorus concentrations in the upper mixed layer have been decreasing steadily since 2003, and the concentrations measured in 2007 were at the lowest levels in 15 years (**Figure 3-5**). Summer average concentrations in the lake's upper waters have ranged from 25 to 74 µg/l over the past 10 years. The annual loading from Metro (both outfalls) is strongly correlated with TP concentrations measured in the lake's upper waters during summer (**Figure 3-6**). In addition to the point source loading, summer TP concentration depends on nonpoint source inputs as well as in-lake processes including sedimentation, grazing by mussels and zooplankton, algal blooms etc. Consequently, a linear relationship as robust as displayed in Figure 3-6 is remarkable and illustrates the central role of Metro performance on summer water quality conditions. **Table 3-4** summarizes the progress toward water quality improvement for phosphorus.

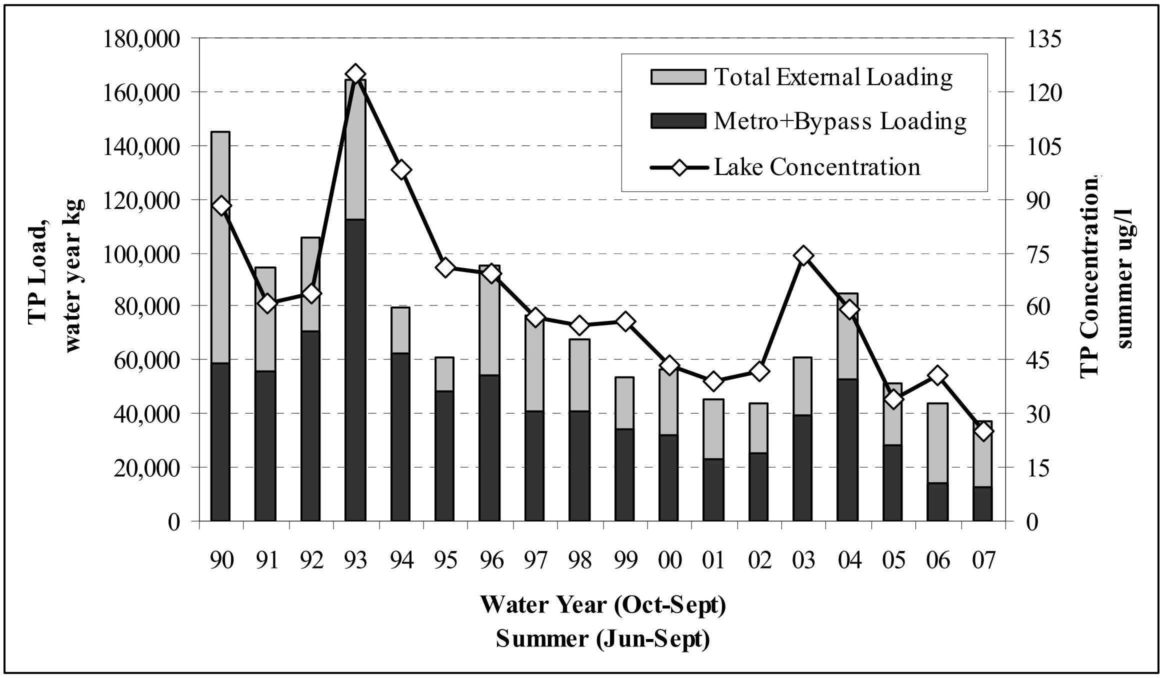

Figure 3-5. Total Phosphorus: Water Year (October to September) external loading and Metro (Outfalls 001 and 002) loading to the lake, compared with South Deep summer (June-September) daily average concentrations for depths 0 to 3 meters. Onondaga Lake, 1990-2007.

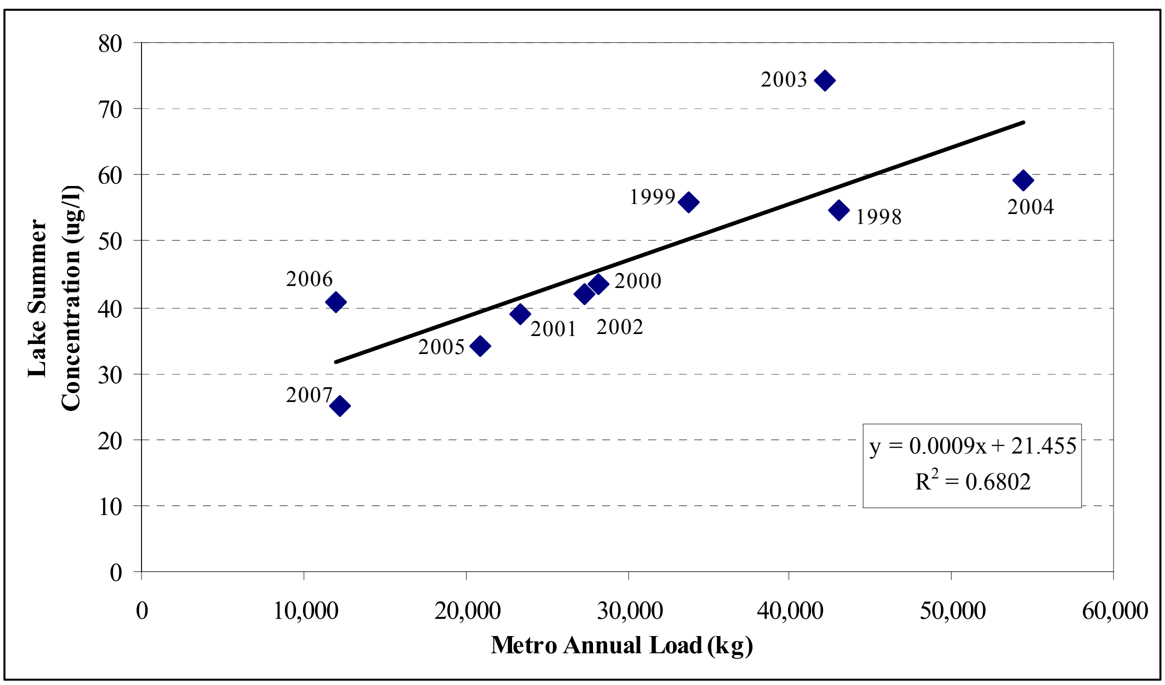

Figure 3-6. Linear regression of total phosphorus annual loading from Metro and Onondaga Lake South Deep summer (June 1 - September 30) average concentration in upper waters (0-3 meters).

Notes: 1998-2007 lake data queried from Onondaga database, and represent summer averages of sample date averages calculated from 0 to 3 meters. 1998-2007 Metro data queried from Historical_Loads_Yearly.xls and represent annual loads from Outfall 001 and Bypass Outfall 002.

Table 3-4. Progress towards water quality improvement: Total Phosphorus. AMP 2007 Annual Report. (Guidance Value)

AMENDED CONSENT JUDGMENT GOAL

Achieve compliance with the applicable ambient water quality standard in the upper waters considering all watershed sources of phosphorus. Achieve phosphorus reduction sufficient to reduce the frequency and duration of nuisance algal blooms and eliminate turbidity as impairment to desired uses of the lake for water contact recreation, aesthetics, aquatic life protection and fish reproduction.

Hypotheses to be tested:	**Status:**
Improvements at Metro will enable the County to meet final effluent limits (as set forth in a revised TMDL on or before Jan 1, 2009)	• NYSDEC 2007 "The lake is also impaired by phosphorus, but a TMDL for these pollutants has been developed and is being implemented so the lake is not listed for these substances"
Reduced phosphorus load from Metro reduces concentration of phosphorus in Onondaga Lake	• Phosphorus loading has been reduced from about 58 metric tons on average annually in the 1990's to 12 metric tons in 2007. • Phosphorus concentration in the lake's upper waters has been reduced from about 79 µg/L in the 1990's to 25 µg/l in 2007.
Reduced phosphorus load from Metro and the nonpoint sources brings the lake into compliance with the numerical TP guidance value 20 ug/l summer average, (or alternative, such as a site-specific guidance value or EPA ecoregional criteria, appropriate for this urban lake).	• The lake is not yet in compliance with the numerical TP guidance value of 20 µg/l summer average; however, summer average concentrations continued to decrease.

Current Conditions with Historical Comparison

Major Sources – Percent Contribution
(Annual Average (standard deviation); 1998 – Stage I Limit caps loading; 2005 – HRFS on-line in February)

Time Period	Metro and Bypass Effluent	Tributaries
1990-1997:	64% (13%)	36% (13%)
1998-2004:	59% (5.7%)	41% (5.7%)
2005-2006:	36% (10%)	64% (10%)
2007:	33%	67%

Upper Waters Concentration
(Annual Average (standard deviation))

Time Period	South Deep, 0-6 meters, Jun 1 – Sept 30 (µg/L)
1990-1997:	79 (23)
1998-2004:	53 (12)
2005-2006:	37 (4.6)
2007:	25

Compliance with NYS AWQS in Upper Waters	
o *Narrative Standard: None in amounts that will result in growths of algae, weeds, and slimes that will impair the waters for their best usages*	Narrative standard met throughout most of 2007, as there were no nuisance algal blooms (chlorophyll-α >30 µg/l) measured in 2007.
o *Guidance Value: 20 µg/l summer average in upper waters*	Guidance value was not met in 2007
Factors Affecting Compliance	Hydrology, Metro performance, land use in watershed, CSO performance.

Table 3-4. Progress towards water quality improvement: Total Phosphorus. AMP 2007 Annual Report. (Guidance Value) (continued).

Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement	Stage I Limit: Cap on Loading • effective Jan. 1998 – April 2006 (completed) Stage II: effective April 2006 – Dec. 2012 • Metro effluent TP 0.12 mg/l (12-month rolling average) Stage III: effective Dec. 2012 • Metro effluent TP at 0.020 mg/l • Watershed nonpoint source reduction of approximately 50% (includes CSO) Or as modified based on revised TMDL (anticipated in 2009)
Monitoring and Assessment Program	
Loading Estimates *Annual County monitoring program*	• Biweekly tributary monitoring, supplemented with samples collected during high flow conditions • Storm event monitoring in tributaries • Daily measurements of Metro effluent
Lake Monitoring *Annual County monitoring program*	• Biweekly profiles in Lake of P fractions (TP, SRP, TDP), April – Nov, 3-meter intervals • Chlorophyll-α, Secchi disk transparency and LiCor measurements • Winter sampling as weather allows
Related Biological Monitoring	• Annual phytoplankton and zooplankton monitoring • Macrophyte survey every five years (began in 2000)
Tools for Decision Making	
Models	• USGS watershed model for Onondaga Lake Partnership • Onondaga Lake Water Quality Model (under development by QEA,LLC) • Mass balance TP framework and linked empirical eutrophication model (William Walker)
TMDL Allocations	NYSDEC Phase I TMDL 8/27/97; Phase II TMDL by January 2009
NYS AWQS and Guidance Value; Federal Criteria	Narrative standard Guidance value of 20 µg/l summer average upper waters Possible site-specific guidance value for TP EPA ecoregional criteria

3.2.4 Algae, Water Clarity and Dissolved Oxygen

External loading of phosphorus from Metro has declined since the inception of the AMP. As a result, lake concentrations of phosphorus have also declined. To evaluate whether reductions in phosphorus have resulted in reductions of algal blooms, improved water clarity, and improved dissolved oxygen levels, metrics such as chlorophyll-a, Secchi disk transparency, and dissolved oxygen are monitored under the AMP.

3.2.4.1 Chlorophyll-a

Concentrations of chlorophyll-a are used to assess trophic status and algal productivity, which contributes to evaluating whether the lake has improved and would meet guidelines for aesthetic quality and use attainment. Chlorophyll-a data are also compared to phytoplankton and zooplankton data to assess the food chain, and to identify trends that indicate changes in nutrient loading.

AMP Hypothesis To Be Tested:

Metro improvements and watershed phosphorus load reductions result in lower chlorophyll-a concentrations in the lake.

As displayed in **Figure 3-7**, there were no measured nuisance bloom events during 2007. Nuisance bloom conditions are defined as chlorophyll-a concentrations greater than 30 μg/L. The concentration 15 μg/L is considered to represent a threshold where the public may perceive impairment for recreational use of a lake.

Summertime is the period of peak recreational use of the lake (June 1 to September 30). Overall, chlorophyll-a concentrations during the summer were below both nuisance bloom and perceived impairment levels. The exception occurred on September 11, 2007, when the peak concentration during the summer was measured at 28.84 μg/L. Concentrations spiked above 15 μg/L in late September and early October then declined sharply from mid-October through the remainder of the monitoring period.

Nuisance bloom frequencies measured in recent years were also lower than those observed since weekly monitoring started in 1998 (**Figure 3-8**). The frequency of chlorophyll-a measurements exceeding the nuisance bloom threshold (30 ug/l) has declined to zero for 2005 through 2007. These observed declines in chlorophyll-a concentrations since 2005 are likely to be related to the corresponding decline in lake phosphorus concentrations resulting from the Metro upgrade in 2005.

Table 3-5 summarizes the progress toward water quality improvement for chlorophyll-a.

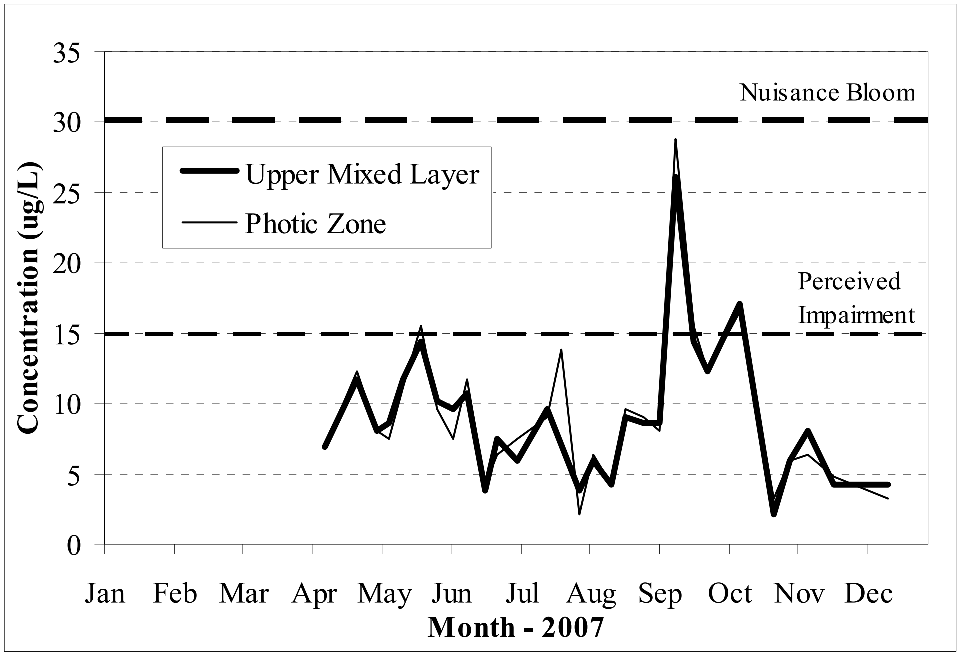

Figure 3-7. Chlorophyll-a concentration at South Deep, upper mixed layer and photic zone sampling, during 2007.

Notes: Upper mixed layer samples are composited from the 0- and 3-meter depths always; and may also include the 6-meter depth (depending on the field temperature profile) during the summer stratified period. During the summer of 2007 (June 1 to September 30), the UML samples were collected from 3 to 7 meters. The Photic Zone is defined as the area from the surface to the 2-times the Secchi disk transparency depth. During the summer of 2007, Secchi depth at South deep ranged from 1.0 to 3.6 meters; as a result, the bottom of the Photic Zone ranged from 2.0 to 7.2 meters.

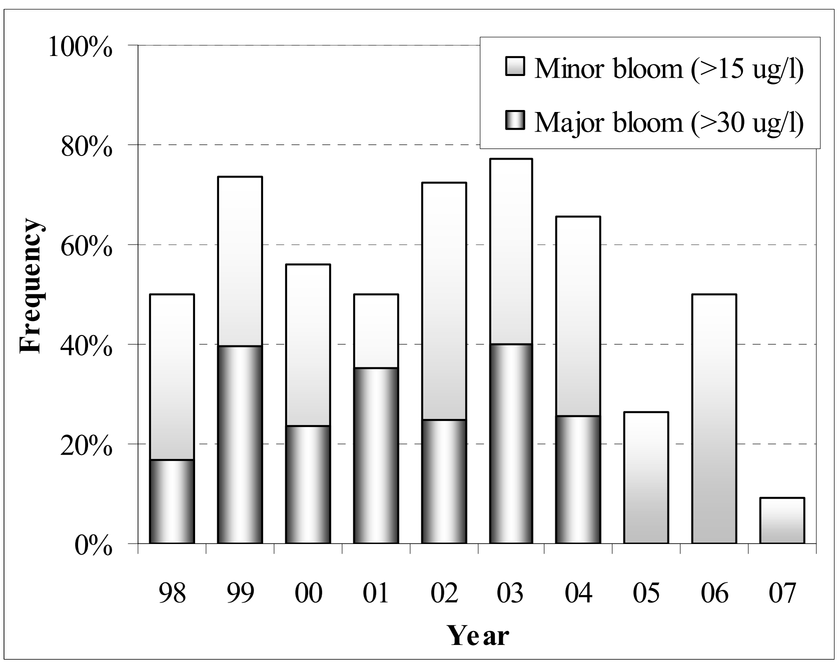

Figure 3-8. Percent of summer (June 1 to Sept 30) chlorophyll-a measurements exceeding algal bloom thresholds in Onondaga Lake, 1998-2007.

Table 3-5. Progress towards water quality improvement: Chlorophyll-a. AMP 2007 Annual Report. (Narrative Standard, Assessment Measure)

AMENDED CONSENT JUDGMENT GOAL

Reduction in average and peak algal biomass, and frequency and duration of bloom conditions as a result of reduced phosphorus loading from Metro, to achieve desired uses of the lake for water contact recreation, aesthetics and aquatic life protection.

Hypotheses to be tested:	**Status:**		
Metro improvements and watershed phosphorus load reductions result in lower chlorophyll-a concentrations in the lake.	• 2005 – HRFS phosphorus treatment came on-line; reduced percent contribution of phosphorus to lake from 49% to 28%. • Chlorophyll-a concentrations have been below the nuisance bloom threshold (30 µg/l) during the summer since 2005.		
Current Conditions with Historical Comparison			
Major Sources	Internal algal production based on nutrients (phosphorus is limiting as of late 1990s), light, and temperature.		
Upper Waters and Photic Zone Concentrations *(Summer= June 1 – September 30, Annual = January 1 – December 31; includes samples designated as "South", "Photic", "Epi", "UML", or "Tube", at depths ranging from 0 to 8 meters)*	Time Period	Summer Average (µg/l) with Standard Deviation	Annual Maximum (µg/l) with Date Observed
	1990-1997:	23.4 (14.6)	716.4 (07/11/1990)
	1998-2004:	24.3 (4.66)	129.2 (04/30/2001)
	2005-2006:	14.8 (3.42)	35.8 (03/28/2006)
	2007:	9.63	28.8 (09/11/2007)
Compliance with NYS AWQS and Guidance Value *(No NY State standard or guidance value for chlorophyll-a. Narrative P standard references algal abundance at nuisance levels. Federal guidance based on ecoregion and reference lakes)*	Time Period	Percent exceeding 15 µg/l (Perceived impairment)	Percent exceeding 30 µg/l (Nuisance bloom)
	1990-1997:	49%	26%
	1998-2004:	65%	31%
	2005-2006:	38%	0%
	2007:	9%	0%
Factors Affecting Compliance	Nutrients, light, temperature, grazing pressure, species composition		
Planned Load Reductions (1998 – 2012)			
Metro SPDES Permit Requirement	• No SPDES requirement for chlorophyll-a • Staged reduction in total phosphorus load from Metro • Staged implementation of CSO and watershed projects to reduce phosphorus loading from nonpoint sources		
Monitoring and Assessment Program			
Lake Monitoring *(Annual County monitoring program)*	• Weekly measurements at South Deep Station, May–September *Collected as depth-integrated tube samples through the UML of the water column and as photic zone (2x Secchi depth,) composites. The UML depth is determined by the temperature profile; should no distinct thermocline be present, 0, 3, 6 meters in depth is the UML default.*		
Related Biological Monitoring	• Phytoplankton community measurements biweekly April-November • Zooplankton community measurements biweekly April-November • Alewife monitoring by hydroacoustics		
Tools for Decision Making			
Model	• Onondaga Lake Water Quality Model (under development by QEA,LLC) • Mass balance TP framework and linked empirical eutrophication model (William Walker)		
TMDL Allocations	Phosphorus - NYSDEC Phase I TMDL 8/27/97; Phase II TMDL by January 2009		

3.2.4.2 Phytoplankton Community

AMP Hypotheses To Be Tested:

- Metro improvements and watershed phosphorus load reductions result in lower biomass of phytoplankton in Onondaga Lake.
- Metro improvements and watershed phosphorus load reductions result in reduced importance of cyanobacteria to the lake's phytoplankton biomass.

The phytoplankton community is monitored to assess community structure and the importance of cyanobacteria (blue-green algae) in the community. The data are correlated with chlorophyll-a, and trends in abundance and biomass reflect changes in the lake.

Since the 1960s, summer blooms of planktonic algae have been associated with the eutrophic conditions of the lake. However, phytoplankton biomass has decreased in recent years when compared to the late 1990s (**Figure 3-9**).

There has also been a change in the composition of the algal community. The percent of the biomass contributed by cyanobacteria has decreased over time (**Figure 3-10**). In addition, the duration and intensity of the cyanobacterial blooms in Onondaga Lake have declined from 1996 through 2007 (**Chapter 5**). The limited cyanobacterial productivity observed from 2004 through 2007 appears to signal an overall improvement of water quality.

Table 3-6 summarizes the progress toward water quality improvement for phytoplankton.

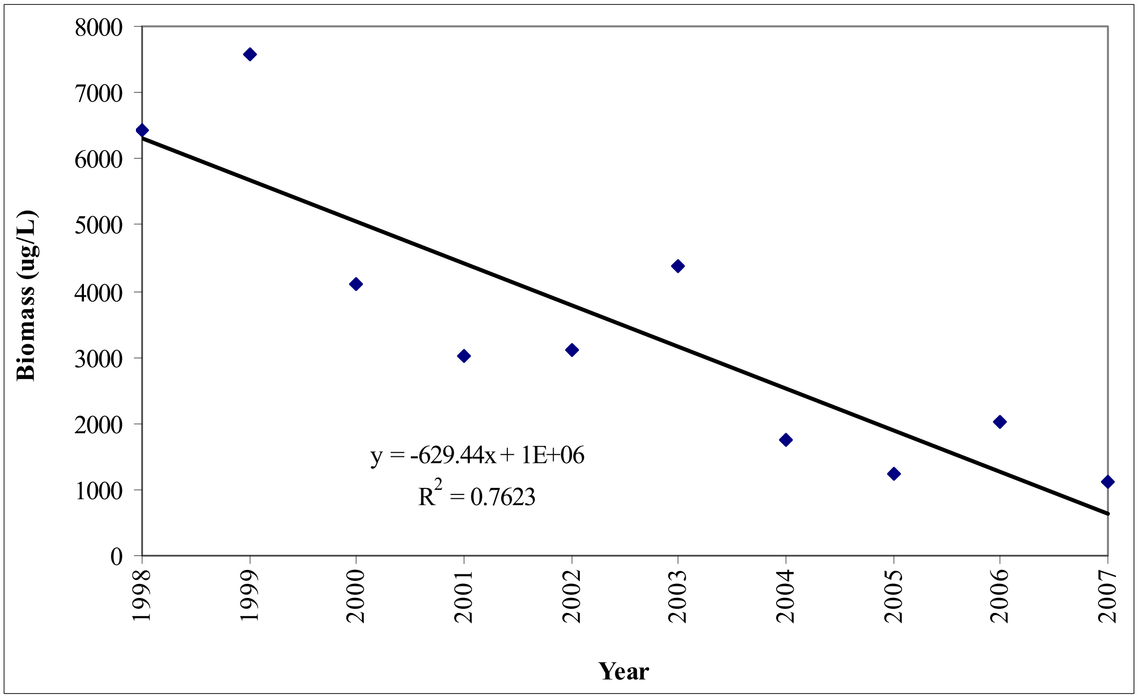

Figure 3-9. Annual average phytoplankton biomass in Onondaga Lake, South Deep Station, 1998-2007.

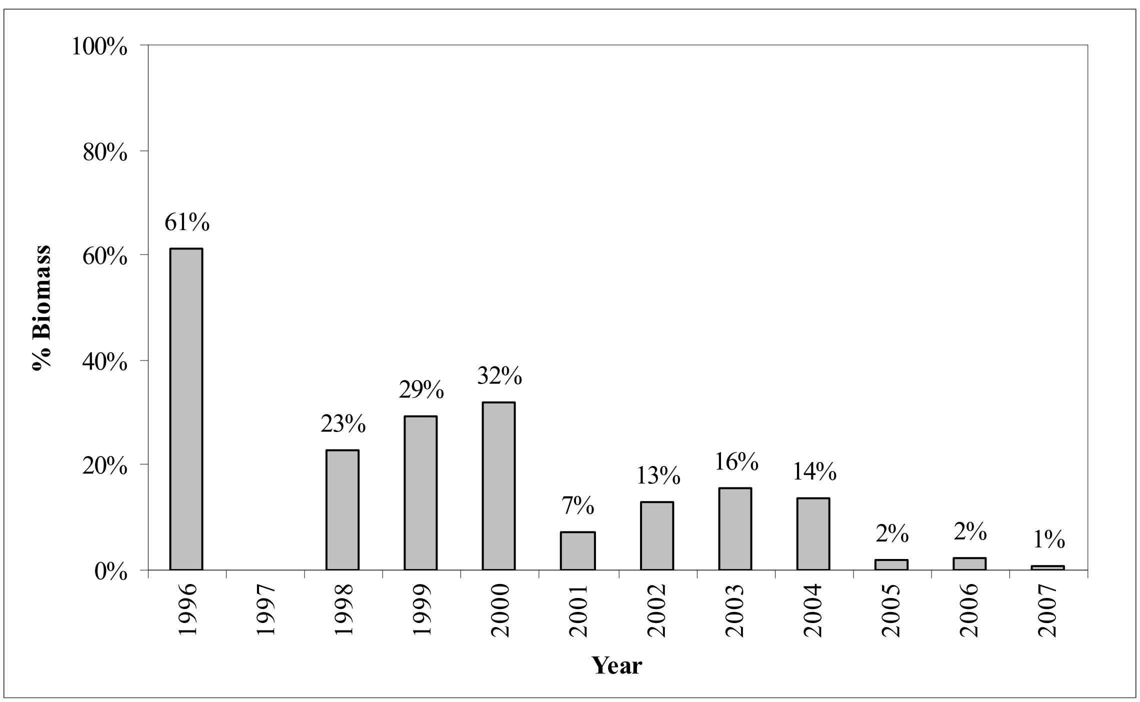

Figure 3-10. Percent contribution of cyanobacteria (blue-green algae) to the phytoplankton community from 1996 to 2007, Onondaga Lake South Deep Station.
Note: 1997 data were not analyzed for biomass.

Table 3-6. Progress towards water quality improvement: Phytoplankton. AMP 2007 Annual Report. (Assessment Measure)

AMENDED CONSENT JUDGMENT GOAL

Reduce the frequency, magnitude and duration of elevated chlorophyll-a- concentrations in Onondaga Lake during the recreational period. Reduce the abundance of cyanobacteria (blue-green algae) in phytoplankton biomass

Hypotheses to be tested:	**Status:**
Metro improvements and watershed phosphorus load reductions result in lower biomass of phytoplankton in Onondaga Lake.	• Since Metro improvements have reduced ammonia and phosphorus loading to the lake, the biomass of phytoplankton in the lake has also declined.
Metro improvements and watershed phosphorus load reductions, reflected in a higher N:P ratio, result in reduced importance of cyanobacteria to the lake's phytoplankton biomass.	• Since Metro improvements have reduced ammonia and phosphorus loading to the lake, the proportion of cyanobacteria in the phytoplankton community has also declined.
Current Conditions with Historical Comparison	
Biomass *(Annual average (standard deviation))*	1998-2004: 5535 µg/L (2688 µg/L) 2005-2006: 2097 µg/L (787 µg/L) 2007: 1109 µg/L
Community Composition *(Annual average biomass (standard deviation))*	Cyanobacteria / All Others 1998-2004: 19% (9%) / 81% (9%) 2005-2006: 2% (0.02%) / 98% (0.02%) 2007: 1% / 99%
Factors affecting algal community	Nutrients, light, temperature, grazing pressure from *Daphnia*
Monitoring and Assessment Program	
Lake Monitoring *(Annual County monitoring program)*	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 • Cyanobacteria relative importance • Shifts 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	
Model	Onondaga Lake Water Quality Model (under development by QEA,LLC)
TMDL Allocations	Phosphorus - NYSDEC Phase I TMDL 8/27/97; Phase II TMDL by January 2009

3.2.4.3 Nearshore Metaphyton (Macroalgae)

Filamentous algae (metaphyton or macroalgae) are a water quality and aesthetic issue with the potential to affect recreational use of Onondaga Lake and its shoreline. Mats of algae accumulate on aquatic plants during the summer months. Wind can cause floating algae to accumulate in certain areas of the lake but, depending on duration and intensity, can also cause the mats to break up and wash ashore where the mats decay and create an unpleasant odor.

> AMP Hypothesis To Be Tested:
>
> Metro improvements and watershed phosphorus load reductions result in reduced areal coverage of macroalgae in nearshore areas of Onondaga Lake

Distribution of filamentous algae is highly variable, both spatially and temporally. The presence and density of algal mats is controlled by water quality (light, nutrients, and temperature) in addition to wind direction and speed. The County has monitored nearshore metaphyton coverage each year since 2004. **Figure 3-11** presents a summary of these observations. **Table 3-7** summarizes the progress toward water quality improvement for metaphyton.

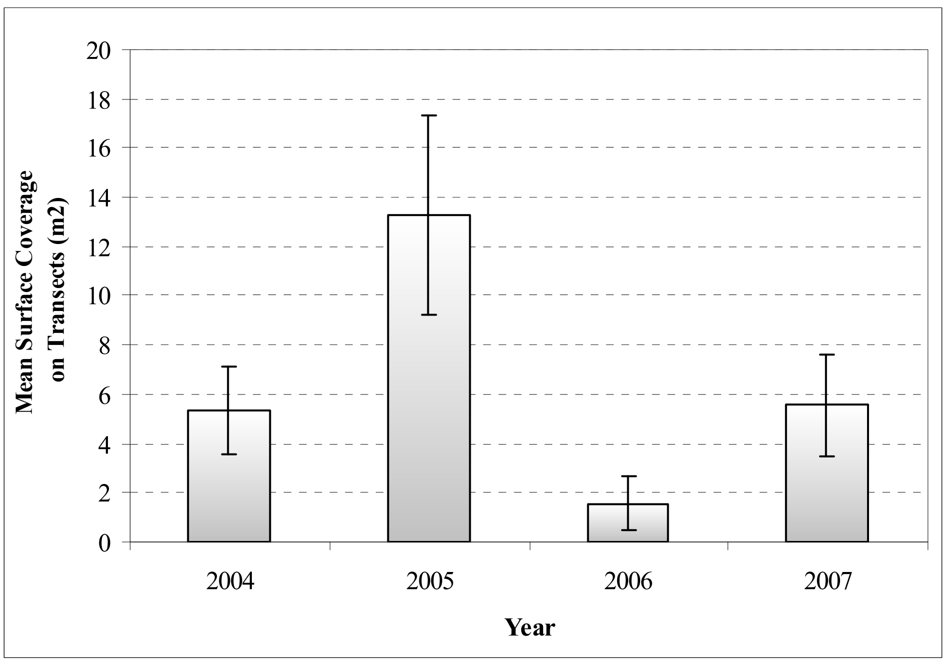

Figure 3-11. Macroalgae abundance at nearshore sample locations in Onondaga Lake from 2004 to 2007.

Table 3-7. Progress towards water quality improvement: Metaphyton. AMP 2007 Annual Report. (Assessment Measure)

AMENDED CONSENT JUDGMENT GOAL

Reduction of the areal coverage of metaphyton (filamentous algae) to improve aesthetic quality of the lake for recreational use, and improve conditions for growth of aquatic plants.

Hypotheses to be tested:	**Status:**
Metro improvements and watershed phosphorus load reductions result in reduced areal coverage of metaphyton in nearshore areas of Onondaga Lake	• Metaphyton coverage was moderate compared to past years.
Current Conditions with Historical Comparison	
Estimated Areal Coverage *(Annual average (standard deviation))*	2004: 5.34 (8.12) square meters (eight stations) 2005: 13.2 (17.2) square meters (eight stations) 2006: 1.57 (4.51) square meters (nine stations) 2007: 5.55 (8.66) square meters (nine stations)
Factors affecting abundance of macroalgae	Phosphorus, water clarity, zebra mussels, lake water level, water temperature, wind, emerged macrophyte growth.
Monitoring and Assessment Program	
Lake Monitoring *(Annual County monitoring program)*	• Weekly surveys during recreational period (June –Sept) at nine nearshore stations (Wastebeds station added in 2006) (see Figure 1 Appendix 1) • Semi-quantitative method employed using visual observation and measurements

3.2.4.4 Water Clarity

Water clarity is also associated with phosphorus loading in the lake. The algal blooms that result from phosphorus loading cloud the water, reducing clarity and turning the water green. Nutrient load reductions are expected to result in improved water clarity as algal biomass is reduced, eventually achieving compliance with recreational safety and aesthetics guidelines.

> AMP Hypothesis To Be Tested:
>
> Metro improvements and related nutrient load reductions result in improved water clarity (as measured by Secchi disk transparency) in Onondaga Lake

Algal biomass, and by extension water clarity, is also affected by grazing pressure from the zooplankton community. In the absence of other limiting factors, predation controls maximum possible growth of phytoplankton (**Mills et al. 1987).**

The 2007 Secchi disk transparency results measured at the deepest point in Onondaga Lake (South Deep station) ranged from 1.0 to 3.6 meters. As shown in **Figure 3-12**, water clarity was greater from summer to fall than in spring to summer. The lowest Secchi disk transparency measurements (1.0 m) were recorded on April 24, June 5 and June 22, when chlorophyll-a concentrations were relatively low; the June 22 result was associated with a rainfall event[3]. Since there was no correlation between Secchi disk transparency measurements and chlorophyll-a concentration, it appears that algae were not the sole factor affecting water clarity during this period.

Seventy percent of the Secchi disk transparency measurements at the South Deep station between June 1 and September 30 exceeded 1.5 m, one guidance value used to indicate suitability for recreational use and aesthetic quality (USEPA Clean Lakes Program Guidance 2000). This suggests that at least 70% of the time during 2007, the lake appeared clear and aesthetically pleasing.

As part of the AMP's focus on indicators of recreational use attainment, Secchi disk transparency measurements were obtained during weekly sampling at nine nearshore lake stations from June 5 – September 25, 2007. The nearshore areas exhibited good water clarity at the north end of the lake during the 2007 monitoring period (**Figure 3-13**). Elevated turbidity was more pronounced in the lake's southern basin which is affected by inflows of the larger tributaries. Reduced water clarity in the nearshore areas may be caused by phytoplankton, sediments entrained in the water (either from plumes entering through the tributary streams or resuspended bottom material), and the presence of algal mats. Wind and waves contribute to resuspension of unstable sediments in the littoral zone as well.

Table 3-8 summarizes the progress toward water quality improvement for Secchi disk transparency.

[3] The June 22 sampling event was a special, nearshore only sampling conducted in response to nearly 2.0 inches of rainfall over 3.5 hours that occurred on June 19.

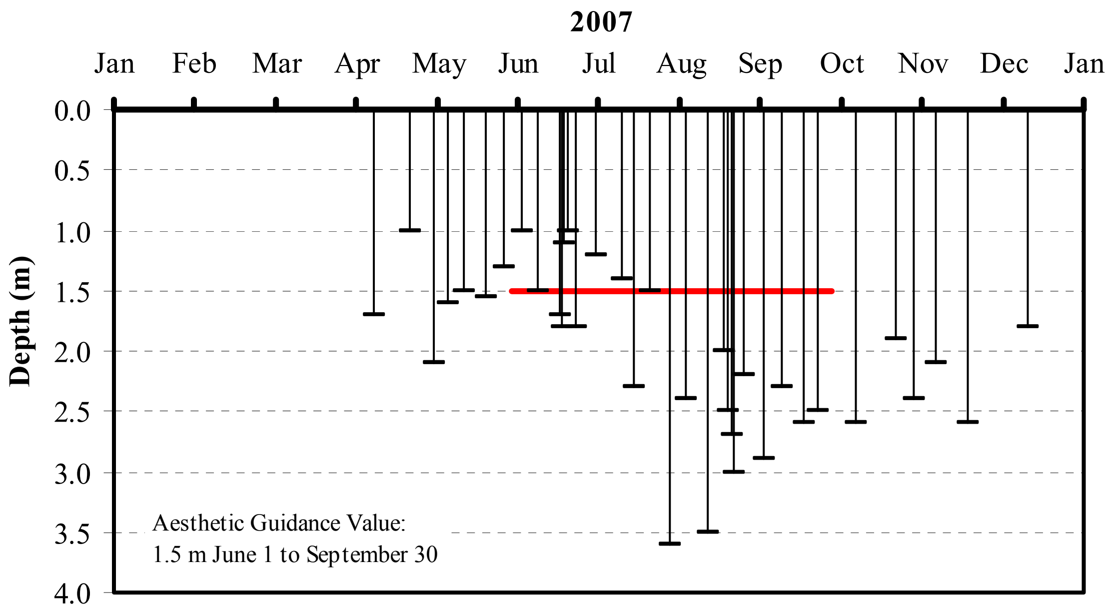

Figure 3-12. Secchi disk transparency in the upper mixed layer of Onondaga Lake during 2007. South Deep Station Locations: "Lake Upper Mixed Layer South" and "Lake 0m South".

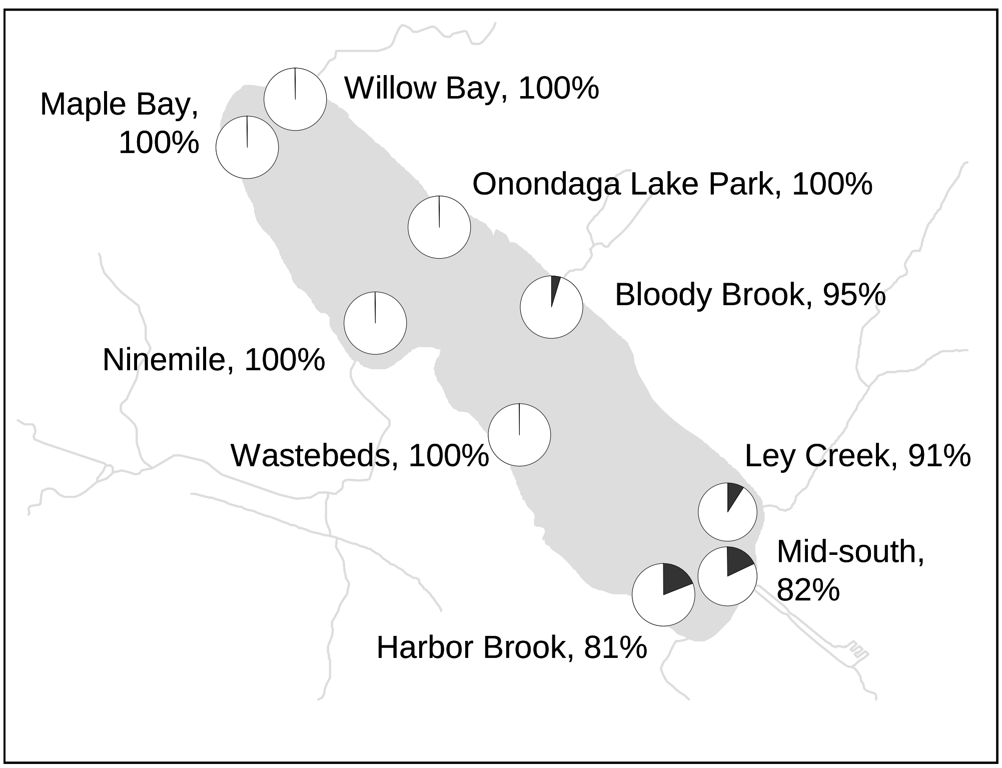

Figure 3-13. Nearshore water clarity conditions in 2007. Percent shown in figure indicates compliance with swimming safety guidance value (1.2 m). Shaded area of pie charts indicates percent of samples where Secchi depth was below guidance value for the period June 1 through September 30.

Table 3-8. Progress towards water quality improvement: Secchi Disk Transparency. AMP 2007 Annual Report. (Guidance Value)

AMENDED CONSENT JUDGMENT GOAL

Eliminate turbidity as an impairment to use of the lake for water contact recreation. Improve water clarity to meet aesthetic quality and public bathing beach safety objectives.

Hypotheses to be tested:	**Status:**
Metro improvements and related nutrient load reductions result in improved water clarity (as measured by Secchi disk transparency) in Onondaga Lake	• Since the 1990's, there has been an increase in the percent of summer Secchi disk measurements that exceed 1.5 m at the South Deep station • Over the past nine years of monitoring at the nearshore stations, there has been an increase in the percent of summer Secchi disk measurements that exceed the NYS DOH 1.2 m safety guidance value for bathing beaches.

Current Conditions with Historical Comparison

Secchi Disk Transparency
(Jun 1 to Sep 30 average (standard deviation))

Time Period	South Deep Station (m)	Nearshore Stations (Class B & C) (m)
1990-1997:	2.1 (0.47)	*No data 1990 - 1998*
1998-2004:	1.9 (0.37)	1.5 (0.17) *(starting 1999)*
2005-2006:	1.7 (0.11)	1.5 (0.09)
2007:	2.1	2.1

Compliance with NYS AWQS and Guidance Value
(Jun 1 to Sep 30 average (standard deviation); No NY State standard or guidance value for Secchi disk transparency. NYS DOH bathing beach swimming safety guidance value of 1.2m)

Time Period	South Deep measurements % greater than 1.5 m	Nearshore (Class B & C) % greater than 1.2 m
1990-1997:	54% (25%)	*No data 1990 - 1998*
1998-2004:	62% (20%)	70% (15%) *(starting 1999)*
2005-2006:	66% (6%)	74% (3%)
2007:	70%	94%

2007 - Nearshore Stations Class B % measurements greater than 1.2 m	2007 - Nearshore Stations Class C % measurements greater than 1.2 m
Bloody Brook: 95%	Ninemile Creek: 100%
Eastside: 100%	Harbor Brook: 81%
Maple Bay: 100%	Ley Creek: 91%
Wastebeds: 100%	Mid-south: 82%
Willow Bay: 100%	

Factors Affecting Water Clarity: Algal abundance (depends on light, temperature, nutrients and grazing pressure), external loading of suspended solids, re-suspension of bottom sediments, precipitation of calcite, suspension of sediment from tributary high flow

Planned Load Reductions (1998 – 2012)

Metro SPDES Permit Requirement
- No SPDES requirement for Secchi disk transparency
- Staged reduction in total phosphorus load from Metro
- Staged implementation of CSO and watershed projects to reduce phosphorus loading from nonpoint sources

Monitoring and Assessment Program

Lake Monitoring
(Annual County monitoring program)
- Biweekly measurements of Secchi disk at South Deep (weekly between 5/1 and 9/30)
- Nearshore Secchi disk measurements: weekly (summer). and following storm events

Related Biological Monitoring
- Phytoplankton and zooplankton abundance and community composition
- Alewife hydroacoustic surveys

Table 3-8. Progress towards water quality improvement: Secchi Disk Transparency. AMP 2007 Annual Report. (Guidance Value) – *continued*

Tools for Decision Making	
Models	• Mass balance TP framework and linked empirical eutrophication model (William Walker) • Onondaga Lake Water Quality Model (under development by QEA,LLC)
TMDL Allocations	Phosphorus - NYSDEC Phase I TMDL 8/27/97; Phase II TMDL by January 2009

3.2.4.5 Macrophytes

Aquatic plants, or macrophytes, are an important component in the aquatic habitat. The plants provide the fish with nursery areas and cover from predators. The macrophyte data collected are used to evaluate fish habitat, compare Onondaga Lake to other regional lakes, and identify trends in growth that may reflect changes in the lake. As reductions in phosphorus loading contribute to reduced algal blooms and improved water clarity, areal coverage of macrophytes is expected to increase, along with an increase in macrophyte species present in the lake.

AMP Hypotheses To Be Tested:

- Metro improvements and watershed phosphorus load reductions indirectly result in increased areal coverage of macrophytes in littoral zone of Onondaga Lake.
- Metro improvements and watershed phosphorus load reductions indirectly result in increased number of macrophyte species in Onondaga Lake.

The AMP-related hypothesis is likely to be an oversimplification. Other factors, including the expansion of zebra mussels, climatic effects, and continued invasions of non-native species are likely to affect the macrophyte coverage. Recent changes in the macrophyte community are discussed in Chapter 5.

Table 3-9 summarizes the progress toward water quality improvement for macrophytes.

Table 3-9. Progress towards water quality improvement: Macrophytes. AMP 2007 Annual Report. (Assessment Measure)

AMENDED CONSENT JUDGMENT GOAL

Expansion of the areal coverage and increase in diversity of macrophyte community, where number of species and biomass in the littoral zone (6m water depth) are comparable to other regional lakes. Increase percent cover of littoral zone to optimal levels (40% – 60%) for largemouth bass habitat, to achieve desired use of the lake for warmwater fish reproduction.

Hypotheses to be tested:	**Status:**
Metro improvements and watershed phosphorus load reductions indirectly result in increased areal coverage of macrophytes in littoral zone of Onondaga Lake.	• Metro improvements to reduce nutrient loading were implemented in 2004 (BAF) and 2005 (HRFS) • Areal coverage in the littoral zone has increased between 2000 and 2005
Metro improvements and watershed phosphorus load reductions indirectly result in increased number of macrophyte species in Onondaga Lake.	• The number of macrophyte species has increased from 5 in 1991 to 17 in 2005; the next survey will be conducted in 2010.

Current Conditions with Historical Comparison

Community Composition *(Lakewide)*	Year	Number of species present	Dominant species by relative % cover
	1991:	5	*no data*
	2000:	10	Sago pondweed (52%) Common waterweed (26%)
	2005:	17	Common waterweed (62%) Coontail (19%)
	1991 data from John Madsen, Army Corps of Engineers, 1996		
Biomass *(Lakewide average)*	1991: *no data* 2000: 16 g/m^2 dry weight 2005: 51 g/m^2 dry weight		
Species Richness *(Transect average)*	1991: 1.3 species per transect (Madsen et al 1996) 2000: 3.6 species per transect 2005: 6.0 species per transect		
Percent of Subplots with Macrophytes	1991: 13% (Madsen et al 1996) 2000: 28% 2005: 62%		
Percent Cover in littoral zone *(Lakewide average)*	1991: *no data* 2000: 18% 2005: 26%		
Aerial Photographs	2000: 85 acres (11%) 2001: 134 acres (17%) 2002: 142 acres (18%) 2003: 267 acres (34%)	2004: No data 2005: 378 acres (49%) 2006: 183 acres (24%)* 2007: 210 acres (27%)*	
	Percent indicates percent coverage of littoral zone. Aerial photographs were obtained in June except for 2006 and 2007 when the photographs were taken in August.		
Factors affecting macrophyte community	• Sediment texture (oncolites are nutrient-poor and unstable), light penetration, salinity, zebra mussels		

Table 3-9. Progress towards water quality improvement: Macrophytes. AMP 2007 Annual Report. (Assessment Measure) (continued).

Monitoring and Assessment Program	
Lake Monitoring	• Survey species composition, percent cover, and biomass every 5 years, from 2000 to 2010. • Annual aerial photographs of littoral zone to estimate acres of macrophytes. *Metrics to track over time* • Number of species (richness) • Percent cover • Biomass
Tools for Decision Making	
Qualitative and Quantitative Analysis	Compare to baseline survey in 2000

3.2.4.6 Dissolved Oxygen

Dissolved oxygen (DO) is important to aquatic life in the lake. Phosphorus loading to the lake affects DO concentrations, as phosphorus supports algal production; algal cells are decomposed by microorganisms that deplete oxygen dissolved in the lake water. When DO is too low, it is harmful to many forms of aquatic life.

AMP Hypotheses To Be Tested:

- Improvements at Metro enable the County to meet interim effluent limits for BOD

Five-day biochemical oxygen demand (BOD-5) is monitored as an indicator of oxygen-demanding material, to provide support for model development, and to analyze trends. The 2007 loading results are summarized and compared with the long-term average (**Table 3-10**). The major sources of 5-day BOD in 2007 were Metro Outfall 001, Onondaga Creek, and Ninemile Creek. Onondaga County has met their SPDES effluent limits for BOD since 2004. Flow-weighted concentrations are presented in **Appendix 12.**

Table 3-10. Summary of BOD loading and long-term comparison.

Tributary	2007 Loading		2007 Percent contribution by gauged inflow	
	Water (hm^3)	***BOD-5 (mt)***	***Water***	***BOD-5***
Metro:				
Metro Outfall 001	88	459	18%	32%
Metro Outfall 002	1.4	81	0.29%	5.6%
Natural Tributaries:				
Onondaga Creek	183	382	37%	26%
Ninemile Creek	170	385	34%	27%
Ley Creek	39	94	7.8%	6.5%
Harbor Brook	14	42	2.8%	2.9%
Industrial Tributaries:				
East Flume	0.68	2.6	0.14%	0.18%
Trib 5A	0.56	1.7	0.11%	0.12%
Total Monitored	**496**	**1,447**	**100%**	**100%**
Average 1990-2006:		**2,457**		
%Change 2007 from Average:		**-41%**		

The DO content of the lake's upper and lower waters during 2007 as measured by in-situ probes is plotted in **Figure 3-14.** The probes measured DO at 15-minute intervals; these high frequency data have been tracked since 1999 to evaluate changes in lake DO. The upper waters (2-meter depth) remained well-oxygenated throughout 2007; the lowest instantaneous reading for the year was 6.72 mg/L on August 15th. The 2-meter probe is consistently in the upper mixed layer and is not subject to surface turbulence. At the onset of thermal stratification, there is a rapid decline of DO in the lower waters (12-meter depth). Anoxic conditions set in by mid-July. As thermal stratification broke down in late October (October 27), dissolved oxygen increased at the 12-meter depth as the upper and lower waters continued to mix and gain oxygen from the atmosphere.

AMP Hypothesis To Be Tested:

- Improvements at Metro and related nonpoint source phosphorus load reductions bring the lake's upper waters into compliance with the ambient water quality standard for dissolved oxygen during fall mixing.

Over time, the dissolved oxygen concentrations during fall turnover have been increasing (**Figure 3-15**). Since 2005, the daily average minimum concentrations have exceeded 7 mg/l. This coincides with the improvement in phosphorus concentrations in the lake since implementation of the HRFS system at Metro in February 2005.

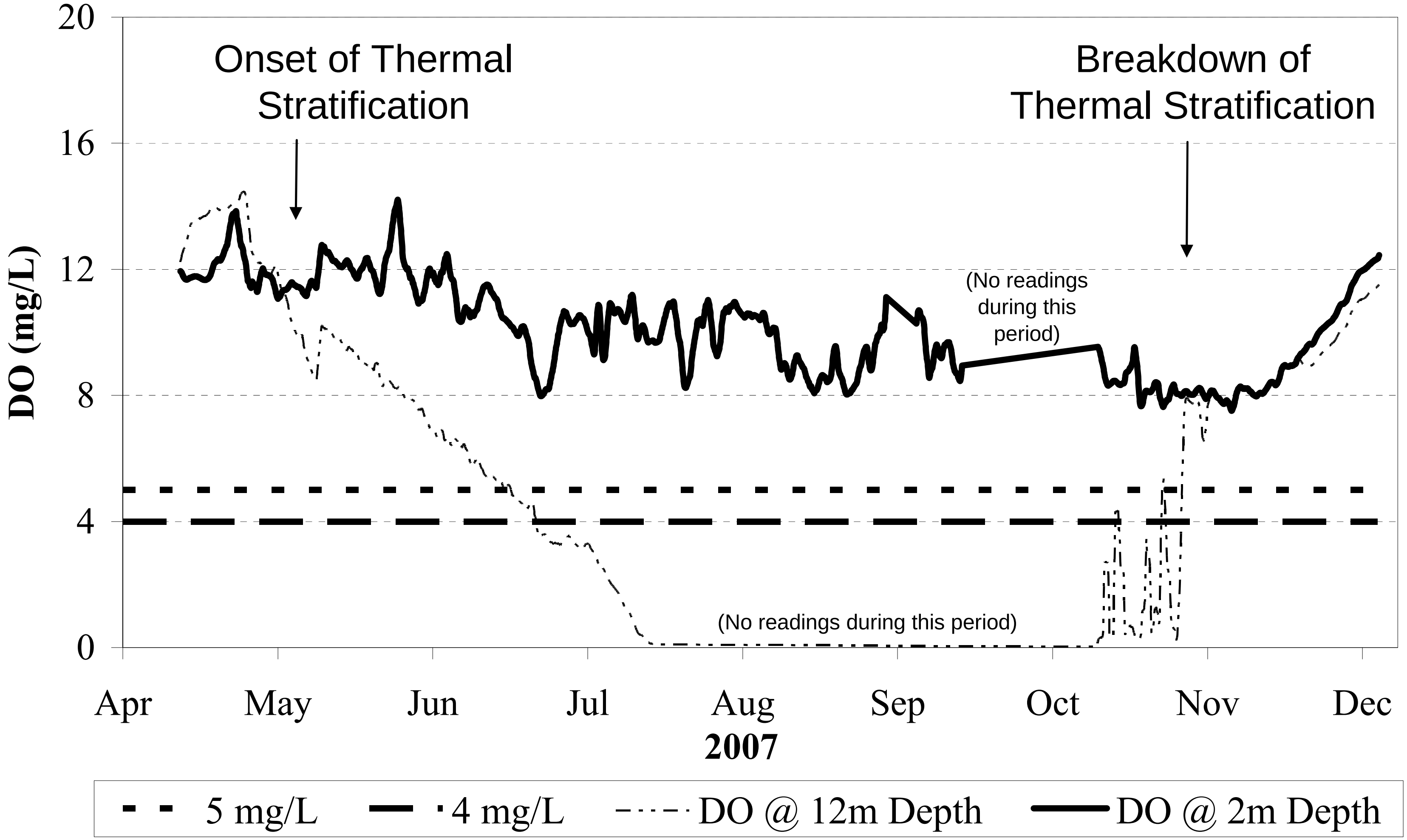

Figure 3-14. Temporal pattern of DO at 2 and 12 meter depths in Onondaga Lake, South Deep Station high frequency monitoring buoy, during 2007.

Note: Data are presented as a moving average, over a 24-hour period, of hourly average DO readings. Lines at 5 mg/L and 4 mg/L designate NYSDEC daily average and instantaneous standards, respectively. To prevent damage to the in-situ probes in the lower waters from long-term exposure to anoxic conditions, these probes are removed when DO levels drop to zero. The lower-level probes are re-installed prior to fall mixing.

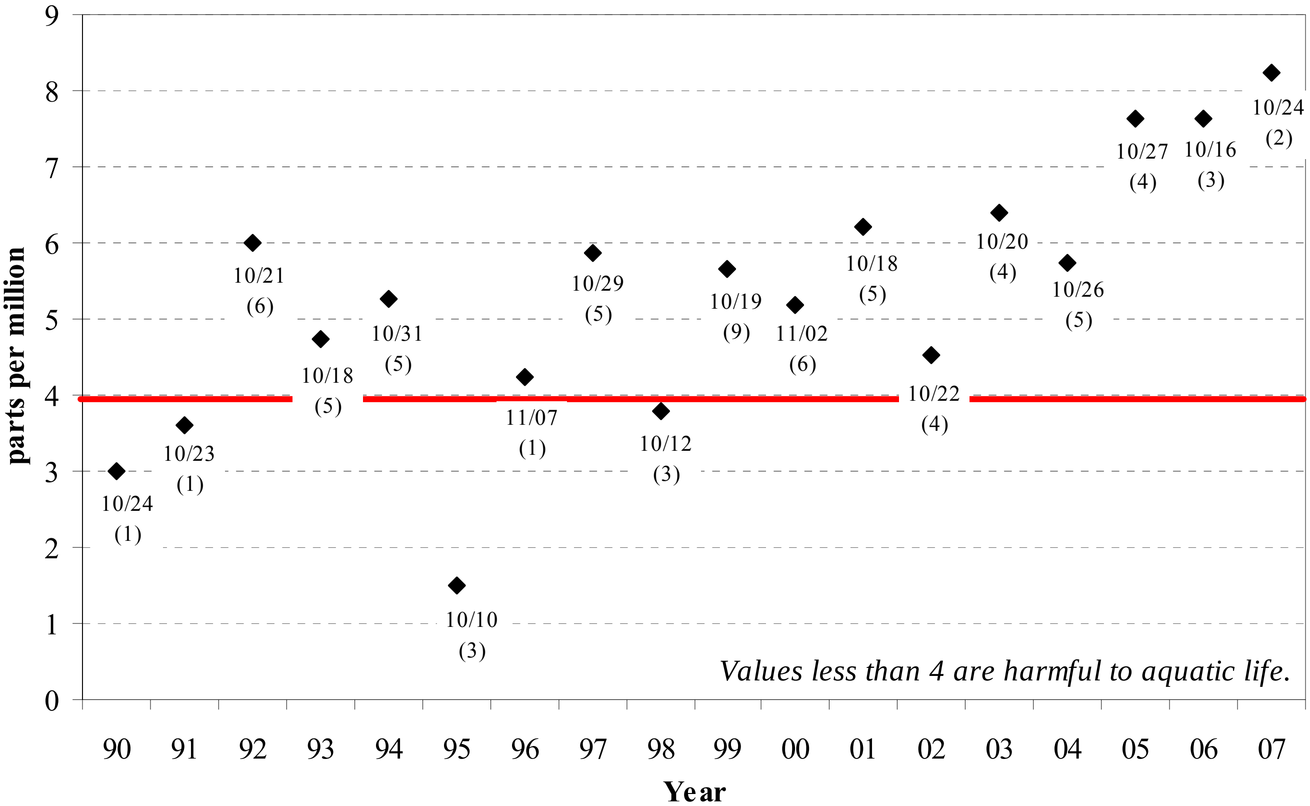

Figure 3-15. Upper waters (0-3m) daily average minimum dissolved oxygen, South Deep field profiles.
Note: Time period based on one week plus and minus the date (shown) of minimum daily average for October and November each year. The minimum daily average during this period is assumed to represent fall turnover, the timing of which varies from year to year. Number of profiles during the period is shown in parentheses.

One measure of the lake's dissolved oxygen status is "volume-days of anoxia". This measurement has been used in Long Island Sound and other aquatic systems where low concentrations of dissolved oxygen (anoxia) are a significant water quality management issue. Both the volume of water affected by anoxia and the duration (days) of anoxia are calculated in a single measurement that can be tracked from year to year.

AMP Hypothesis To Be Tested:

- Improvements at Metro and nonpoint sources reduce the volume-days of anoxia and hypoxia

As shown in **Figure 3-16**, volume-days of hypoxia (defined as DO less than 2 mg/l) have decreased since the early 1990's. Volume-days of anoxia (defined as DO less than 0.5 mg/l) have also declined. In years prior to 2007, volume-days of anoxia account for a proportionally higher percentage of the volume-days of hypoxia; in 2007, the anoxia accounted for less than half of the total volume-days of hypoxia. This suggests continued improvement in DO conditions in the lake.

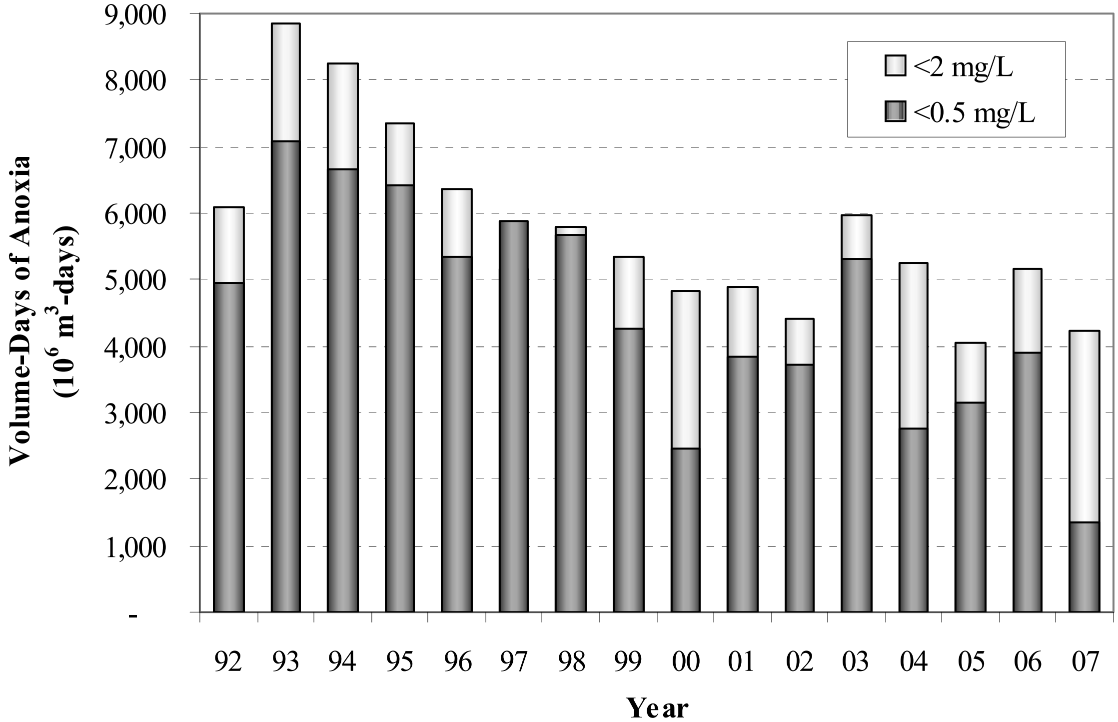

Figure 3-16. Volume-Days of anoxia in Onondaga Lake, South Deep Station 1992-2007 (using field profile dissolved oxygen readings taken at half-meter intervals down to about 20 meters depth.)

Aerial hypolimnetic oxygen depletion rates have been computed from oxygen and temperature profiles collected at 0.5 or 1.0 meter increments, as extracted from the AMP long-term water quality database. The rate reflects oxygen consumption below the thermocline between the first sampling date with thermal stratification and the last date prior to development of anoxic conditions (hypolimnetic mean < 2 mg/L). The areal rate is computed as the product of the mean hypolimnetic depth and the decrease in volume-averaged concentration divided by the number of days between sampling events. Rates have been computed for three assumed average thermocline levels (6, 9, 12 m).

> AMP Hypothesis To Be Tested:
>
> - Improvements at Metro and nonpoint sources reduce the areal hypolimnetic oxygen depletion rate.

For the period 2001-2005, the observed oxygen depletion rate was 998 mg/m^2-day. This was similar to the observed oxygen depletion rate for the period 2003-2007, at 987 mg/m^2-day.

Table 3-11 summarizes the progress toward water quality improvement for dissolved oxygen.

Table 3-11. Progress towards water quality improvement: Dissolved Oxygen. AMP 2007 Annual Report. (Water Quality Standard)

AMENDED CONSENT JUDGMENT GOAL

Achieve compliance with the applicable ambient water quality standard in the upper waters, and removal of oxygen depletion as impairment to designated best use for survival and propagation of a coolwater fish community such as walleye. Eliminate dissolved oxygen as impairment to desired uses of the lake for aquatic life protection and fish reproduction.

Hypotheses to be tested:	**Status:**
Improvements at Metro enable the County to meet interim effluent limits for BOD	• Since 2004, interim effluent limits for BOD have been met.
Improvements at Metro and nonpoint sources reduce the volume-days of anoxia and hypoxia.	• Volume days of anoxia and hypoxia have decreased since the 2004-2005 improvements at Metro to treat ammonia and phosphorus were implemented (BAF and HRFS, respectively).
Improvements at Metro and related nonpoint source phosphorus load reductions bring the lake into compliance with NYS AWQS for DO during fall mixing.	• Since 2003, NYS AWQS (daily average DO >5 mg/l) has been met in upper waters (0-3m) during fall turnover, based on field profiles data.
Improvements at Metro and nonpoint sources reduce the areal hypolimnetic oxygen depletion rate.	• The average oxygen depletion rate for the period 2001-2005 was 998 mg/m^2-day, and was 987 mg/m^2-day for the period 2003-2007. *The rate reflects oxygen consumption below the thermocline between the first sampling date with thermal stratification and the last date prior to development of anoxic conditions (hypolimnetic mean < 2 ppm). The areal rate is computed as the product of the mean hypolimnetic depth and the decrease in volume-averaged concentration divided by the number of days between sampling events.*

Current Conditions with Historical Comparison

Major Sources	Oxygen depletion in the LWL is primarily due to decomposing algal biomass (excess algae is caused by phosphorus load). Other sources include ultimate oxygen demand from organic material in watershed and reduced nitrogen species (including ammonia from Metro)
Upper Waters Concentration during fall mixing *(Annual Average of minimum daily averages (standard deviation))*	Time Period / South Deep, 0-3 meters (mg/l) 1994-2003: 5.5 (1.6) 2004-2006: 8.0 (1.6) 2007: 8.3 *(Source: calculated from field profile data collected 1 week before and 1 week after measured DO minimum for each year)*
Volume-days of anoxia *(Annual Average (standard deviation))*	Time Period / Anoxia (<0.5 mg/l) / Hypoxia (< 2 mg/l) 1994-2003: 4958 (1342) / 5834 (1209) 2004-2006: 3261 (577) / 4818 (664) 2007: 1360 / 4234 *(Source: calculated from field profile data)*
Compliance with NYS AWQS in Upper Waters *("For nontrout waters, the minimum daily average shall not be less than 5.0 mg/L, and at no time shall the DO concentration be less than 4.0 mg/L")*	In Onondaga Lake upper waters in 2007, the minimum daily average was 7.5 mg/l (11/6/2007), and the minimum instantaneous reading was 6.7 mg/l (8/15/2007 at 7:48 a.m.). *(Source: 2-meter depth in-situ buoy).*
Factors Affecting Compliance	Algal abundance (related to phosphorus load), ammonia N concentration and dynamics, meteorology,

Table 3-11. Progress towards water quality improvement: Dissolved Oxygen. AMP 2007 Annual Report. (Water Quality Standard) – (continued).

Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement	See staged effluent limits for total phosphorus Interim BOD limit: 21 mg/l (30-day average)
Monitoring and Assessment Program	
Loading Estimates *Annual County monitoring program*	• Biweekly tributary monitoring, supplemented with samples collected during high flow conditions to estimate TP, N and BOD inputs, which influence DO concentrations in the lake. • Storm event monitoring in tributaries • Daily measurements of Metro effluent
Lake Monitoring *Annual County monitoring program*	• Biweekly DO profiles in Lake, Apr to Nov, 0.5-meter intervals • 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 • Macroinvertebrate monitoring • Assessment of fish community
Tools for Decision Making	
Models	• Onondaga Lake Water Quality Model (under development by QEA,LLC) • Mass balance TP framework and linked empirical eutrophication model (developed by William Walker)
TMDL Allocations	• NYSDEC Phase I TMDL for phosphorus 8/27/97 • Phase II TMDL for phosphorus by January 2009

3.3 NITROGEN

Another focus of the AMP is external loading of nitrogen species (ammonia, nitrite and nitrate) to the lake. Elevated concentrations of ammonia can be toxic to aquatic life, particularly early life stages of sensitive organisms. By reducing ammonia loading to the lake, water quality conditions for aquatic life will improve.

Amended Consent Judgment Goals for Nitrogen:

- Achieve compliance with the applicable ambient water quality standard for ammonia in the upper waters, and removal of ammonia toxicity as impairment to designated best use for survival and propagation of a warmwater fish community
- Achieve compliance with the applicable ambient water quality standard for nitrite in the upper waters to meet designated best use for survival and propagation of a warmwater fish community

3.3.1 External Loading and Trends

Ammonia-N and nitrite-N loading from the Metro plant has decreased as a direct result of the improvements in ammonia treatment, including the nitrification provided by operation of the BAF which went on-line in January 2004. (**Figure 3-17**) Concurrent with the decrease in ammonia-N and nitrite-N, loading of nitrate-N has increased, since nitrate-N is the by-product of the nitrification process that the BAF operation provides.

In 2007, Metro represented the largest source of ammonia-N and nitrate-N to the lake, as percent contribution by gauged inflow on an annual basis (**Table 3-12**), exceeding the combined contributions of the other tributaries. The combined loadings of nitrite from the other tributaries exceeded the nitrite loading from Metro during 2007. Compared with the shift from ammonia to nitrate loading from Metro, the nitrogen loadings from the watershed remain relatively consistent year to year.

Ten-year trends in load and concentration for nitrogen species are listed in **Chapter 8** (**Tables 8-11 and 8-12**, respectively). Results are shown with and without adjustment for precipitation using the multiple regression technique described in **Chapter 8**. Some analyses were potentially impacted by detection limits for ammonia-N and nitrite-N at two sites with relatively low concentrations (Velasko and Dorwin).

Decreasing trends in load and concentration are indicated for nitrogen species (TKN, ammonia-N, nitrite-N) in the Metro discharge, total inflow, and total outflow. Decreasing trends in ammonia concentration and/or load are also indicated for all of the non-point inflows to the Lake. At sites with relatively low ammonia concentrations (Velasko, Dorwin), these trends are likely to be artifacts of the decrease in the ammonia Minimum Reportable Limit (MRL) from 0.1 to 0.03 ug/l over this period. Since these data are used to compute the net loads from the lower subwatersheds of Harbor Brook and Onondaga Creek, those results are suspect also. Results for other sites with concentrations in a higher range would not be impacted by the decrease in MRL. Flow-weighted concentrations are presented in **Appendix 12**.

Table 3-12. Summary of nitrogen loading and long-term comparison.

Tributary	2007 Loading					
	Water (hm^3)	*TKN (mt)*	*NH3-N (mt)*	*Nitrate-N (mt)*	*Nitrite-N (mt)*	*Org-N (mt)*
Metro:						
Metro Outfall 001	88	166	75	857	6.3	67
Metro Outfall 002	1.4	14	7.7	2.5	0.13	4.2
Natural Tributaries:						
Onondaga Creek	183	82	13	184	5.0	66
Ninemile Creek	170	104	34	160	3.6	69
Ley Creek	39	27	11	16	0.64	16
Harbor Brook	14	8.1	1.2	21	0.24	7.1
Industrial Tributaries:						
East Flume	0.68	0.67	0.27	2.3	0.77	0.36
Trib 5A	0.56	0.30	0.10	0.38	0.019	0.20
Total Monitored	**496**	**402**	**142**	**1,244**	**17**	**230**
Average 1990-2006:		**1,306**	**879**	**741**	**47**	**414**
% Change 2007 from Average:		**-69%**	**-84%**	**68%**	**-65%**	**-44%**

Notes: mt = metric tons; hm3 = million cubic meters. Metro Outfall 001 calculated loads of NH3-N are based on daily measurements. Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events). Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms.

Tributary	2007 Percent contribution by gauged inflow					
	Water	*TKN*	*NH3-N*	*Nitrate-N*	*Nitrite-N*	*Org-N*
Metro:						
Metro Outfall 001	18%	41%	53.1%	69%	38%	29%
Metro Outfall 002	0.29%	3.4%	5.4%	0.20%	0.75%	1.8%
Natural Tributaries:						
Onondaga Creek	37%	20%	9.1%	15%	30%	29%
Ninemile Creek	34%	26%	24%	13%	21%	30%
Ley Creek	7.8%	6.8%	7.6%	1.3%	3.8%	6.9%
Harbor Brook	2.8%	2.0%	0.83%	1.7%	1.4%	3.1%
Industrial Tributaries:						
East Flume	0.14%	0.17%	0.19%	0.19%	4.6%	0.16%
Trib 5A	0.11%	0.075%	0.071%	0.031%	0.11%	0.087%
Total Monitored	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

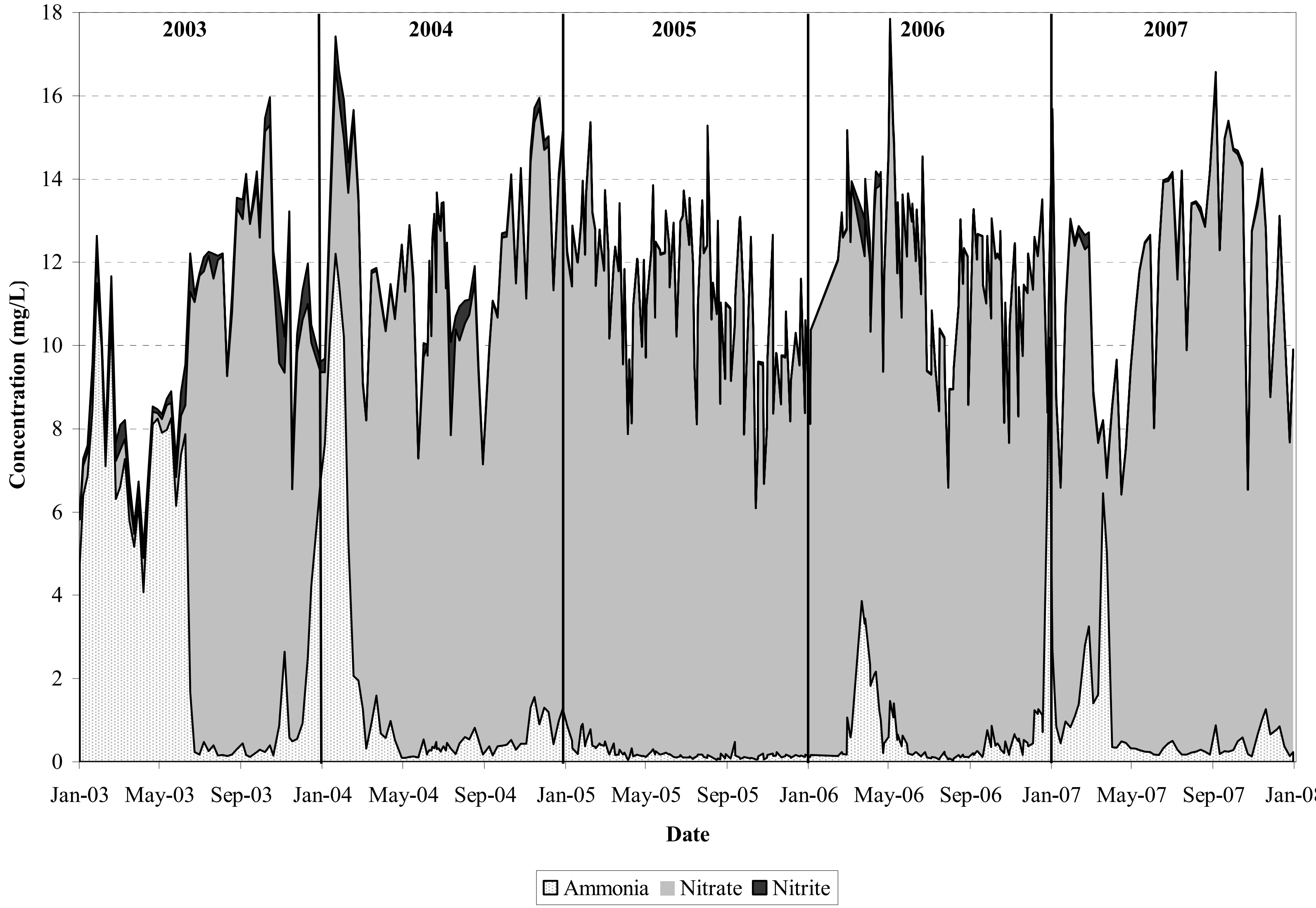

Figure 3-17. Inorganic nitrogen species concentration in Metro effluent over time.

3.3.2 Lake Concentration and Trends

Concentrations of ammonia and nitrite, the two potentially toxic forms of nitrogen, have declined in the lake as the Biologically Aerated Filtration (BAF) system came on line in 2004; this technology optimizes biological conversion of reduced N forms to nitrate. The water quality benefits of improved ammonia treatment at Metro were evident in the lake in 2007. As displayed in **Figure 3-18**, both ammonia-N and nitrite-N concentrations met the current NYS ambient water quality standards in the lake's upper waters.

AMP Hypotheses to be Tested:

- Reduced ammonia load results in compliance with ambient water quality standards and federal criteria for ammonia in Onondaga Lake
- Achievement of Stage III effluent limits for ammonia results in compliance with the NYS ambient water quality standard for nitrite (warmwater fish community)

The single most important factor governing ammonia-N and nitrite-N in the lake is Metro performance; recall that Metro Outfalls 001 and 002 have historically contributed more than 90% of the external ammonia-N load to the lake. The reduction in Metro loading achieved with the BAF – down to 53% of total external loading in 2007 – has resulted in improved water quality conditions in Onondaga Lake.

The lower waters of the lake exhibit an increase in ammonia-N during the stratified period (**Figure 3-19**), reflecting decay of settled organic matter (primarily phytoplankton) and release of ammonia from the sediments. At fall turnover, the ammonia accumulated in the LWL mixed throughout the water column, coming into contact with oxygen and becoming nitrified.

On an annual average basis over time, the LWL has exhibited a decrease in ammonia-N concentrations similar to the decrease in the UML concentrations as a result of improvements at Metro.

Table 3-13 and **Table 3-14** summarize the progress toward water quality improvement for ammonia and nitrite, respectively.

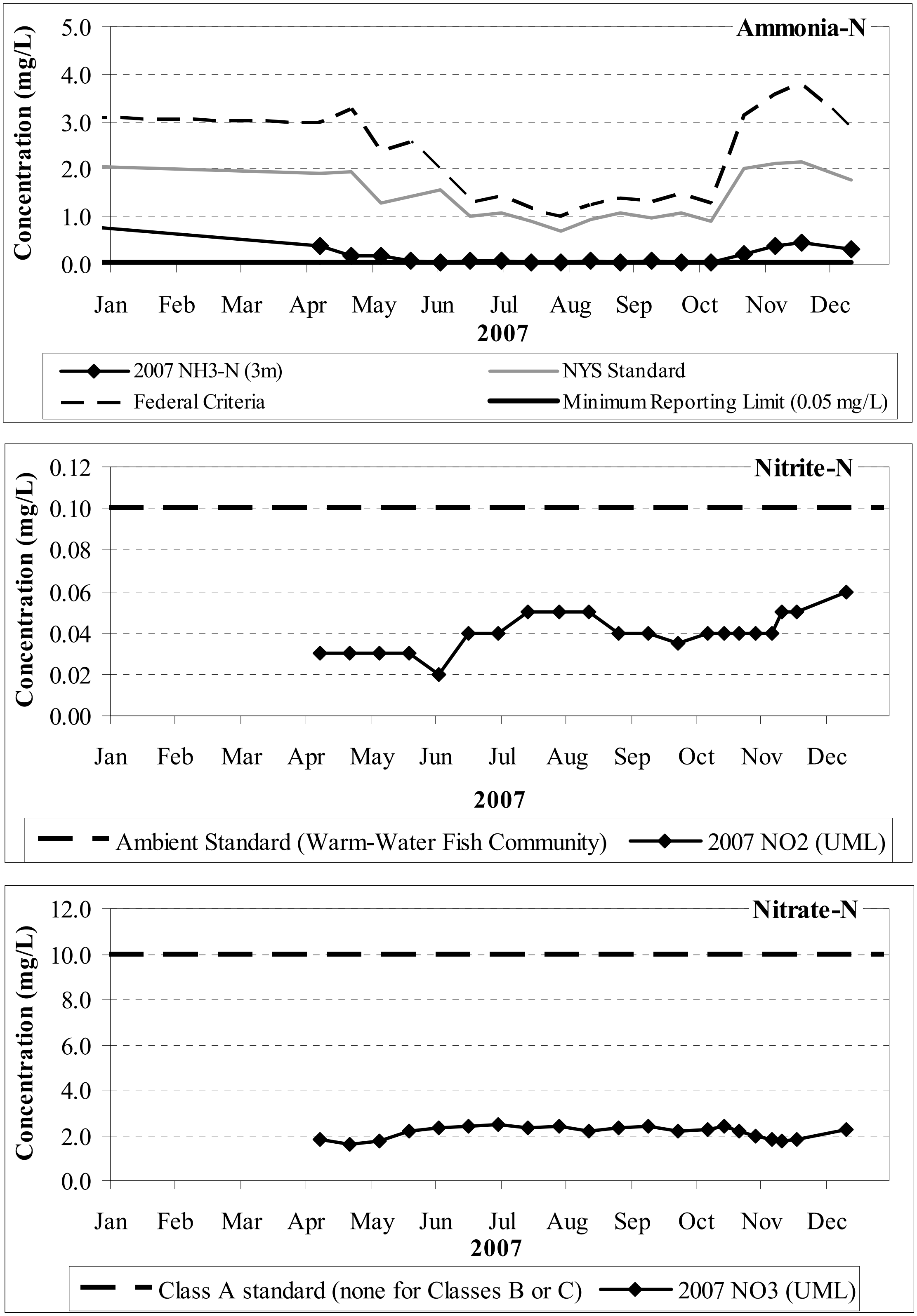

Figure 3-18. Concentrations of ammonia-N (3-meter depth), nitrite-N (UML) and nitrate-N (UML), Onondaga Lake South Deep Station in 2007, compared with water quality standards and/or criteria.

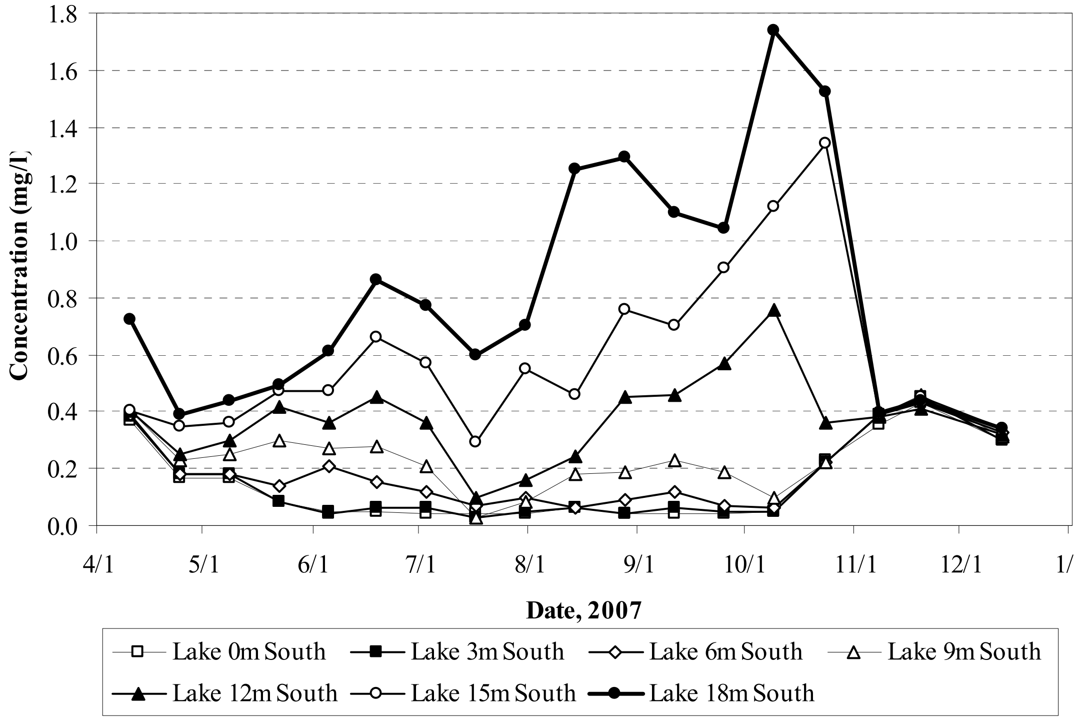

Figure 3-19. 2007 concentrations of ammonia at Onondaga Lake South Deep by depths.

Table 3-13. Progress towards water quality improvement: Ammonia-N. AMP 2007 Annual Report. (Water Quality Standard)

AMENDED CONSENT JUDGMENT GOAL

Achieve compliance with the applicable ambient water quality standard in the upper waters, and removal of ammonia toxicity as impairment to designated best use for survival and propagation of a warmwater fish community. Achieve desired use of aquatic life protection.

Hypotheses to be tested:	**Status:**
Improvements at Metro enables the County to meet Stage III effluent limits for ammonia N	• Stage III effluent limits have been met for ammonia-N since 2004, after the BAF upgrade was implemented for year-round ammonia treatment.
Reduced ammonia load results in compliance with ambient water quality standards and federal criteria for ammonia in Onondaga Lake	• Since 2004, Onondaga Lake has been in full compliance with NYS AWQS in upper waters.
Current Conditions with Historical Comparison	
Major Sources – Percent Contribution *(Annual Average (standard deviation))*	Time Period / Metro Effluent and Bypass / Tributaries 1985-2003: 89% (6%) / 11% (6%) 2004-2006: 53% (18%) / 47% (18%) 2007: 59% / 41%
Upper Waters Concentration *(Annual Average (standard deviation))*	Time Period / South Deep, 0-6 meters, Jan-Dec (mg/l) 1985-2003: 1.56 (0.63) 2004-2006: 0.22 (0.10) 2007: 0.16
Compliance with NYS AWQS in Upper Waters	Full compliance in 2007 Full compliance in upper waters since 2004.
Factors Affecting Compliance	Metro performance, hydrology, pH, and water temperature
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement *(Stage III Limit has been met since 2004, eight years ahead of schedule)*	Stage I Limit: Cap on Loading • effective Jan 1998 - April 30, 2004 (completed) Stage II Limit: effective May 1, 2004 – Dec. 2012 • June 1 – Oct. 31: 2.0 mg/l (as NH_3) • Nov. 1 – May 31: 4.0 mg/l (as NH_3) Stage III Limit: 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)
Monitoring and Assessment Program	
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, 3-meter intervals • Winter sampling as weather allows
Related Biological Monitoring	• Assessment of fish community began in 2000 • Annual zooplankton monitoring
Tools for Decision Making	
Model	Onondaga Lake Water Quality Model (under development by QEA, LLC)
TMDL Allocations	NYSDEC Phase I TMDL 8/27/97

Table 3-14. Progress towards water quality improvement: Nitrite-N. AMP 2007 Annual Report. (Water Quality Standard)

AMENDED CONSENT JUDGMENT GOAL

Achieve compliance with the applicable ambient water quality standard in the upper waters to meet designated best use for survival and propagation of a warmwater fish community. Achieve desired use of aquatic life protection.

Hypotheses to be tested:	**Status:**
Achievement of Stage III effluent limits for ammonia results in compliance with the NYS ambient water quality standard for nitrite (warmwater fish community)	• Stage III effluent limits have been met for ammonia-N since 2004, after the BAF upgrade was implemented for year-round ammonia treatment. • Since 2006, Onondaga Lake has been in full compliance with NYS AWQS for nitrite-N in upper waters.

Current Conditions with Historical Comparison

Major Sources – Percent Contribution
(Annual Average (standard deviation))

Time Period	Metro Effluent Outfall 001	Tributaries
1985-2003:	75% (14%)	25% (14%)
2004-2006:	47% (22%)	53% (22%)
2007:	38%	61%

Upper Waters Concentration
(Annual Average (standard deviation))

Time Period	South Deep, 0-6 meters, Jan-Dec (µg/L)
1985-2003:	166 (76)
2004-2006:	62 (17)
2007:	40

Compliance with NYS AWQS in Upper Waters	Percent of observations exceeding standard (100 µg/l): 1985-2003: 55% 2004-2006: 13% 2007: 0% Full compliance in 2007
Factors Affecting Compliance	Metro performance, Hydrology

Planned Load Reductions (1998 – 2012)

Metro SPDES Permit Requirement	No numerical limit for nitrite in SPDES permit; Monitor only (one sample per week)

Monitoring and Assessment Program

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, UML and LWL • Additional sampling during fall mixing • Winter sampling as weather allows
Related Biological Monitoring	• Assessment of fish community began in 2000 • Annual zooplankton monitoring

Tools for Decision Making

Model	Onondaga Lake Water Quality Model (under development by QEA, LLC)
NYS AWQS	100 µg/l

3.4 TROPHIC STATE INDICATORS

Limnologists and lake managers have developed guidelines to define the transition between trophic states based on phosphorus, water clarity, chlorophyll-a, and deep water dissolved oxygen concentrations (**Table 3-15**). However, assigning a lake to one category still requires professional judgment considering the cumulative evidence of water quality conditions and the level of productivity.

Table 3-15. Trophic state indicator parameters and trophic state designation compared to measured conditions in Onondaga Lake 2007. Shading indicates the range in which the 2007 lake conditions occur under the trophic state designations.

Indicator Parameters	**Trophic State Designation**			**Onondaga Lake Measured Conditions, 2007**
	Oligotrophic	**Mesotrophic**	**Eutrophic**	
Summer average total phosphorus, upper waters (µg/l)	<10	10-35	35 -100	**25 (Jun-Sep)**
Summer average chlorophyll-*a*, upper waters (µg/l)	<2.5	2.5 – 8	8 – 25	**9.5 (Jun-Sep)**
Peak chlorophyll-*a* (µg/l)	<8	8-25	25-75	**29 (Sep 11)**
Average Secchi disk transparency, m	>6	6-3	3-1.5	**2.1 (Jun-Sep)**
Minimum Secchi disk transparency, m	>3	3-1.5	1.5-0.7	**1.0 (4/24; 6/5; 6/22)**
Dissolved oxygen in lower waters (% saturation at 15m)	80 – 100	10-80	Less than 10	**0 – 60 (Jun-Sep)**

Source: **Janus and Vollenweider 1981**

Based on the 2007 data, Onondaga Lake remains a eutrophic system, as summarized in **Table 3-15**. **Figure 3-20** shows the trends of the trophic status parameters over time.

External loading and lake concentrations of phosphorus, as well as lake conditions for chlorophyll-a, Secchi disk transparency, and dissolved oxygen, were discussed in Section 3.3.

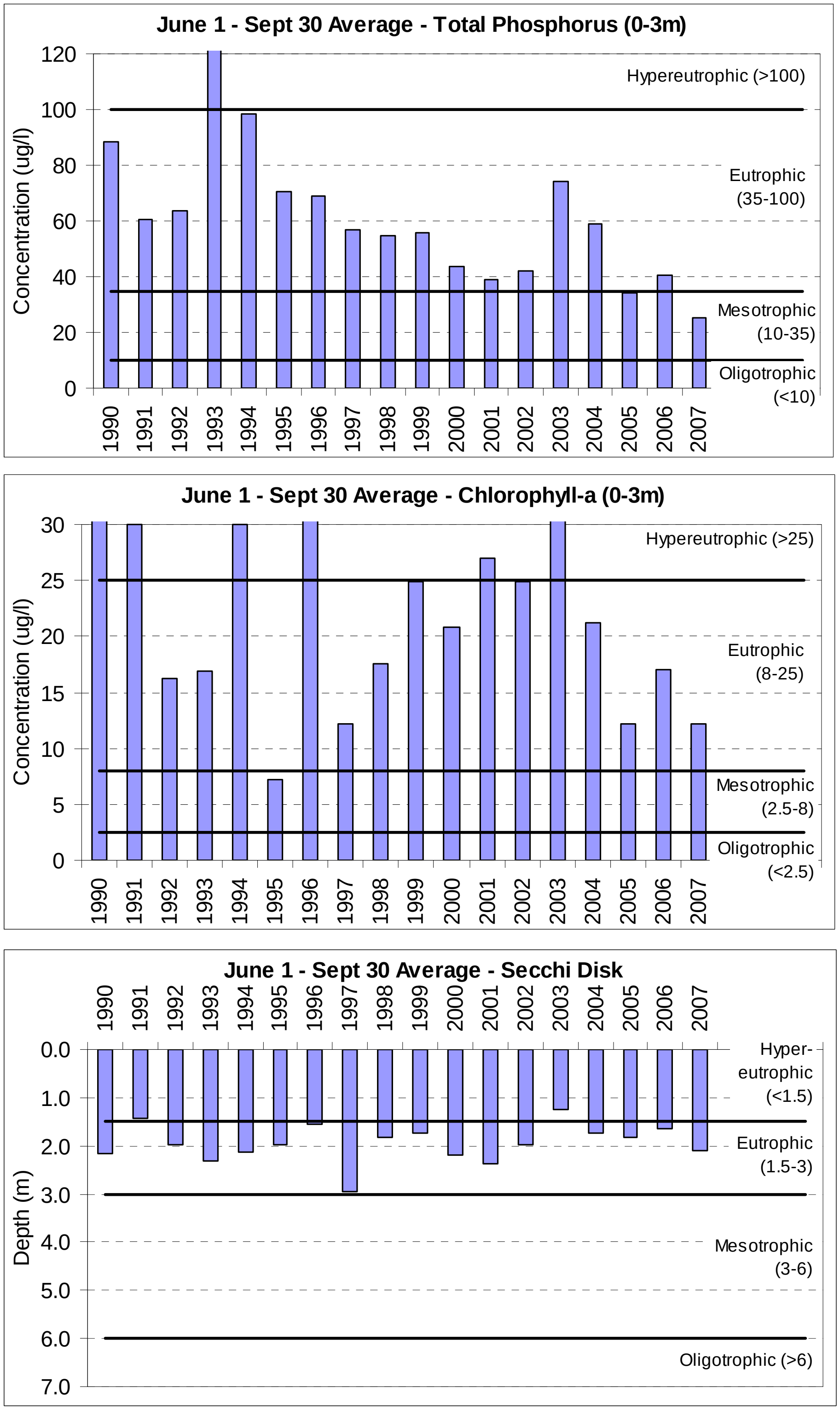

Figure 3-20. Phosphorus, chlorophyll-a, and transparency trophic state indicators over time, South Deep Station.

3.5 NITROGEN PHOSPHORUS RATIO

Generally, lakes are considered to be phosphorus limited when the nitrogen: phosphorus (N:P) ratio is greater than 15, and nitrogen limited when the N:P ratio falls to 7 or below. In general, higher values are associated with more oligotrophic conditions. The nitrogen/phosphorus ratio, on average, decreases from more than 100 on the oligotrophic side to less than 10 on the eutrophic side. This can be interpreted as a tendency for lakes to shift from phosphorus dependency to nitrogen dependency with increasing trophy (**Janus and Vollenweider 1981**).

In Onondaga Lake, the annual summer average N:P ratio was fairly stable, averaging around 69 (**Figure 3-21**). The ratios drop for 2002 through 2004, averaging 44. After implementation of the BAF and HRFS systems (2004 and 2005, respectively) the ratios for 2005 and 2006 rebounded to pre-2004 levels. In 2007, the summer average ratio was 123, higher than the historical values back to 1995.

Changes in the N:P ratio would be expected as a result of the Metro improvements. The BAF nitrification system reduces the concentrations of ammonia-N and nitrite-N, while the concentration of nitrate-N increases; as a result, total nitrogen loading from Metro to the lake has not decreased as rapidly over time as total phosphorus loading. The HRFS system, on the other hand, removes phosphorus from the effluent, reducing loading of total phosphorus to the lake. Corresponding concentrations in the lake respond to the changes in loading. The value of the N:P ratio increases as the denominator – the phosphorus concentration – decreases (**Figure 3-22**).

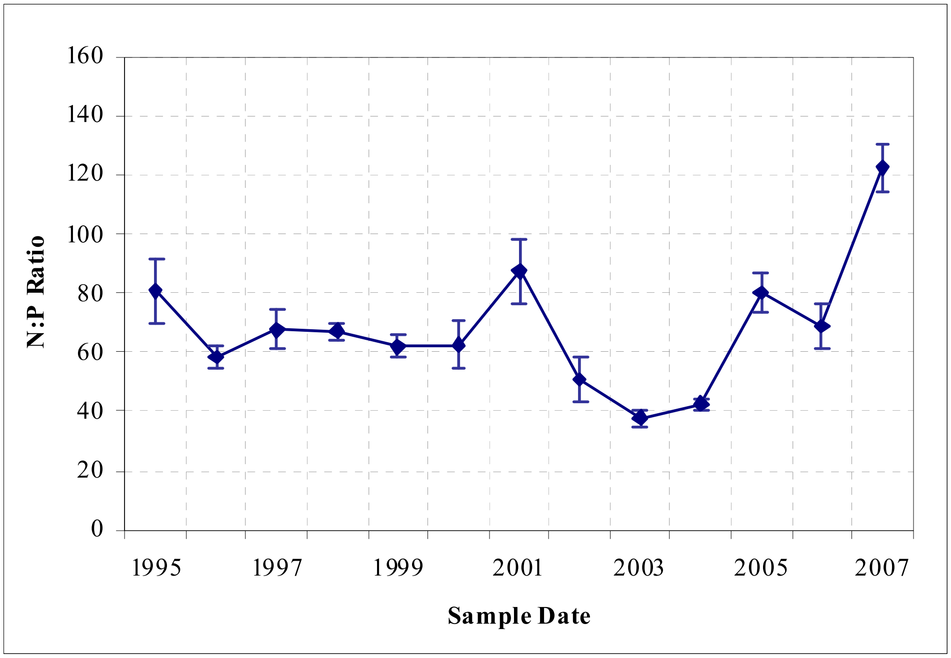

Figure 3-21. Total Nitrogen to Total Phosphorus ratio (N:P), Summer Average (June 1 - September 30) with standard error, South Deep, 0-3m, 1995-2007.
Total nitrogen calculated as the sum of TKN, nitrite-N and nitrate-N concentrations; total phosphorus reported by the laboratory. Nitrite-N and nitrate-N collected as composite samples of the UML; TKN and phosphorus collected at discrete depths and results averaged for 0m and 3m depths.

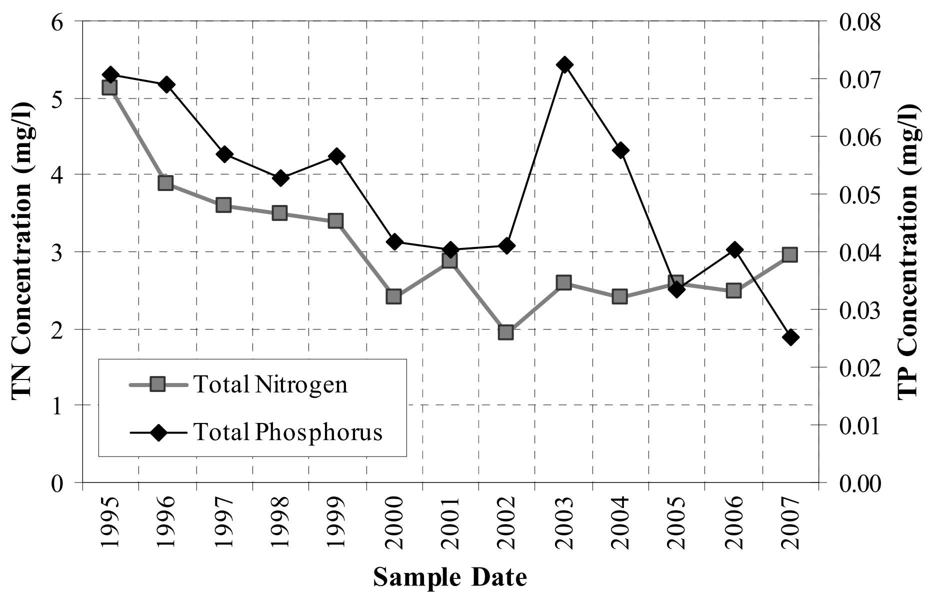

Figure 3-22. Concentrations of total nitrogen and total phosphorus, summer average (June 1 - September 30), South Deep, 0-3m, 1995-2007.
Total nitrogen calculated as the sum of TKN, nitrite-N and nitrate-N concentrations; total phosphorus reported by the laboratory. Nitrite-N and nitrate-N collected as composite samples of the UML; TKN and phosphorus collected at discrete depths and results averaged for 0m and 3m depths

3.6 BIOCHEMICAL TRANSFORMATIONS IN ANOXIC WATERS

As discussed in Section 3.2.4.6, lower waters in Onondaga Lake become anoxic during the summer months as a result of biological decomposition and thermal stratification. Under anoxic conditions, reduction processes occur in which microorganisms utilize oxidized forms of different compounds. These biochemical transformations in the sediments occur in a predictable sequence as different compounds in turn become electron receptors (**Mitsch and Gosselink, 1986**):

1. Nitrate is reduced to nitrous oxide and molecular nitrogen
2. Manganese is transformed from manganic to manganous compounds
3. Iron is transformed from ferric to ferrous compounds
4. Sulfate is reduced to sulfides
5. Carbon dioxide is reduced to methane

Phosphorus bioavailability is indirectly affected by these reduction processes. As ferric iron is reduced to ferrous compounds, phosphorus bound in ferric phosphate compounds is released into solution. This is measured as SRP (**Mitsch and Gosselink, 1986**).

This process is evident in the lower waters of Onondaga Lake during 2007 (**Figure 3-23**). A decrease in nitrate concentrations occurred gradually from April to July as dissolved oxygen concentrations decreased. Once anoxic conditions were present, the decrease in nitrate occurred more rapidly from July through October. From April through September, SRP concentrations remained relatively stable. By late September, as nitrate concentrations approached the minimum for the year, SRP concentrations began to increase. This suggests that by late summer, the microorganisms had progressed to iron in the redox cycle, thus releasing SRP from the sediments.

Fall turnover occurred late in October (October 27) in 2007, which re-introduced oxygenated waters into the lower waters of the lake. This increase in lower water DO concentrations was evident at the 15-meter buoy depth by about November 20th. During turnover, nitrate concentrations in lower waters increased, and were comparable to concentrations in the upper waters (**Figure 3-24**). As discussed in Section 3.3.3, ammonia concentrations during the summer increased in the lower waters; during fall turnover, this ammonia mixed throughout the water column, coming into contact with oxygen and becoming nitrified. SRP released in the lower waters during the stratified period mixed with the upper waters during turnover, resulting in SRP concentrations distributed evenly in both upper and lower waters (**Figure 3-24**).

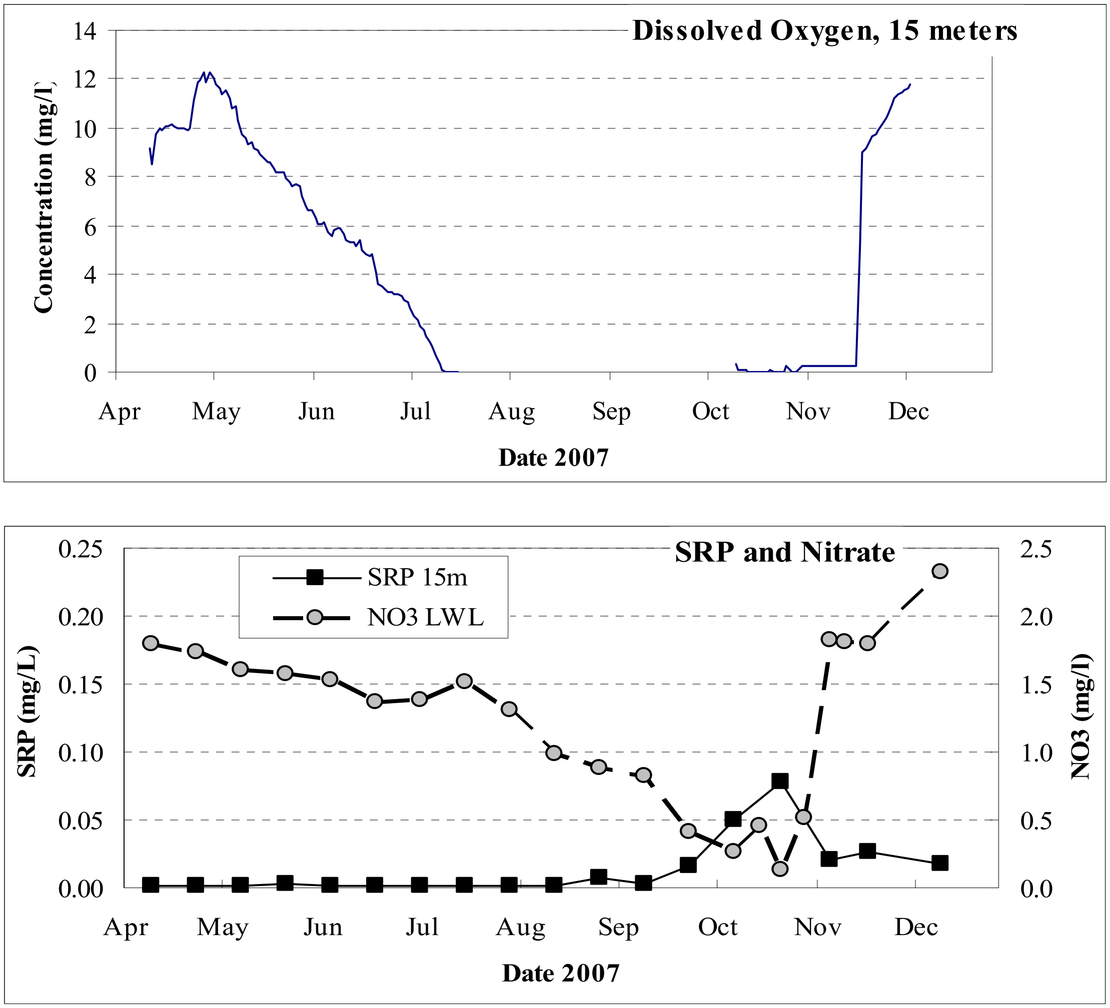

Figure 3-23. Dissolved oxygen, nitrate and SRP in lower waters, South Deep, Onondaga Lake 2007.
Note: Daily average dissolved oxygen concentrations calculated from 15-minute interval data from the buoy. To prevent damage to the in-situ probes in the lower waters from long-term exposure to anoxic conditions, these probes are removed when DO levels drop to zero. The lower-level probes are re-installed prior to fall mixing.

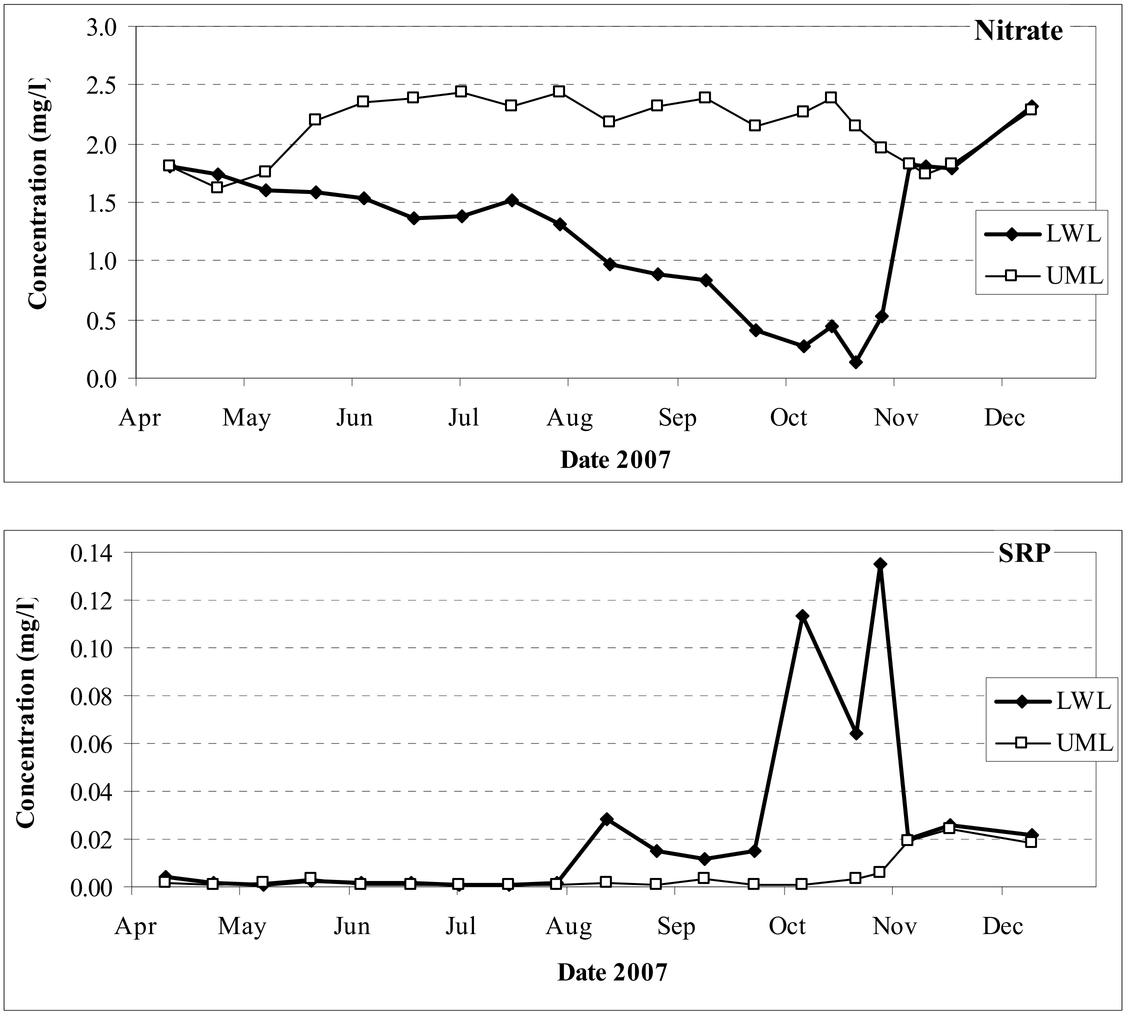

Figure 3-24. Concentrations of nitrate and SRP in the upper and lower waters, South Deep, Onondaga Lake 2007.

3.7 REFERENCES

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CHAPTER 4: OTHER PARAMETERS STATUS AND TRENDS

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CHAPTER 4. OTHER PARAMETERS STATUS AND TRENDS

The approved 2007 annual workplan (**Appendix 1**) for the Onondaga County Department of Environmental Protection's Ambient Monitoring Program (AMP) included sampling, analysis and evaluation of many parameters. The rationale for the design of the AMP and the specific way the data are used to interpret compliance and trends are outlined in the Data Analysis and Interpretation Plan (DAIP – **Appendix 5**).

This chapter summarizes the 2007 results of parameters such as bacteria, metals, salts, carbon and solids. There are several appendices to the 2007 AMP report that contain additional details about the sample collection and data analysis:

- **Appendix 2** contains the quality control review of the 2007 database.

- **Appendix 10** provides a comparison of paired samples collected from the North and South basins of the lake.

4.1 BACTERIA

The Ambient Monitoring Program is designed to assess external loading of bacteria to Onondaga Lake. High levels of bacteria affect the use of the lake for water contact recreation.

> Amended Consent Judgment Goals for Bacteria:
>
> - Achieve compliance with the applicable ambient water quality standard for fecal coliform bacteria, Class B segment, applicable during the period of Metro disinfection (April 1 to October 15); include bacteria concentrations in nearshore areas following storm events.
>
> - Reduce fecal coliform bacteria levels in Class B segments of the lake to achieve desired use for water contact recreation.

Wastewater discharged from Metro to Onondaga Lake is required to be disinfected between April 1 and October 15 to protect the lake's recreational uses. Bacteria levels in the lake are monitored as part of the AMP to evaluate potential presence of pathogens, compliance with water quality standards, and effectiveness of CSO control measures.

Fecal coliform bacteria are used as indicators of the potential presence of pathogenic (disease-causing) microorganisms. This class of bacteria is currently used by NYSDEC as an indicator of microbiological purity. The Environmental Protection Agency is strongly encouraging states to base their assessment of recreational suitability of freshwater on the presence and abundance of a second indicator organism, *E. coli*. Studies have shown that *E. coli* levels are more closely associated with human health impacts of contact recreation, particularly incidence of gastrointestinal illness (**EPA 2002**). Onondaga County is currently monitoring and reporting both classes of indicator organisms in Onondaga Lake.

4.1.1 External Loading and Trends

In 2007, Metro Outfall 001 was the largest source of fecal coliform bacteria; this reflects the loading during the period when disinfection is not required (October 16 to March 31). Bypass Outfall 002, operational only during periods when high flows reach the treatment plant, is a source of bacteria far out of proportion to its annual flow contribution (**Table 4-1**). During the period of disinfection at Metro (April 1 to October 15), Onondaga Creek was the dominant source of fecal coliform bacteria.

> AMP Hypotheses to be Tested:
>
> - CSO remedial measures and improved stormwater management reduce the loading of fecal coliform bacteria entering the lake.

Table 4-1. Summary of fecal coliform bacteria loading, 2007.

	2007 Loading			**2007 Percent contribution by gauged inflow**		
Tributary	***Water (hm^3)***	***Jan-Dec (10^{10} cfu)***	***Apr 1-Oct 15 (10^{10} cfu)***	***Water***	***Jan-Dec***	***Apr 1-Oct 15***
Metro:						
Metro Outfall 001	88	182,473	7,855	18%	11%	1.8%
Metro Outfall 002	1.4	1,117,480	266,312	0.29%	66%	61%
Natural Tributaries:						
Onondaga Creek	183	234,859	112,107	37%	14%	26%
Ninemile Creek	170	78,652	19,559	34%	4.7%	4.5%
Ley Creek	39	29,931	16,105	7.8%	1.8%	3.7%
Harbor Brook	14	47,051	14,043	2.8%	2.8%	3.2%
Industrial Tributaries:						
East Flume	0.68	244	97	0.14%	0.014%	0.022%
Trib 5A	0.56	361	264	0.11%	0.021%	0.060%
Total Monitored	**496**	**1,691,052**	**436,341**	**100%**	**100%**	**100%**
Average 1990-2006:		**2,622,745**				
% Change 2007 from Average:		**-36%**				

Notes: mt = metric tons; hm3 = million cubic meters; cfu = colony-forming units. Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events). Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms.

The flow-weighted abundance of fecal coliform bacteria were associated with a high relative standard error from all the tributary streams (**Table 4-2**). This is due to the episodic nature of rainfall and stormwater runoff, and is exacerbated by the CSOs.

Table 4-2. Flow-weighted average of fecal coliform bacteria, 2007, in Onondaga Lake tributaries, with standard error of estimate.

	Fecal Coliform Bacteria cells/100ml	
	Concentration	**RSE**
Metro:		
Metro Outfall 001	2,079	60%
Metro Outfall 002	776,088	45%
Natural Tributaries:		
Onondaga Creek	1,285	78%
Ninemile Creek	462	147%
Ley Creek	770	67%
Harbor Brook	3,373	158%
Industrial Tributaries:		
East Flume	360	96%
Trib. 5A	646	516%

Notes:
RSE = relative standard error of the concentration estimate.
Calculated using a multiple regression algorithm relating concentration to flow, season, and trend with residual interpolation.
Based on data collected bi-weekly.
Calculations use the laboratory reported minimal reportable limit (MRL) when observations were below the MRL.

The results for 2007 are displayed in **Figure 4-1** (Onondaga Creek), **Figure 4-2** (Harbor Brook) and **Figure 4-3** (Ley Creek and Ninemile Creek) using different symbols to indicate the streamflow conditions during the sampling event. For the purpose of this evaluation, "low flow" is defined as stream discharge (cfs) less than or equal to the long-term monthly average (1970 through 2003); "high flow" is defined as stream discharge greater than the long-term monthly average plus one standard deviation. Stream discharge values that fall between the monthly average and high flow are identified as "between flow". There was no correlation between flow and fecal coliform concentrations.

Of note in 2007 were exceptionally high concentrations of fecal coliform bacteria in Harbor Brook on August 22 and 23:

Fecal Coliforms (cfu/100 ml)	August 22	August 23
Upstream (Velasko)	>60,000	32,000
Downstream (Hiawatha)	25,000	454*

** High flow conditions*

These higher concentrations were associated with repairs at the Hillcrest Pumping Station. A section of the Hillcrest Force Main had to be replaced due a leak discovered adjacent to the City of Syracuse Water Department's St. Andrews Gate House. The force main was excavated and found to have a flex break at a joint. The force main was repaired[1].

Other unusually high concentrations – relative to other concentrations measured during 2007 - were also observed on two other dates in 2007:

Tributary	Date	Concentration (cfu/100ml)	Notes
Harbor Brook (Hiawatha)	04/03/07	21,000	"Between flow" conditions; This concentration did not exceed the 10-year average plus 2 standard deviations for this location.
Ley Creek (Park)	07/24/07	5,100	Low flow conditions; This concentration exceeded the 10-year average plus 2 standard deviations for this location.

Over time, the annual load of fecal coliform bacteria to Onondaga Lake has been highly variable (**Figure 4-4**). As noted in **Table 4-1**, the 2007 annual load of fecal coliform bacteria to Onondaga Lake was 35% less than the average loading for the period 1990-2006.

CSO remedial measures and improved stormwater management techniques are in the process of being implemented. Although the results for 2007 were 35% lower than the average for the previous 17 years, the inherent variability of the bacterial loading as related to storm events and runoff make a direct observation of improvements difficult. The expected reduction in loading as a result of these measures is not conclusively evident in the data to date.

Low flow data were segregated from high flow data for the period 1999-2007 in order to examine the quality of the CSO-affected streams at baseflow and when they are affected by stormwater runoff. Geometric mean concentrations of fecal coliform bacteria during the summer (June through September) are plotted in **Figure 4-5**. Both Harbor Brook and Onondaga Creek have stations upstream and downstream of the urban CSO-affected corridor. For comparison, data from Ninemile Creek and Ley Creek are also shown; Ninemile Creek receives stormwater runoff from a separate sewer system.

In all four tributaries, concentrations of fecal coliform bacteria associated with summertime high flows are greater than concentrations associated with summertime low flows. For Harbor Brook and Onondaga Creek, concentrations at the downstream monitoring stations are greater than concentrations at stations located upstream of CSOs.

[1] Onondaga County Department of Water Environment Protection 2007 Annual Report (http://www.ongov.net/WEP/wepdf/we1120a.pdf)

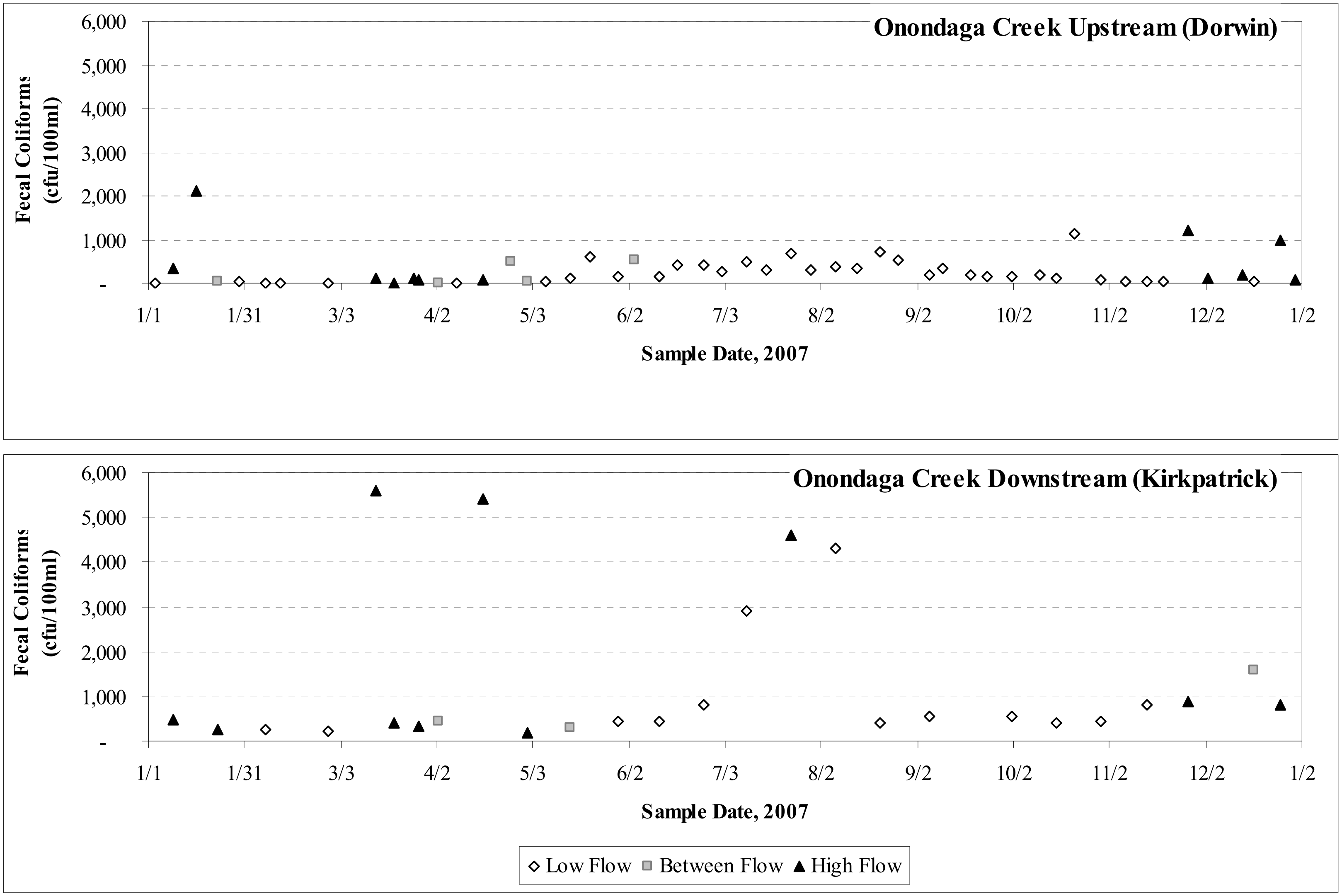


Figure 4-1. Measured concentrations of fecal coliform bacteria in Onondaga Creek during 2007.
Notes: Low flow is defined as flows less than or equal to the long-term monthly average flow for the period of record. High flow is defined as flows greater than one standard deviation above the long-term monthly average flow. "Between" indicates flows that occur between low and high flows.

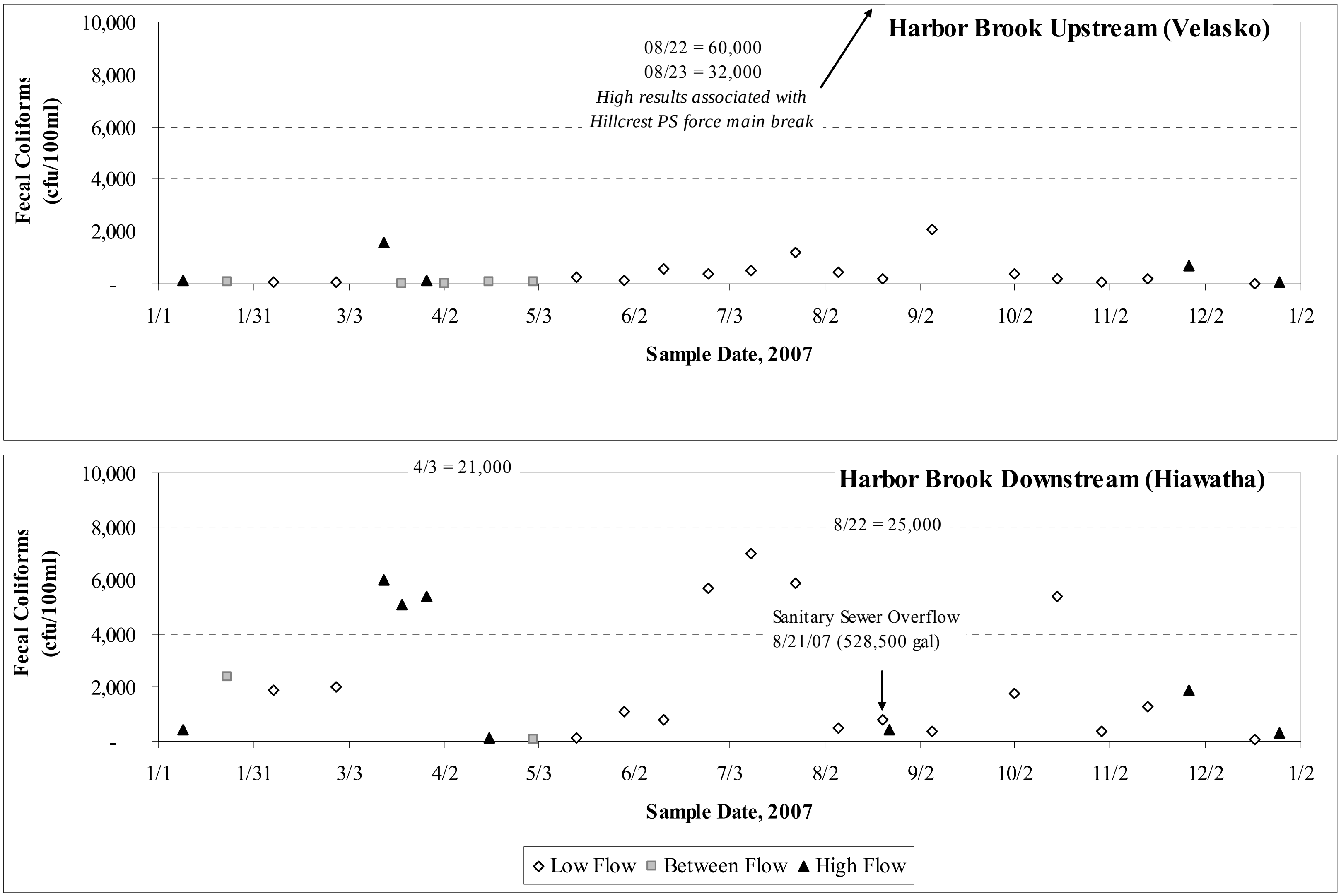
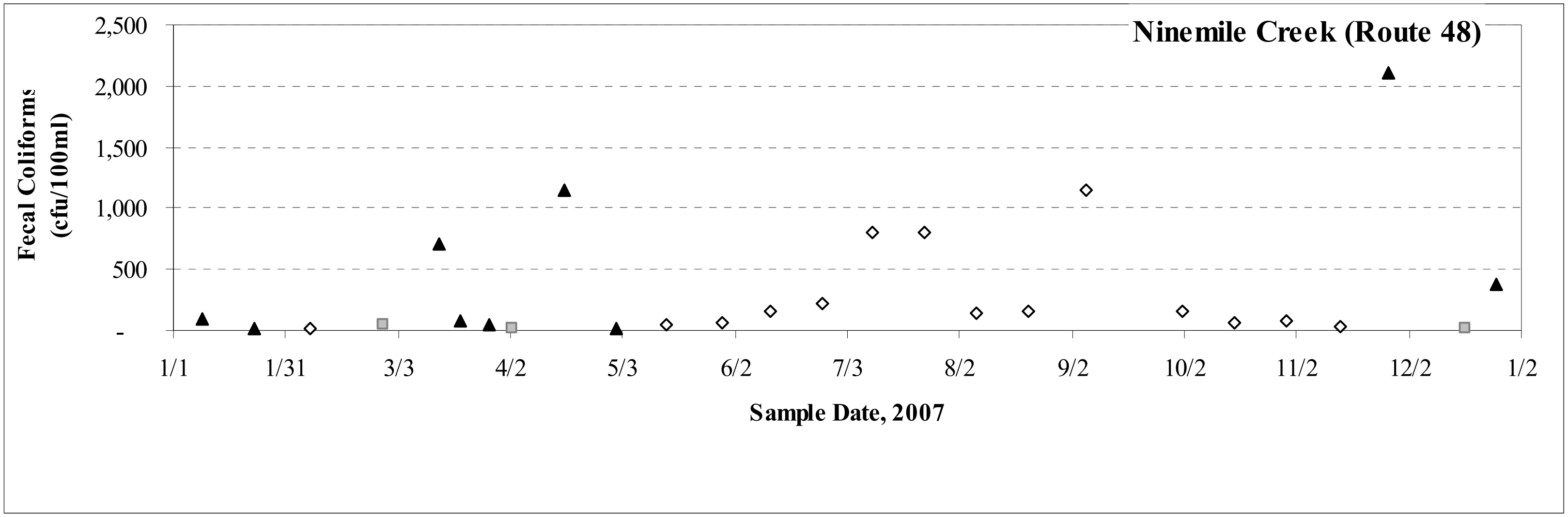


Figure 4-2. Measured concentrations of fecal coliform bacteria in Harbor Brook during 2007.
Notes: Low flow is defined as flows less than or equal to the long-term monthly average flow for the period of record. High flow is defined as flows greater than one standard deviation above the long-term monthly average flow. "Between" indicates flows that occur between low and high flows.



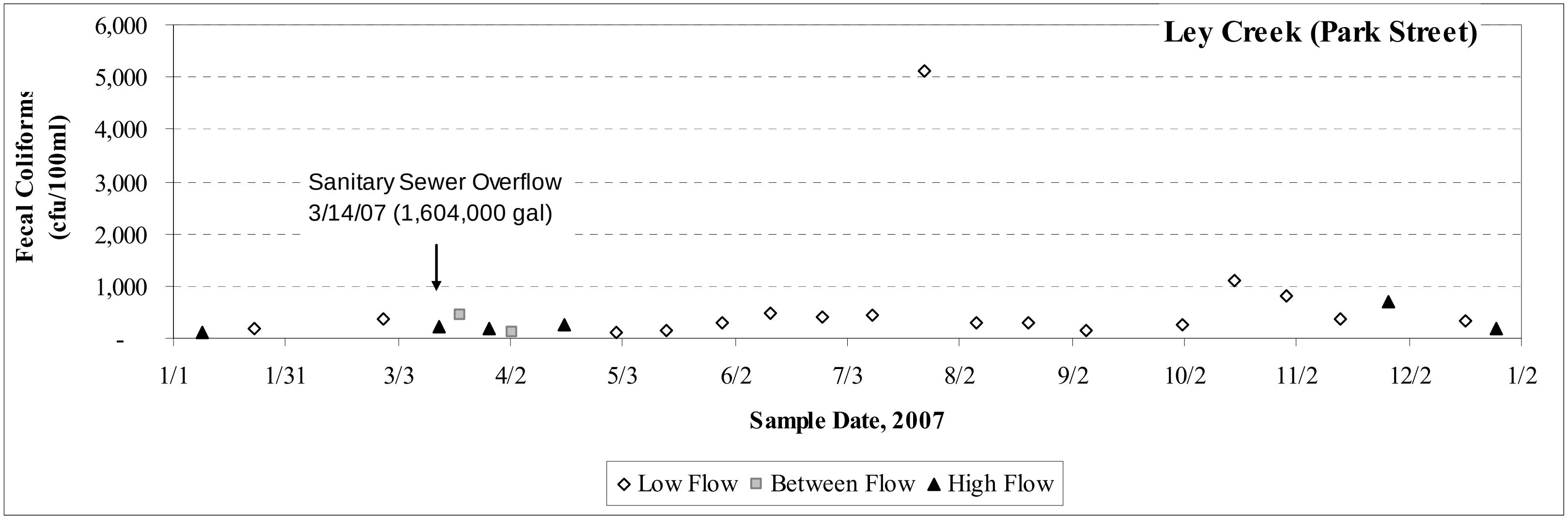


Figure 4-3. Measured concentrations of fecal coliform bacteria in Ninemile and Ley Creeks during 2007.
Notes: Low flow is defined as flows less than or equal to the long-term monthly average flow for the period of record. High flow is defined as flows greater than one standard deviation above the long-term monthly average flow. "Between" indicates flows that occur between low and high flows.

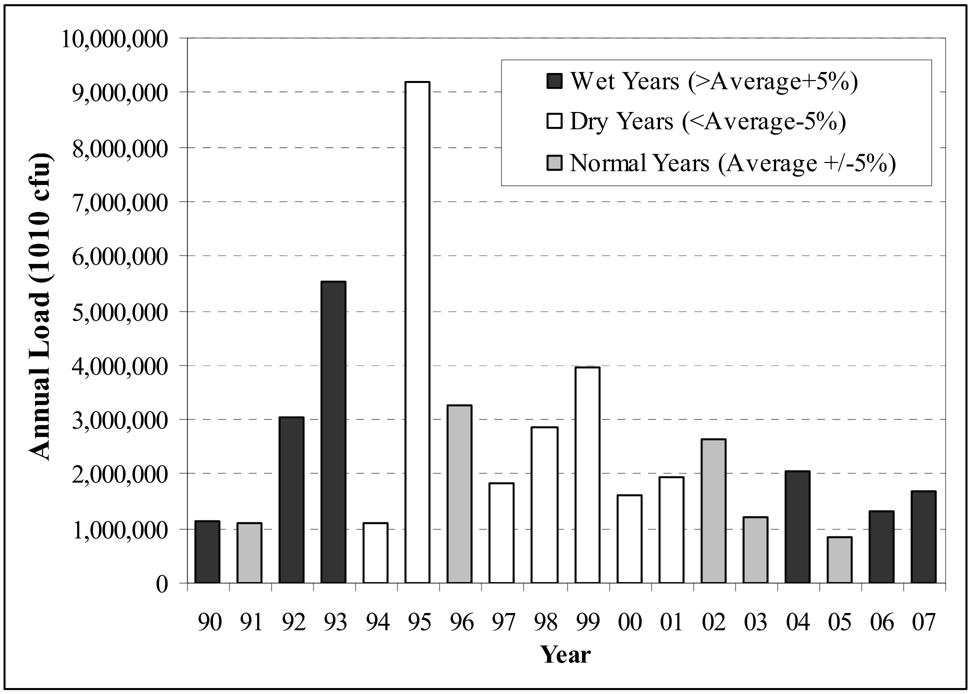


Figure 4-4. Annual loading of fecal coliforms over time, with wet, dry and normal precipitation years.

Note: wet years defined as 5% greater than the preceding 30-year average; dry years defined as 5% less than the preceding 30-year average; normal defined as preceding 30-year average ± 5%.

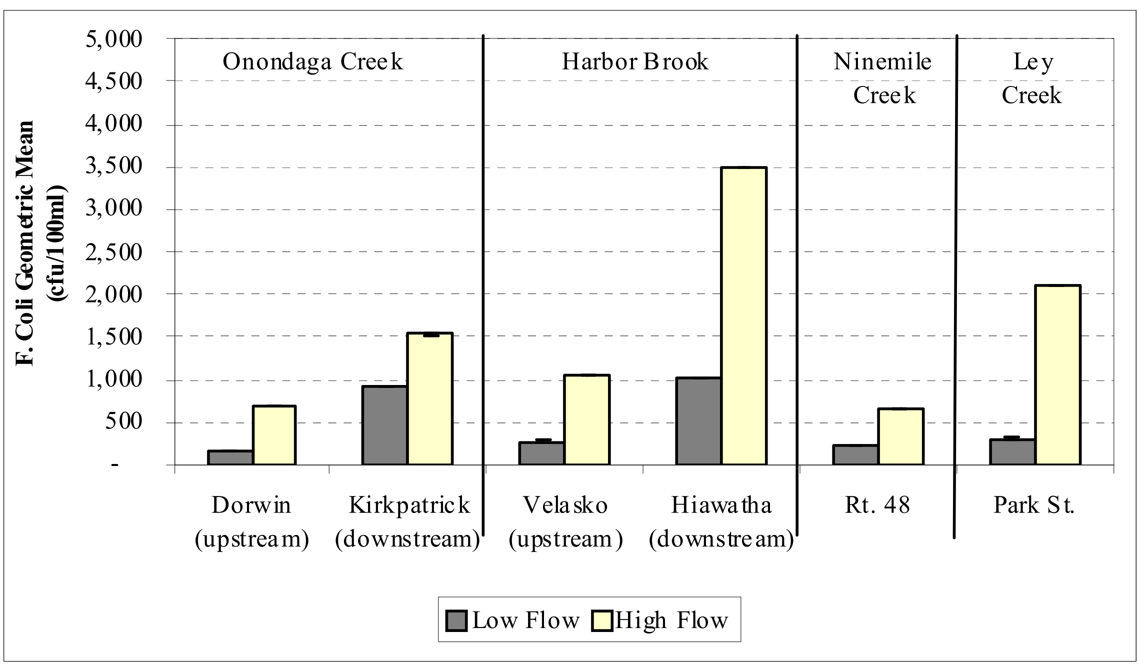


Figure 4-5. Fecal Coliform bacteria (geometric mean and standard deviation) for the period June-September, 1999-2007, low flow and high flow data by site.

Note: Low flow represents samples collected when daily average flow was less than or equal to the long-term monthly average flow. High flow represents samples collected when daily average flow was greater than one standard deviation above the monthly average flow.As there were no samples collected when daily flows met the low flow definition at Onondaga Creek Kirkpatrick site in 2000 and 2006, samples with flow less than 100 cfs were used.

Concentrations of fecal coliform bacteria during summer low flow conditions are compared for upstream and downstream locations in **Figure 4-6**. Both Harbor Brook and Onondaga Creek exhibit an increase in average concentration of fecal coliform bacteria from upstream to downstream under summer low flow conditions.

Concentrations of bacteria measured at the downstream Onondaga Creek station (Kirkpatrick) have decreased in recent years (2003 through 2006) during summer low flow conditions; these concentrations are comparable to those measured in Ninemile Creek under the same flow regime (recall that the urban portion of the Ninemile Creek subwatershed is served by separate sewers). Average summer low flow concentrations were slightly elevated in 2007 compared with previous years.

In contrast to Onondaga Creek, concentrations of fecal coliform bacteria measured at the downstream Harbor Brook station (Hiawatha) during summer low flow conditions have not improved over time, continuing to exhibit elevated fecal coliform bacteria levels. The 2007 average concentrations at both upstream and downstream stations were elevated significantly compared to previous years as a result of including the data associated with the Hillcrest Pumping Station force main repair in calculating the average.

Measurements of fecal coliform bacteria in the streams have been segregated in accordance with the flow regime at the time of collection. The annual geometric mean concentrations at low flows, intermediate ("between") flows, and high flows, as well as storm event sampling, are plotted with different symbols in **Figure 4-7** (Onondaga Creek), **Figure 4-8** (Harbor Brook), and **Figure 4-9** (Ley Creek and Ninemile Creek).

With few exceptions, the highest concentrations are associated with the high flow and storm event samplings. The upstream and downstream plots show a consistent shift to higher concentrations downstream of the urban/CSO corridor.

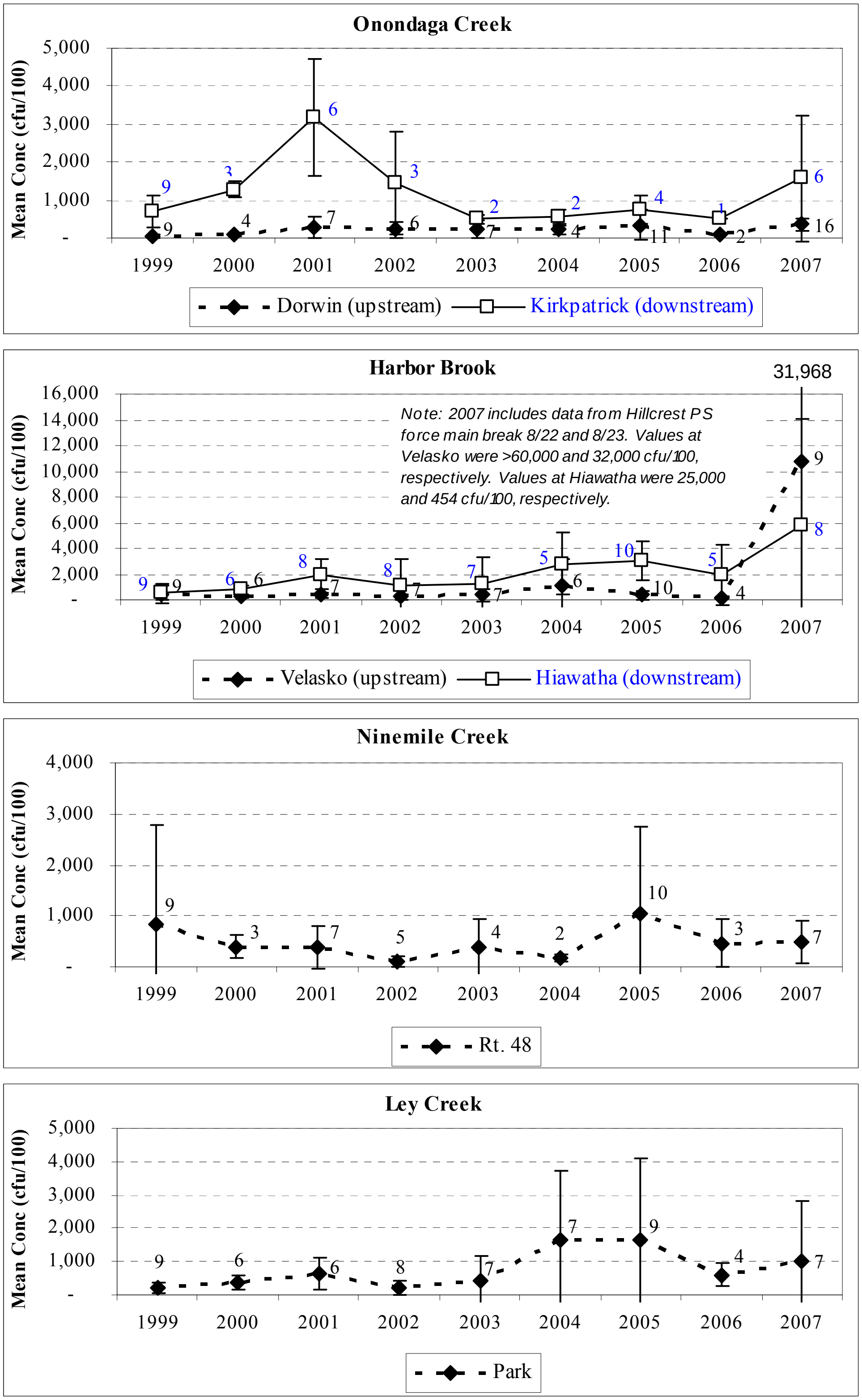
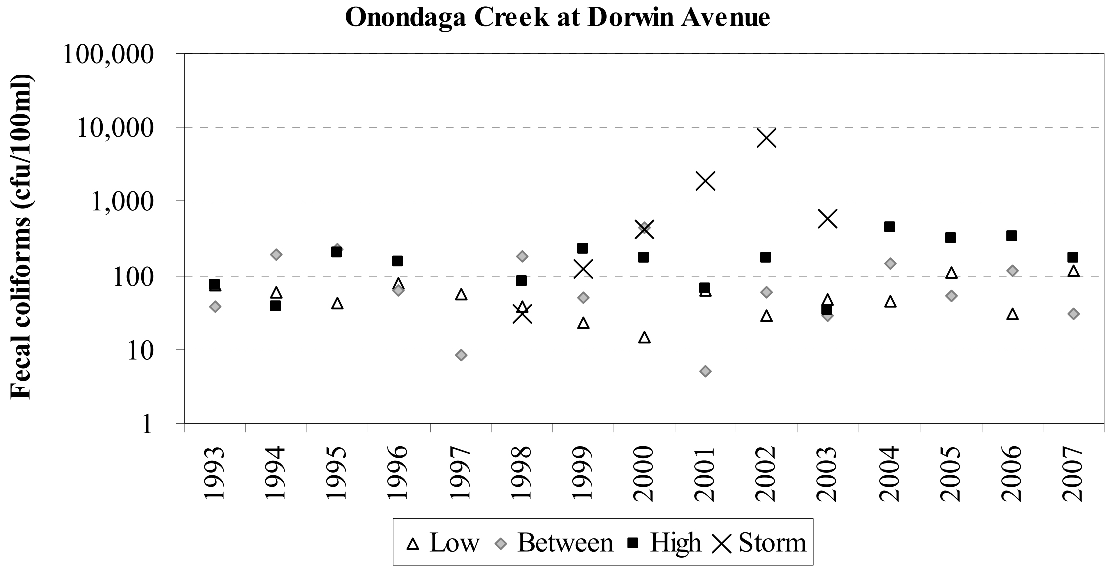


Figure 4-6. Average concentration, with standard deviation, of Fecal Coliform bacteria at base flow, for the summer period June 1 to September 30, 1999-2007. Number of samples per summer is shown. Base flow is defined as daily flow (cfs) at or less than the monthly average.
Note: As there were no daily flows that met the base flow definition at Onondaga Creek Kirkpatrick site in 2000 and 2006, samples with flows less than 100 cfs were used.



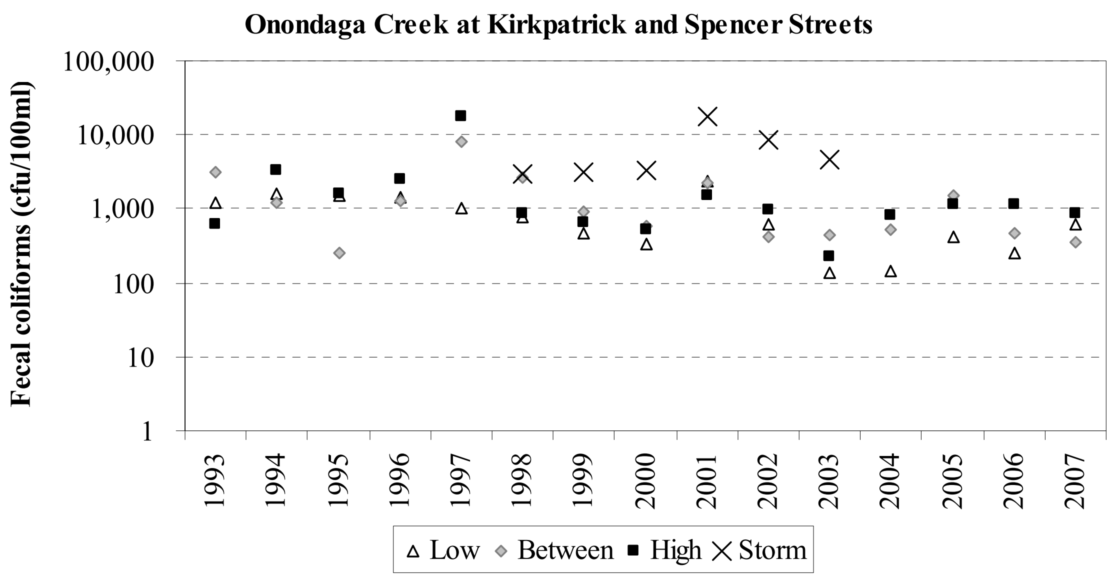
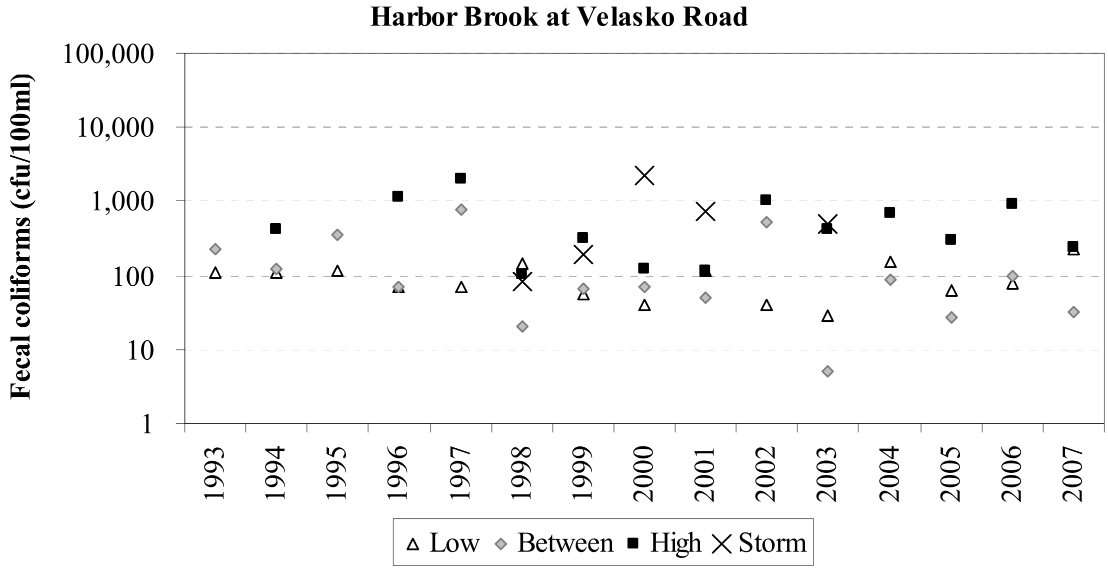


Figure 4-7. Annual (January to December) geometric means of fecal coliform concentrations at two stations on Onondaga Creek.
Note: "Low" represents means for samples collected when stream flow was less than or equal to the monthly average flow. "High" represents means for samples collected when stream flow was greater than one standard deviation above the monthly mean. "Between" represents samples collected when flows were between low and high flows. Storm represents storm event samples.



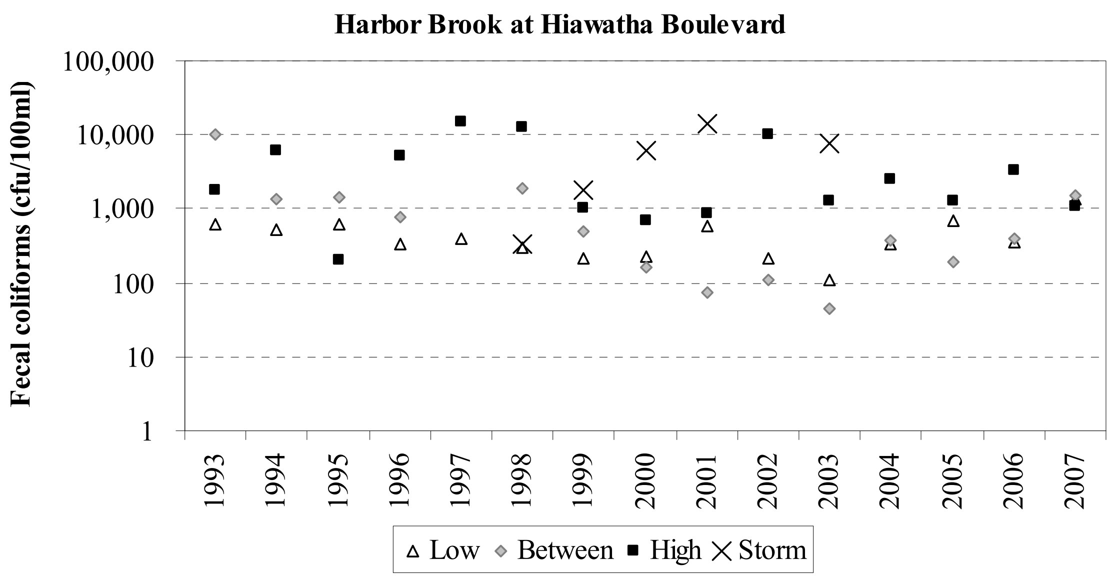
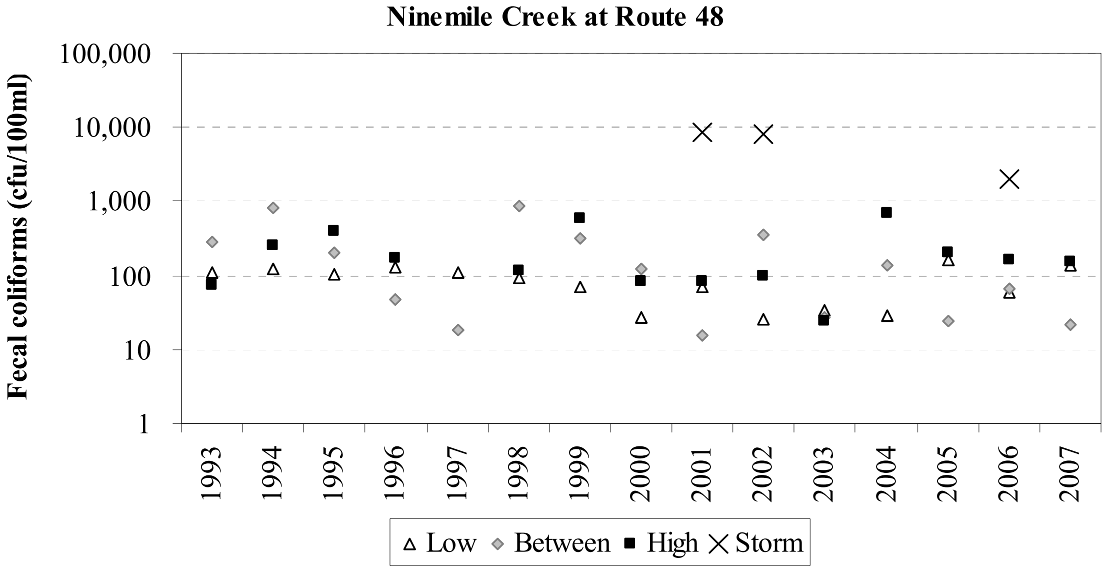


Figure 4-8. Annual (January to December) geometric means of fecal coliform concentrations at two stations on Harbor Brook.

Note: "Low" represents means for samples collected when stream flow was less than or equal to the monthly average flow. "High" represents means for samples collected when stream flow was greater than one standard deviation above the monthly mean. "Between" represents samples collected when flows were between low and high flows. Storm represents storm event samples.



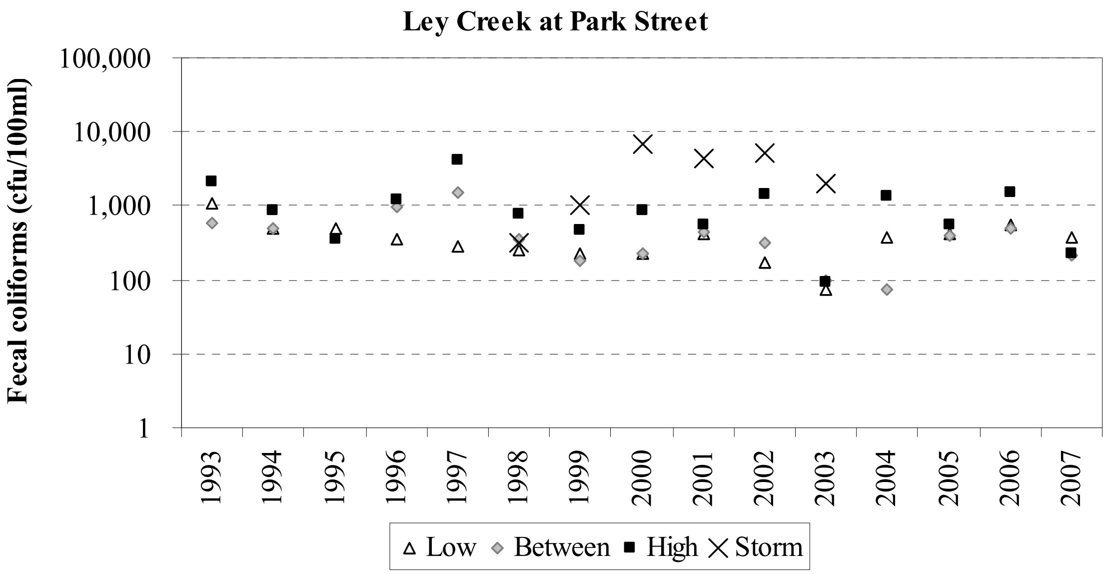


Figure 4-9. Annual (January to December) geometric means of fecal coliform concentrations at stations on Ninemile Creek and Ley Creek.

Note: "Low" represents means for samples collected when stream flow was less than or equal to the monthly average flow. "High" represents means for samples collected when stream flow was greater than one standard deviation above the monthly mean. "Between" represents samples collected when flows were between low and high flows. Storm represents storm event samples.

4.1.2 Lake Concentration and Trends

Fecal coliform and *E. coli* bacteria levels are measured at multiple sites in Onondaga Lake. Sampling stations are located within both Class B and Class C segments, at both nearshore and offshore stations.

The 2007 data show that indicator bacteria levels in the lake's southern basin, near the CSOs and major streams, are occasionally elevated in response to storms of sufficient intensity and duration to cause the combined sewer system to overflow. This finding highlights the need for continued progress with the CSO abatement projects. However, water quality bacterial standards were met (using the New York State standards, which are calculated as monthly geometric means) for water contact recreation during 2007 (**Figures 4-10 and 4-11**) in all stations within both Class B and Class C segments. The one exception was elevated *E. coli* counts at the South Deep monitoring station, which is within the Class C segment.

AMP Hypotheses to be Tested:

- Implementation of Stage I and II improvements to the wastewater collection and treatment system (including CSO projects) and progress with stormwater management will reduce concentration of indicator organisms in Onondaga Lake.

Table 4-3 summarizes the progress toward water quality improvement for bacteria.

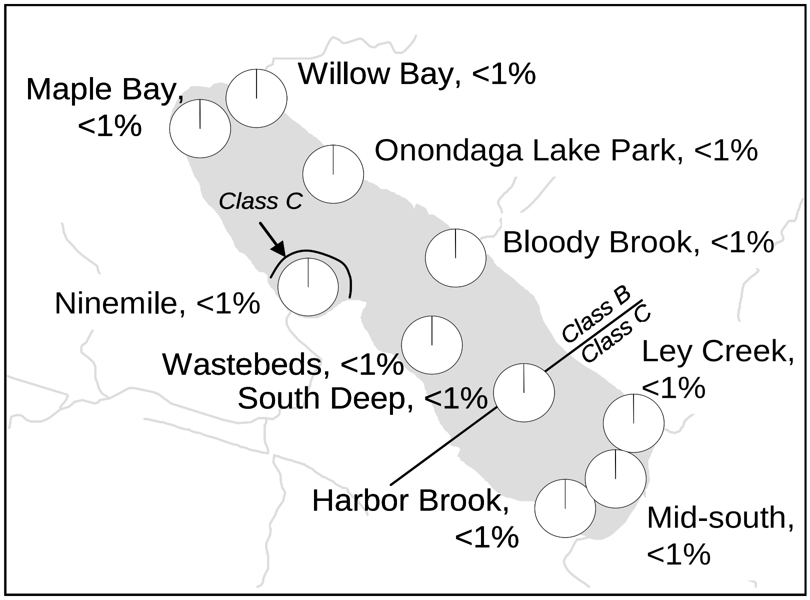


Figure 4-10. Nearshore and South Deep fecal coliform bacteria results in 2007. Shaded area of pie charts indicates percent of monthly geometric means that exceeded 200 cells per 100 ml for the disinfection period April 1 through October 15.

Note: §703.4 Water quality standards for coliforms - The monthly geometric mean, from a minimum of five examinations, shall not exceed 200 cfu/100ml during disinfection period Apr 1 to Oct 15. During 2007, fewer than five measurements were collected in April (nearshore 0, South Deep 2); September (nearshore 4, South Deep 4); and October (nearshore 0, South Deep 2).

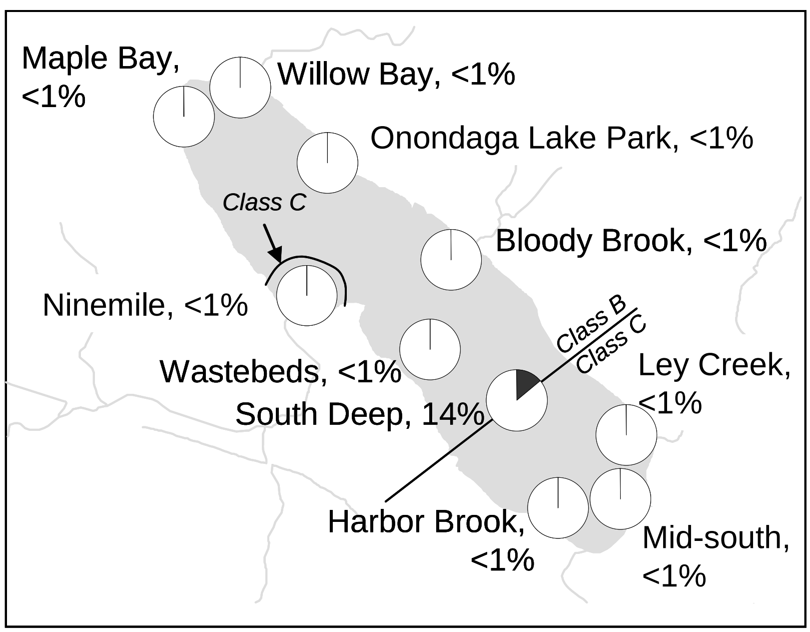


Figure 4-11. Nearshore E coli results in 2007. Shaded area of pie charts indicates percent of monthly geometric means that exceeded 126 cells per 100 ml for the disinfection period April 1 through October 15.

Note: The EPA criterion for bathing beaches is based on the geometric mean of a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period). During 2007, fewer than five measurements were collected in April (nearshore 0, South Deep 2); September (nearshore 4, South Deep 4); and October (nearshore 0, South Deep 2).

Table 4-3. Progress towards water quality improvement: Bacteria. AMP 2007 Annual Report. (Water Quality Standard)

AMENDED CONSENT JUDGMENT GOAL

Achieve compliance with the applicable ambient water quality standard for fecal coliform bacteria, Class B segment, applicable during the period of Metro disinfection (April 1- October 15). Include bacteria concentrations in nearshore areas following storm events. Reduce fecal coliform bacteria levels in the lake to achieve desired use for water contact recreation.

Hypotheses to be tested:	**Status:**
CSO remedial measures and improved stormwater management reduce the loading of fecal coliform bacteria entering the lake	• The annual load of fecal coliform bacteria in 2007 was 1,691,052 10^{10} CFU, a 36% decrease from the 1990-2006 annual average of 2,622,745 10^{10} CFU
Implementation of Stage I and II improvements to the wastewater collection and treatment system (including CSO projects) and progress with stormwater management will reduce concentration of indicator organisms in Onondaga Lake	• In 2007, bacteria levels were low throughout the lake during the summer, coincident with below average summer precipitation.
Current Conditions with Historical Comparison	
Major Sources	Combined sewer overflows (major); sanitary sewer overflows (rare) Stormwater from urban and agricultural land use Metro effluent (disinfection period April 1– Oct 15) and by-pass Other sources (wildlife, birds, etc.)
Compliance with NYS AWQS in Class B Segment	<u>Percent in compliance Class B</u> 1999-2003: 99% 2004-2006: 100% 2007: 100% <u>Class B Locations</u>: Bloody Brook, Willow Bay Maple Bay, Wastebeds Onondaga Lake Park North Basin
Factors Affecting Compliance	Metro disinfection, extent of CSO and Sanitary Sewer Overflow (SSO) Meteorological conditions (rainfall, temperature, sunlight, winds) Lake water quality (turbidity); Abundance of waterfowl
Planned Load Reductions (1998 – 2012)	
Metro SPDES Permit Requirement	Seasonal disinfection (4/1 – 10/15) of Metro effluent required
Staged CSO Remediation	CSO phased plan to capture combined sewage and stormwater: • Stage I captures 62% of volume through best management practices • Stage II eliminates and/or captures 85% of volume and provides equivalent of primary treatment.
Monitoring and Assessment Program	
Loading Estimates *(Annual County monitoring program)*	• Biweekly tributary monitoring for fecal coliform bacteria supplemented with samples collected during high flow conditions. • Daily measurements of Metro (001 and 002 if active) for fecal coliform bacteria • Storm event monitoring in tributaries for fecal coliform bacteria
Lake Monitoring *(Annual County monitoring program)*	• Weekly monitoring for Fecal coliform and E. coli bacteria at South Deep, Class C segment (May – Sept) • Quarterly monitoring for Fecal coliform and E. coli bacteria at North Deep, Class B segment (Apr – Nov) • Nine nearshore stations weekly (summer) and following storms, both Class B and Class C segments, for Fecal coliform and E. coli bacteria

Table 4-3. Progress towards water quality improvement: Bacteria. AMP 2007 Annual Report. (Water Quality Standard) – (Continued).

Tools for Decision Making	
Model	Storm Water Management Model (simulates bacteria loads in tributaries from collection system given rainfall conditions)
TMDL Allocations	Based on presumptive approach for CSO control: percent capture of combined storm and wastewater. Must account for urban stormwater.
NYS AWQS	The monthly geometric mean of fecal coliforms, from a minimum of five examinations, shall not exceed 200 cfu/100ml during disinfection period Apr 1 to Oct 15.
Federal Criteria	NYS indicator bacteria standards include total and fecal coliform. EPA criteria now use *E. coli* (freshwater) and *Enterococcus* (marine water) as indicators; states are encouraged to adopt *E. coli*.

4.2 OTHER PARAMETERS

In addition to the parameters discussed thus far, the County collects data on other parameters from tributaries and the lake. These parameters are:

- Mercury
- Metals (arsenic, cadmium, chromium, copper, nickel, lead, potassium, selenium, and zinc)
- Metals/Salts (calcium, chloride, iron, magnesium, manganese, silica, sodium, and sulfate)
- Carbon (total organic, total organic filtered, total inorganic)
- Alkalinity
- Solids (total, total suspended, total volatile, volatile suspended, total dissolved)

The 2007 external load of these materials to Onondaga Lake, loading data from 1990 – 2007, and the relative contribution of each source to the 2007 materials and water budget for Onondaga Lake are summarized in the following sections. Flow-weighted average concentrations of the lake inflows (tributaries and point sources) for these parameters are summarized in **Appendix 12**, reporting the relative standard error (RSE) of the annual means, a reflection of the variability in measurements.

4.2.1 Mercury

Mercury is one of the industrial contaminants of concern for Onondaga Lake. The County has been monitoring mercury concentrations in the tributaries since 2003 and in the lake since 1998.

4.2.1.1 Water Sample Results

Samples are collected quarterly from the tributaries for mercury analyses. Overall, concentrations were below detectable levels in natural tributaries. Mercury was detected in the two industrial tributaries, and in three Bypass (Outfall 002) events (**Table 4-4**).

Table 4-4. Mercury results in tributaries, 2007.

Tributary	Number of Samples	Results (ug/l)
Metro:		
Metro Outfall 001	50	<0.02
	4	<0.2
Metro Outfall 002	3	<0.02
	1	0.023
	1	0.034
	1	0.065
Natural Tributaries:		
Bloody Brook	5	<0.020
Harbor Brook	8	<0.020

Table 4-4. Mercury results in tributaries, 2007 (continued).

Tributary	Number of Samples	Results (ug/l)
Ley Creek	4	<0.020
Ninemile Creek	4	<0.020
Onondaga Creek	8	<0.020
Sawmill Creek	5	<0.020
Industrial Tributaries:		
Trib 5A	3	<0.020
	1	0.023
East Flume	1	0.035
	1	0.058
	1	0.064
	1	0.105

In the lake, samples are collected from upper and lower waters and analyzed for ultra low-level mercury and methyl mercury four times during the year – twice during thermal stratification and twice when the lake is fully mixed. In 2007, the October 26th sample was collected while the lake was still stratified (fall turnover occurred on October 27), so three samples were collected during stratification and one when the lake was fully mixed.

In the lower waters during the period of stratification, anoxic conditions allow bacteria to convert mercury into methyl mercury, a more toxic form that is readily bioaccumulated by aquatic organisms. This process of biomethylation allows mercury from the sediments to migrate into the water column. Historically, there has been a pattern of peak mercury levels in late summer and early fall, typical of data collected since 1999, which is consistent with the conceptual model of mercury cycling in productive lakes (see, for example, **Driscoll et al. 1995**). Consistent with historic data, the highest mercury concentrations in 2007 occurred in late fall, just before turnover. Results of the 2007 ultra low-level mercury sampling program are summarized in **Table 4-5**.

Table 4-5. Ultra low-level mercury sampling, Onondaga Lake 2007.

Sampling Event	Location and Depth	Total Hg (ng/l)	Methyl Hg (ng/l)	Detection Limits (ng/l) Total Hg	Detection Limits (ng/l) Methyl Hg
April 10, 2007	South Deep 3 m	3.53	0.047 B	0.15; 0.40	0.020; 0.050
Lake fully mixed	South Deep 18 m	1.97	0.098 U		
	South Deep 18 m Dup	1.32	0.115 U		
	North Deep 3 m	1.86	0.04 B		
	North Deep 18 m	1.58	0.036 B		
June 5, 2007	South Deep 3 m	2.37	0.092	0.15; 0.40	0.020; 0.050
Stratified	South Deep 18 m	1.24	0.036 B		
	South Deep 18 m Dup	1.65	0.036 B		
	North Deep 3 m	1.78	0.074 B		
	North Deep 18 m	1.21	0.03 B		
August 28, 2007	South Deep 3 m	2.51	0.09	0.5	0.050
Stratified	South Deep 18 m	1.86	0.214		
	South Deep 18 m Dup	1.91	0.273		
	North Deep 3 m	1.68	0.067		
	North Deep 18 m	1.65	0.212		
October 24, 2007	South Deep 3 m	5.24	0.12	0.5	0.050
Stratified	South Deep 18 m	5.66	1.68		
	South Deep 18 m Dup	5.28	1.69		
	North Deep 3 m	1.97	0.072		
	North Deep 18 m	4.63	1.9		

Notes:
Ultra low-level mercury analyses (EPA Method 1631) were performed by both Brooks Rand, LLC (Brooks Rand) and Frontier Geosciences, Inc (Frontier). Brooks Rand detection limits are shown as the Method Detection Limit (MDL) and Practical Quantitation Limit (PQL); Frontier detection limit is shown as minimum reportable limit (MRL).
* Data represented as the average of sample and field duplicate results.
U - indicates result was reported as non-detect.
B – detected by the instrument above the MDL (method detection limit) but less than the PQL (practical quantitation limit). Measured result is reported and considered an estimate.

Mercury concentrations in the upper waters of the lake have remained relatively stable over time, whereas in lower waters, concentrations appear to be declining (**Figure 4-12**). Methyl mercury concentrations in upper and lower waters also appear to be in decline in recent years.

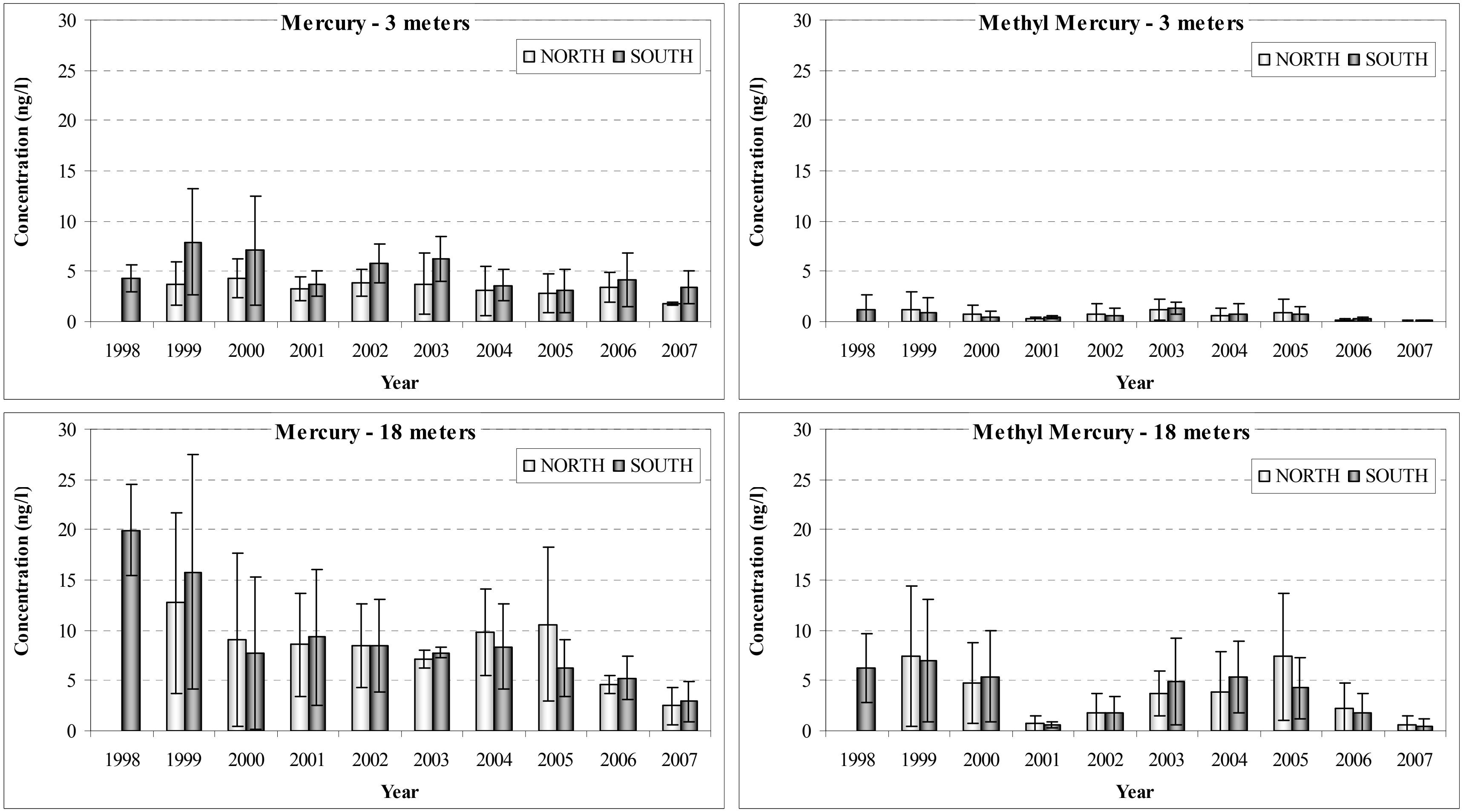


Figure 4-12. Average mercury and methyl-mercury concentrations in Onondaga Lake North and South Basins, at 3-meter and 18-meter depths, with standard deviation, 1998-2007.

4.2.1.2 Fish Flesh Update

The New York State Department of Health (NYSDOH) produces an annual report detailing advisories for the consumption of fish and game in New York. The most recent report; "2007-2008 Health Advisories: Chemicals in Sport Fish and Game" released in mid-May 2007 indicates a significant revision regarding Onondaga Lake. The NYSDOH now advises that largemouth and smallmouth bass longer than 15 inches and walleye of any size should not be consumed because of elevated mercury levels.

EcoLogic contacted the NYSDEC to obtain the 2007 fish mercury data; however, the data will not be available until late in 2008.

4.2.2 Metals

Certain metals are analyzed quarterly as part of the AMP; including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), potassium (K), selenium (Se), and zinc (Zn). Because these data are collected quarterly and many of the measured concentrations are close to the limit of detection, the data are used for general surveillance and compliance.

4.2.3 Metals/Salts

Data gathered on metals/salts are used to check data quality (charge balance), evaluate trends, conduct geochemical analyses, evaluate redox and density stratification, and contribute to evaluation of phytoplankton community structure. The metals/salts analyzed for the AMP include calcium (Ca), chloride (Cl), iron (Fe), magnesium (Mg), manganese (Mn), silica (SiO_2), sodium (Na) and sulfate (SO_4). **Table 4-6** summarizes the loading for metals/salts.

Table 4-6. Summary of metals/salts loading and long-term comparison.

	2007 Loading								
Tributary	***Water (hm^3)***	***Ca (mt)***	***Cl (mt)***	***Fe (mt)***	***Mg (mt)***	***Mn (mt)***	***SiO_2 (mt)***	***Na (mt)***	***SO_4 (mt)***
Metro:									
Metro Outfall 001	88	11,830	36,502	112	2,067	3.46	468	20,584	12,971
Metro Outfall 002	1.4	145	703	2.4	28	0.060	7.9	431	112
Natural Tributaries:									
Onondaga Creek	183	20,673	100,322	354	4,362	14	905	61,509	21,237
Ninemile Creek	170	30,900	47,749	31	815	3.8	220	15,943	4,203
Ley Creek	39	4,267	16,366	155	4,488	10	693	9,736	26,625
Harbor Brook	14	2,633	3,655	16	488	0.55	67	2,048	4,001
Industrial Tributaries:									
East Flume	0.68	80	368	0.23	15	0.019	6.6	281	201
Trib 5A	0.56	73	190	0.63	8.9	0.047	4.7	90	49
Total Monitored	**496**	**70,602**	**205,855**	**671**	**12,272**	**32**	**2,372**	**110,621**	**69,399**
Average 1990-2006*		**68,145**	**172,698**	**617**	**10,974**	**32**	**2,287**	**85,247**	**71,386**
%Change 2007 from Average:		**4.0%**	**19%**	**8.7%**	**12%**	**0.76%**	**3.7%**	**30%**	**-2.8%**

Notes: mt = metric tons; hm3 = million cubic meters. Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events). Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms.

Table 4-6. Summary of metals/salts loading and long-term comparison (continued).

Tributary	2007 Percent contribution by gauged inflow *Water*	*Ca*	*Cl*	*Fe*	*Mg*	*Mn*	*SiO_2*	*Na*	*SO_4*
Metro:									
Metro Outfall 001	18%	17%	18%	17%	17%	11%	20%	19%	19%
Metro Outfall 002	0.29%	0.21%	0.34%	0.36%	0.23%	0.19%	0.33%	0.39%	0.16%
Natural Tributaries:									
Onondaga Creek	37%	29%	49%	53%	36%	43%	38%	56%	31%
Ninemile Creek	34%	44%	23%	23%	37%	32%	29%	14%	38%
Ley Creek	7.8%	6.0%	8.0%	4.6%	6.6%	12%	9.3%	8.8%	6.1%
Harbor Brook	2.8%	3.7%	1.8%	2.3%	4.0%	1.7%	2.8%	1.9%	5.8%
Industrial Tributaries:									
East Flume	0.14%	0.11%	0.18%	0.034%	0.12%	0.061%	0.28%	0.25%	0.29%
Trib 5A	0.11%	0.10%	0.092%	0.093%	0.073%	0.15%	0.20%	0.081%	0.070%
Total Monitored	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

** Averages for Fe, Mg, Mn and SO4 from 1992-2006.*

Chapter 8 contains a mass balance summary for the previous 5 years for chloride. Since chloride is expected to be conservative, the chloride balance provides a basis for testing the accuracy and completeness of the data and methods used to develop the mass balances. Onondaga Lake outflow loads of chloride exceeded inflow loads by 3.6% ± 2.1% in 2003-2007. This compares with 5.7+/- 2.1% in the previous 5-year interval and 0.4 +/- 3.4% in last 2 years (2006-2007). An apparent increasing trend in the chloride load from the lower portion of Onondaga Creek (between the Dorwin and Kirkpatrick monitoring sites) may be responsible for the gradual convergence of the chloride balance, although the loading trend analysis is uncertain because of increases in precipitation. In 2003-2007, the chloride load to this reach accounted for 34% of the total load to the Lake.

Trends in the sodium balance are similar to chloride (**Chapter 8**). Salt springs enter the lower reach of Onondaga Creek between the Dorwin and Kirkpatrick sites (**Kappel, 2003**). Concentrations of chloride and sodium from the SpencePatrick Spring during 2007 ranged from 33,300 mg/l to 71,000 mg/l and 22,600 mg/l to 46,900 mg/l, respectively. Increases in road salt contributions associated with increasing precipitation may also contribute to increasing chloride and sodium loads.

As part of the Midland Phase 2 Regional Treament Facility and Conveyances construction projects, major dewatering efforts were conducted. Significant chloride concentrations werre encountered in the dewatering effluent from this project. Monitoring and control procedures for dewatering were developed and implemented. A Best Management Plan has been developed in order to provide guidance for monitoring and control of the chloride loadings. The Clinton RTF and Conveyances projects target the Clinton Street Combined Overflow Service Area. The completed project will result in the reduction of CSO discharges by providing conveyance, storage, and high-rate treatment of combined sewer overflows at the Clinton Street CSO Regional Treatment Facility (RTF). The Clinton Phase 1 and 2 projects will provide for the proper routing of flows to the RTF

Both with respect to concentration and load, increasing trends in sodium and chloride are indicated for the total inflow and for the inflow from each tributary except for Ninemile Creek. On a mass basis, the trend in load from the lower Onondaga Creek watershed accounts for most of the trend in the total inflow load (**Chapter 8**). Despite the apparent trends in inflow loads for sodium and chloride, no trends in outflow loads are indicated. Increases in loads of calcium, chloride and sodium at the Hiawatha (Harbor Brook) site are associated with increases in flow. Similarly, decreases in Trib5A loads reflect an apparent decrease in flow (**Chapter 8**).

Apparent increasing trends in silica concentration and load in the Lake outflow are not paired with corresponding trends in the lake inflow. This may be an indirect consequence of reduced algal productivity in the Lake resulting from decreases in phosphorus load. If diatom growth were increasingly limited by phosphorus levels, silica uptake by diatoms and subsequent sedimentation would also to decrease (**Chapter 8**).

4.2.4 Carbon

Carbon is also analyzed as part of the AMP. Total carbon, filtered carbon and inorganic carbon data are used to evaluate trends, trophic status, as an indicator of oxygen-demanding material and to support model development. **Table 4-7** summarizes the loading of carbon to Onondaga Lake.

Table 4-7. Summary of carbon loading and long-term comparison.

	2007 Loading			**2007 Percent contribution by gauged inflow**		
Tributary	***Water (hm^3)***	***TOC (mt)***	***TIC (mt)***	***Water***	***TOC***	***TIC***
Metro:						
Metro Outfall 001	88	663	3,789	18%	36%	15%
Metro Outfall 002	1.4	26	76	0.29%	1.4%	0.30%
Natural Tributaries:						
Onondaga Creek	183	408	10,245	37%	22%	40%
Ninemile Creek	170	462	8,458	34%	25%	33%
Ley Creek	39	230	1,972	7.8%	13%	7.8%
Harbor Brook	14	34	843	2.8%	1.8%	3.3%
Industrial Tributaries:						
East Flume	0.68	2.9	26	0.14%	0.16%	0.10%
Trib 5A	0.56	2.5	24	0.11%	0.14%	0.093%
Total Monitored	**496**	**1,827**	**25,433**	**100%**	**100%**	**100%**
Average 1990-2006:		**2,896**	**23,906**			
%Change 2007 from Average:		**-37%**	**6.4%**			

Notes: mt = metric tons; hm3 = million cubic meters. Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events). Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms.

4.2.5 Alkalinity

Total alkalinity is monitored in the AMP for data quality (charge balance), evaluation of trends and to compute hardness. **Table 4-8** summarizes loading and long-term trends for alkalinity.

Table 4-8. Summary of alkalinity loading and long-term comparison.

Tributary	2007 Loading		2007 Percent contribution by gauged inflow	
	Water *(hm^3)*	*ALK* *(mt)*	*Water*	*ALK*
Metro:				
Metro Outfall 001	88	13,712	18%	14%
Metro Outfall 002	1.4	301	0.29%	0.31%
Natural Tributaries:				
Onondaga Creek	183	39,927	37%	41%
Ninemile Creek	170	32,379	34%	33%
Ley Creek	39	7,474	7.8%	7.7%
Harbor Brook	14	3,158	2.8%	3.3%
Industrial Tributaries:				
East Flume	0.68	106	0.14%	0.11%
Trib 5A	0.56	93	0.11%	0.10%
Total Monitored	**496**	**95,150**	**100%**	**100%**
Average 1990-2006:		**92,988**		
%Change 2007 From Average:		**4.5%**		

Notes: mt = metric tons; hm3 = million cubic meters. Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events). Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms.

Increased loads of alkalinity at the Hiawatha (Harbor Brook) site are associated with increased flow.

4.2.6 Solids

Solids are monitored as part of the AMP for compliance with water quality standards, trend analyses, chemical stratification and correlation with turbidity. Solids are analyzed as total solids (TS), total suspended solids (TSS), volatile suspended solids (VSS), total volatile solids (TVS), and total dissolved solids (TDS). **Table 4-9** shows the 2007 loading and long-term comparison of total suspended solids.

Table 4-9. Summary of solids loading and long-term comparison.

Tributary	2007 Loading		2007 Percent contribution by gauged inflow	
	Water *(hm^3)*	*TSS* *(mt)*	*Water*	*TSS*
Metro:				
Metro Outfall 001	88	523	18%	3.3%
Metro Outfall 002	1.4	113	0.29%	0.71%
Natural Tributaries:				
Onondaga Creek	183	8,927	37%	56%
Ninemile Creek	170	5,197	34%	33%
Ley Creek	39	543	7.8%	3.4%

Table 4-9. Summary of solids loading and long-term comparison (continued).

Tributary	2007 Loading		2007 Percent contribution by gauged inflow	
	Water (*hm*^{3})	*TSS* (*mt*)	*Water*	*TSS*
Harbor Brook	14	635	2.8%	4.0%
Industrial Tributaries:				
East Flume	0.68	11	0.14%	0.071%
Trib 5A	0.56	8.9	0.11%	0.056%
Total Monitored	**496**	**15,959**	**100%**	**100%**
Average 1990-2006:		**13,610**		
%Change 2007 from Average:		**17%**		

Notes: mt = metric tons; hm3 = million cubic meters. Metro Outfall 001 calculated loads of TSS are based on daily measurements. Metro Bypass Outfall 002 estimates based on periodic grab samples when outfall is active (high flow events). Natural tributaries, East Flume and Tributary 5A calculations based on biweekly program, plus high flow events and storms.

The flow-weighted average concentration of suspended solids is reported in **Table 4-10.** The high RSE associated with total suspended solids measurements in the natural tributaries as compared to Metro demonstrates the natural variability of TSS as compared with a controlled point source.

Table 4-10. Flow-weighted average of solids, 2007, in Onondaga Lake tributaries, with standard error of estimate.

Tributary	Total Suspended Solids mg/l		Total Dissolved Solids mg/l	
	Concentration	RSE	Concentration	RSE
Metro:				
Metro Outfall 001 **	6.0	4.9%	1,170	3.6%
Metro Outfall 002	78	9.7%	1,150	28%
Natural Tributaries:				
Onondaga Creek	49	51%	1,271	4.2%
Ninemile Creek	31	31%	969	2.9%
Ley Creek	14	45%	1,057	12%
Harbor Brook	46	98%	1,114	6.0%
Industrial Tributaries:				
East Flume	17	43%	1,551	7.1%
Trib. 5A	16	72%	941	4.6%

Notes:
*RSE = relative standard error of the concentration estimate. ** Metro TSS based on observations made daily.*
Calculated using a multiple regression algorithm relating concentration to flow, season, and trend with residual interpolation.
Based on data collected bi-weekly.
Calculations use the laboratory reported minimal reportable limit (MRL) when observations were below the MRL.

4.3 REFERENCES

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CHAPTER 5: BIOLOGICAL COMMUNITY

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CHAPTER 5. BIOLOGICAL COMMUNITY

Biological monitoring of Onondaga Lake incorporates several trophic levels, including primary producers (phytoplankton, macroalgae and macrophytes), primary consumers (zooplankton, zebra mussels, benthic invertebrates and early life stages of fish), and higher level consumers (fish and piscivorous birds).

> Amended Consent Judgment Goals for Biological Monitoring:
>
> - Evaluate physical habitat conditions in the lake and tributaries
> - Evaluate the lake's trophic state (level of productivity)
> - Characterize the lake's biological community

During 2007, the AMP completed sampling and analysis of several trophic level: phytoplankton, zooplankton, fish and zebra mussels. Qualitative assessments were made of macroalgae and macrophytes.

5.1 PHYTOPLANKTON COMMUNITY

> AMP Hypotheses To Be Tested:
>
> - Metro improvements and watershed phosphorus load reductions result in lower biomass of phytoplankton in Onondaga Lake

Since the 1960s, summer blooms of planktonic algae have been associated with the eutrophic condition of the lake. Recent studies have shown that overall phytoplankton abundance has been low compared to values prior to 1988, and that there has been a change in the composition of the algal community (**Mills et al 2008**).

5.1.1 Community Structure and 2007 Results

The phytoplankton data are summarized in **Appendix 3**.

Onondaga Lake remains a productive aquatic system as evidenced by its high levels of algal biomass. The community is comprised of Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Pyrrhophyta, Euglenophyta, and "miscellaneous microflagellates" (**Table 5-1**).

Table 5-1. Most common algal species in taxonomic groups, Onondaga Lake 2007. Taxonomic groups listed in descending order by total biomass for 2007.

Taxonomic	Most common algal species	
Group	By density	By biomass
Bacillariophyta	*Stephanodiscus parvu*	*Asterionella fermosa*
Cryptophyta	*Rhodomonas minuta*	*Cryptomonas erosa*
Chlorophyta	Unknown spp. (Chlorococcaceae family)	Unknown spp. (Chlorococcaceae family)
Pyrrhophyta	Unknown spp. (genus *Gymnodinium*)	*Peridinium umbonatum*
Chrysophyta	*Erkenia subaequiciliata*	*Erkenia subaequiciliata*
Cyanophytes	*Synechocystis* sp.	*Aphanizomenon issatschenkoi*

The biomass of each division of phytoplankton observed in Onondaga Lake in 2006 and 2007 are summarized in **Table 5-2**. Bacillariophytes (diatoms) were the most abundant taxa in the lake in both years; however, biomass in 2007 was much lower than in 2006. Cryptophytes (unicellular algae) and Chlorophytes (green algae) were also common in both years. Cryptophytes were documented in similar quantities in both years, but, like bacillariophytes, there was a marked decrease in Chlorophtytes in 2007.

Table 5-2. Phytoplankton biomass peak and total in Onondaga Lake, by taxonomic group. Sorted by total biomass 2007.

Taxonomic Group	**Biomass** (µg/L)					
	Peak			***Total***		
	2006	**2007**	**% Change**	**2006**	**2007**	**% Change**
Bacillariophyta	8,926	2,644	-70%	22,174	11,791	-47%
Cryptophyta	1,666	1,974	18%	6,459	6,775	5%
Chlorophyta	2,517	1,024	-59%	9,324	3,999	-57%
Pyrrhophyta	722	681	-6%	2,326	1,956	-16%
Chrysophyta	371	726	96%	1,193	1,832	54%
Cyanobacteria	331	62	-81%	842	188	-78%
Miscellaneous flagellates	22	26	18%	49	76	55%
Euglenophytes	3.2	8.6	169%	3.2	8.6	169%

In both 2006 and 2007, spring blooms in Onondaga Lake were dominated by bacillariophytes. The spring biomass peak in 2006 (9,783 µg/L) and 2007 (2,644 µg/L) occurred in early April and in both years bacillariophyte biomass remained comparatively high into May. Note the dramatic reduction in cyanobacteria abundance, which is discussed in more detail in section 5.2.2.

Average annual algal biomass in 2007 (26,625 µg/L) decreased substantially compared to 2006 (42,369 µg/L). This continues a trend towards decreasing phytoplankton biomass in the lake in recent years. The annual average phytoplankton biomass (all species totaled) since 1998 is displayed in **Figure 5-1**. Reductions in biomass are coincident with reduced point and nonpoint source nutrient loads.

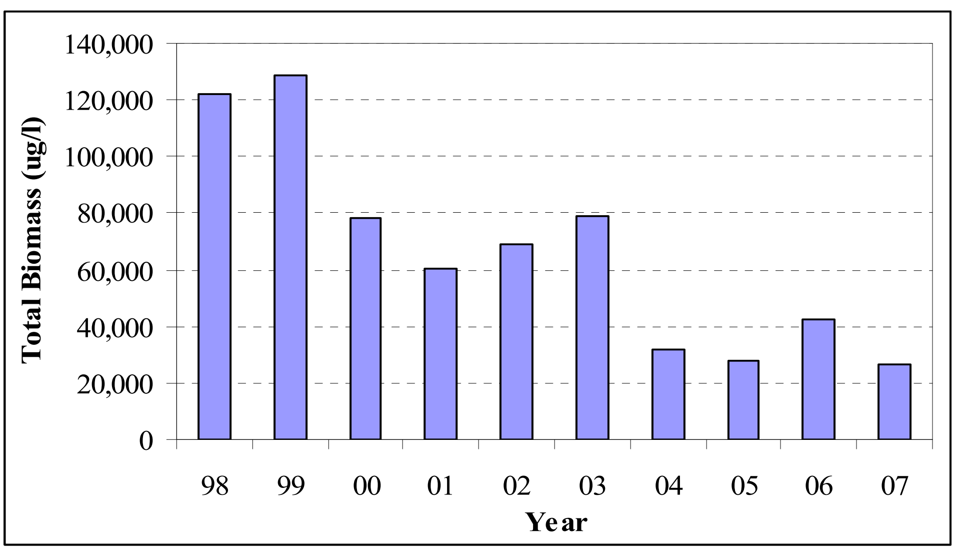


Figure 5-1. Annual average phytoplankton biomass in Onondaga Lake, 1998 – 2007.

5.1.2 Cyanobacteria

The relative importance of cyanobacteria (blue-green algae) is of concern to lake managers; cyanobacterial blooms can negatively affect recreational use. Most cyanobacteria do not produce chemicals harmful to humans or other animals. However, certain species of cyanobacteria produce substances called cyanotoxins. Harmful algal blooms, which may also affect zooplankton, are not present in Onondaga Lake. As displayed in **Figure 5-2**, the percent contribution of cyanobacteria to Onondaga Lake's phytoplankton community has continued to decline since the 1990s. Because these are percent figures, the change from 2006 to 2007 was not significant; total phytoplankton biomass continued to decline (refer to **Figure 5-1**).

> AMP Hypotheses To Be Tested:
>
> - Metro improvements and watershed phosphorus load reductions result, and an associated increase in the N:P ratio, in reduced importance of cyanobacteria to the lake's phytoplankton biomass

A further analysis of cyanobacterial biomass since 1998 demonstrates that, while cyanobacteria are present, there have been declines in both the duration and intensity of cyanobacterial blooms in the lake **(Figure 5-3).** For example, cyanobacterial blooms that historically occurred throughout the summer and fall have been reduced in intensity, frequency and duration since 2000. Beginning in 2005, these blooms have been essentially absent.

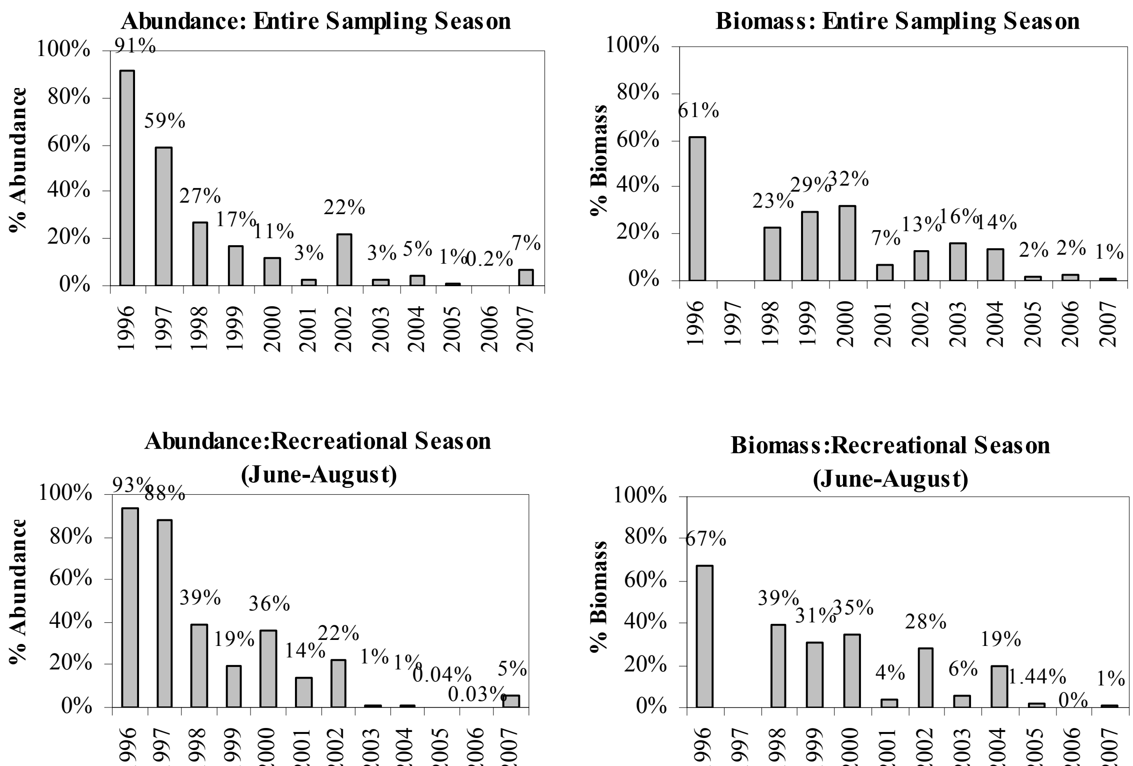


Figure 5-2. Percent contribution of Cyanobacteria (blue-green algae) to the phytoplankton community 1996 to 2007, Onondaga Lake South Deep.
Note: 1997 data were not analyzed for biomass.

The limited cyanobacterial productivity observed from 2004 through 2007 is consistent with an overall improvement of water quality as phosphorus inputs are reduced.

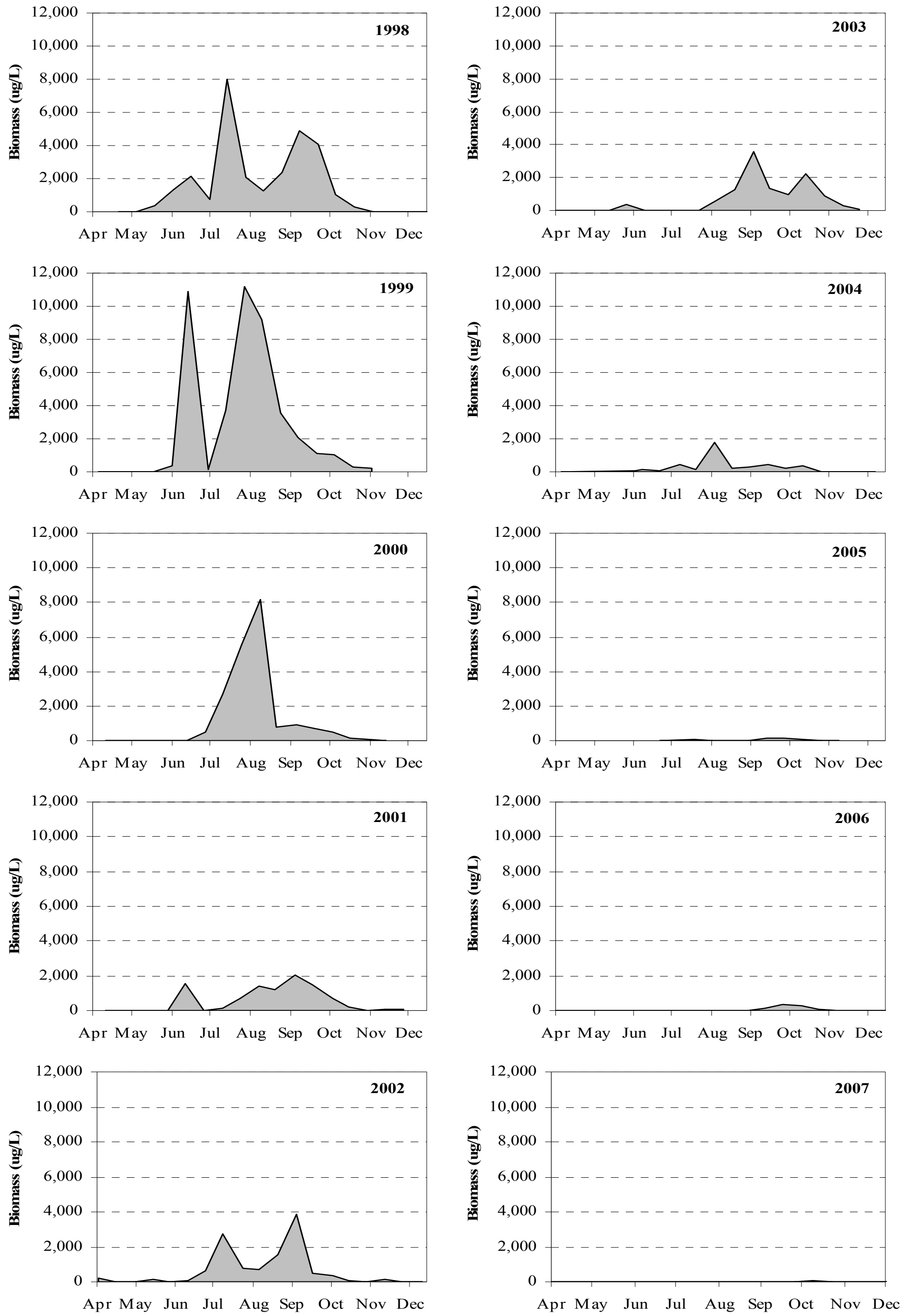


Figure 5-3. Cyanobacterial biomass, 1998 – 2007, Onondaga Lake, South Deep.

5.2 ZOOPLANKTON COMMUNITY

The composition of the zooplankton community in Onondaga Lake 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* species, the cladocerans *Ceriodaphnia quadrangula* and *Bosmina longirostris*, the copepods *Acanthocyclops vernalis* and *Diacyclops thomasi* and a variety of rotifers have been documented in varying abundances in the lake. The proportion of these and other species in the zooplankton community has fluctuated over time, responding to influences such as industrial discharges and predation. For example, the introduction of the exotic *Daphnia exilis* in the 1920s, its successful colonization through the 1970s, and subsequent disappearance in the early 1980s corresponded with distinct events in the history of industrial activity in Onondaga Lake (**Mills et al. 2008**).

> AMP Hypotheses To Be Tested:
>
> - Metro improvements and watershed phosphorus load reductions reduce the biomass of zooplankton by reducing the algal food supply in Onondaga Lake

The AMP data suggest that the zooplankton biomass in Onondaga Lake has been influenced to a greater extent by predation by the alewife (a planktivorous fish) than by changes in the algal food supply. Larger sized zooplankton are the most effective grazers of phytoplankton and exert a major control on their standing crop (**Mills et al. 1987**). Alewives tend to select for larger zooplankton; years with abundant alewives in Onondaga Lake have consistently exhibited the smallest-sized zooplankton and lowest water clarity. This is consistent with the "trophic cascade" hypothesis (**Carpenter and Kitchell 1993; Gulati et al. 1990**), which states that changes in predator-prey relationships at one trophic level can impact the ecosystem structure at other trophic levels.

5.2.1 Community Structure and 2007 Results

A summary of the zooplankton community in Onondaga Lake from December 29, 2006 to December 13, 2007 is presented in **Appendix 3**. A total of 12 species, as well as nauplii and copepodite groups, were identified in Onondaga Lake in 2007:

Cladocerans		**Copepods**
*Bosmina longirostris**	*Daphnia retrocurva**	*Diacyclops thomasi**
Diaphanosoma birgei	*Daphnia ambigua*	*Acanthocyclops vernalis*
Ceriodaphnia quadrangula	*Daphnia sp.*	nauplii*
Eubosmina coregoni	*Leptodora kindtii*	
Daphnia mendotae	*Cercopagis pengoi*	

*Dominant species in the 2007 zooplankton community

No calanoid copepods were detected during the 2007 monitoring season. These taxa have been rare since alewives became abundant in 2003. The potential impacts on grazing, phytoplankton abundance, and water clarity have not been explored.

Seasonally, in 2007 total zooplankton density and biomass were highest during spring, and lowest in mid-March. Zooplankton density and biomass peaked in mid-June and were generally high from early June to early July. During the rest of the season they remained relatively low.

The zooplankton community was evaluated by assessing the relative proportion in density and biomass by taxa and by species (**Appendix 3**). By taxa, cladoceran proportional abundance was high from early June through November, with copepod proportional abundance dominating in February through May, and in December. The proportion of zooplankton biomass contributed by cladocerans and copepods mirrored their relative abundance (**Figure 5-4**).

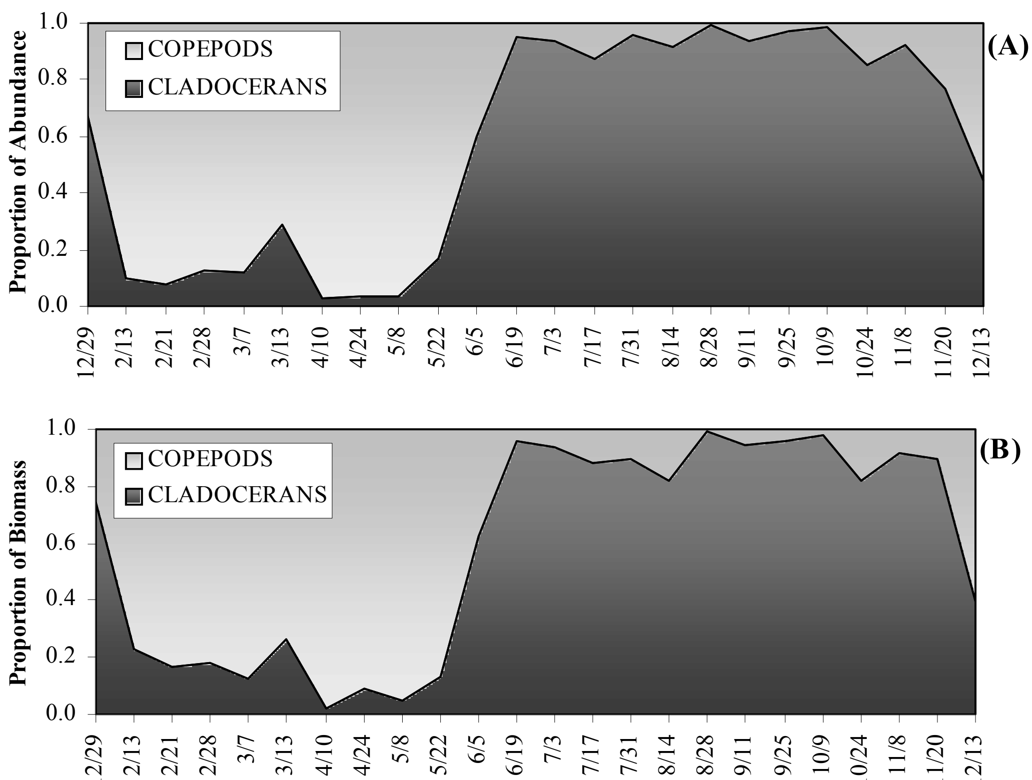


Figure 5-4. (A) Proportion of abundance and (B) proportion of biomass of cladocerans and copepods in Onondaga Lake during 2007.

The cladoceran zooplankton community was proportionally dominated by *Bosmina longirostris* throughout the season. The prevalence of *Bosmina longirostris* was consistent with observations from 1996 through 2006. In 2007, *Daphnia mendotae* was a minor contributor to cladoceran biomass. *Daphnia retrocurva,* however, was a significant contributor to cladoceran biomass from mid-July to late October in 2007.

The copepod community was largely dominated by *D. thomasi* throughout the season except mid-August when *Acanthocyclops vernalis* predominated.

A summary of mean size of the crustacean zooplankton community is shown in **Appendix 3**, and tabulated below:

Mean size of crustacean community	0.29 mm January – December 0.32 mm Winter 0.25 mm Spring 0.29 mm Summer 0.36 mm Fall
Maximum mean size zooplankton	0.56 mm in mid-April
Average body lengths 2007	0.25 mm to 0.51 mm

The small average size of the zooplankton community in Onondaga Lake throughout the seasons in 2007 (0.29 mm average) was smaller than values observed in 2006 (0.38 mm) but consistent with conditions documented in the lake since 2003. In contrast, during 2002 the zooplankton community showed greater size and variation, varying from 0.92 mm during the winter (January – March) to 0.27 mm in fall (October – December).

5.2.2 Trophic Cascade

Larger zooplankton, such as *Daphnia* species, are the most effective grazers of phytoplankton and exert a major control on the standing crop (**Mills et al. 1987**). Large numbers of *Daphnia pulicaria* and *Daphnia mendotae* in Onondaga Lake the late 1980s were accompanied by increases in water clarity (**Auer et al. 1990**), referred to in past AMP reports as the late spring "clearing event." This was a period in the late spring (usually June) when water clarity increased to depths greater than was typical during the rest of the year. As displayed in **Figure 5-5** high water clarity during the spring period May 1 to June 15 was evident during the late 1980s and early 1990s. The timing of this event correlated with peak *Daphnia* abundance (**Wang et al. 2008**). However, water clarity from 2003 to 2007 was not as high as the in 1990s. This suggests a loss of the spring clearing event during these years.

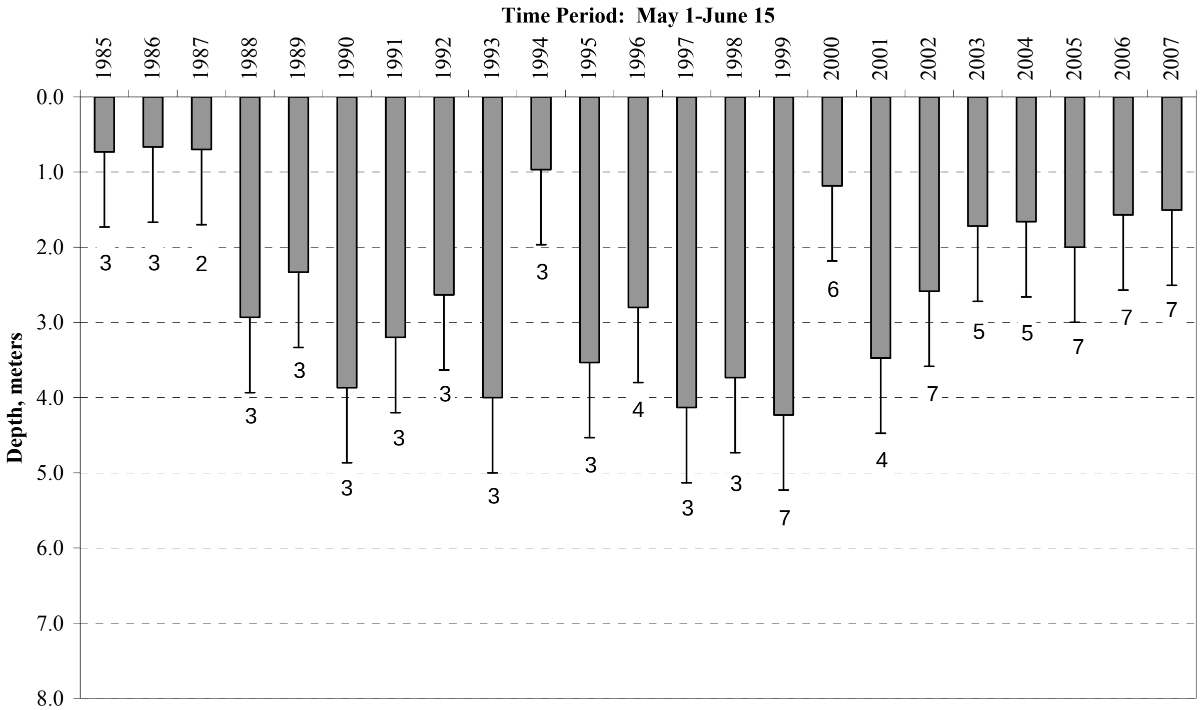


Figure 5-5. Mean Secchi disk readings from May through June 15 since 1985 in Onondaga Lake.

As discussed above, since 2003 the abundance of larger zooplankton in Onondaga Lake has declined. The small cladoceran *Bosmina logirostris* has become dominant, the *Daphnia* population has been reduced, and calanoid copepods have diminished to such an extent that they have not been documented in samples for the past two years (**Appendix 3**). Planktivory by alewife is likely the cause for this shift from the larger *Daphnia* species to the smaller *Bosmina logirostris*. Alewife populations based on electrofishing catches were relatively low from 2000 through 2002. Since 2003, alewife has been abundant in electrofishing and vertical gill net catches; their high abundance has been verified by hydroacoustics (**Wang et al. 2008**). For these years, the disappearance of large bodied *Daphnia* species has coincided with the absence of the spring clearing event

For reference, zooplankton sizes have been compared between Onondaga Lake (containing a substantial alewife population in recent years) and Oneida Lake (where alewife have not been as abundant). Unlike in prior years (1997 – 2003), from 2004 to 2007 small zooplankton dominated Onondaga Lake while larger species, especially *Daphnia pulicaria* and *Daphnia mendotae*, led to high average total zooplankton biomass in Oneida Lake (**Appendix 3**). This suggests alewife predation continues to have a significant impact on the size structure of the zooplankton community in Onondaga Lake.

The increase in alewife abundance began in 2002 with a strong year class. At least two additional year classes (2004 and 2006) have been produced since then (**Wang et al. 2008**). The alewife population in the lake has been relatively constant since 2005 when hydroacoustics surveys of the population began (**Wang et al. 2008).** That the alewife population has suddenly flourished and continued to prosper in Onondaga Lake may be attributable to the reduction in ammonia loading from the Metro treatment plant (**Wang et al. 2008**).

5.2.3 *Cercopagis pengoi*

After its initial discovery in 2000, the exotic zooplankter *Cercopagis pengoi* has been detected in Onondaga Lake in each year from 2002 through 2007. This Ponto-Caspian invader has been established in Lake Ontario since 1998 and has subsequently spread to several of the Finger Lakes (**Makarewicz et al. 2001**). In 2007, it was found in samples collected on 10 dates spanning from early summer to mid-fall (**Appendix 3**).

The biomass of the species was relatively small throughout most of the season (maximum value of 8.25 µg/L); however, reaching a proportion of 35.9% of the total biomass in mid-summer, 2007, *Cercopagis* possesses some potential to impact the zooplankton community through predation (**Ojaveer et al. 2000**). Interestingly, the periods of *Cercopagis* detection in the lake also represent periods of decreased dominance by *Bosmina longirostris* (**Appendix 3**), suggesting possible predatory impacts by *Cercopagis* leading to a restructuring of the zooplankton community. This relationship between *Cercopagis* and *Bosmina* has been documented in Lake Ontario (Benoit et al. 2002).

Table 5-3. Progress towards water quality improvement: Zooplankton. AMP 2007 Annual Report. (Assessment Measure)

AMENDED CONSENT JUDGMENT GOAL

Achieve abundance and species composition of a zooplankton community comparable to productive lakes in the geologic and climatic setting of Onondaga Lake.

Hypotheses to be tested:	**Status:**
Metro improvements and watershed phosphorus load reductions reduce the biomass of zooplankton by reducing the algal food supply in Onondaga Lake.	• Data suggest that the biomass of zooplankton in Onondaga Lake is influenced more by alewife predation than by fluctuations in the algal food supply. In the aquatic environment, larger zooplankton are the most effective grazers of phytoplankton and exert a major control on the standing crop (Mills et al. 1987). Alewives graze on larger zooplankton; years with abundant alewives consistently exhibit the smallest zooplankton and poorest water clarity.
Current Conditions with Historical Comparison	
Biomass *(Annual average (standard deviation))*	1998-2004: 670 (259) 2005-2006: 275 (61) 2007: 65 (124)
Community Composition *(Annual average density (standard deviation))*	Cladocerans / Copepods 1998-2004: 44% (10%) / 56% (10%) 2005-2006: 61% (4%) / 39% (4%) 2007: 57% (39%) / 43% (39%)
Forcing Functions	Food supply (algal abundance), species composition, grazing pressure (alewives), water quality (ammonia, chlorides, extent of aerobic habitat)
Monitoring and Assessment Program	
Lake Monitoring *(Annual County monitoring program)*	Biweekly monitoring for density (organisms 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 cladoceran types • Relative biomass of major copepod types Number of crustacean taxa (1995 to present)
Tools for Decision Making	
Model	None developed. Zooplankton grazing rate will be specified in the Onondaga Lake Water Quality Model (under development by QEA,LLC)

5.3 DREISSENID MUSSELS

Zebra mussels (*Dreissena polymorpha*) and the closely-related quagga mussels (*Dreissena rostriformis bugensis*) are small, fingernail-sized mussels native to the Caspian Sea region of Asia. They were probably introduced to the United States through ballast water released by a trans-Atlantic vessel(s). Dreissenid mussels were first detected in the Great Lakes in the late 1980s. Since that time, they have spread rapidly to all of the Great Lakes and waterways of many nearby states. They were first documented in the Seneca River in 1991 and Onondaga Lake in 1992. High densities in the River have persisted since 1993 (**Spada et al. 2002**). Until 1999, the density of dreissenids in the lake was very limited; the rapid increase post-1999 has been attributed to reduced ammonia levels in the lake (**Spada et al. 2002**).

OCDWEP staff has sampled the Seneca River and Onondaga Lake for zebra/quagga mussels in support of the Three Rivers Water Quality Model (TRWQM) and Onondaga Lake Water Quality Model (OLWQM). The locations sampled vary each year depending on the needs of the modeling team. Sampling locations in the Seneca River and Onondaga Lake are illustrated in **Figure 5-6 and 5-7,** respectively. The methods and detailed data comparisons can be found in **Appendix 6.**

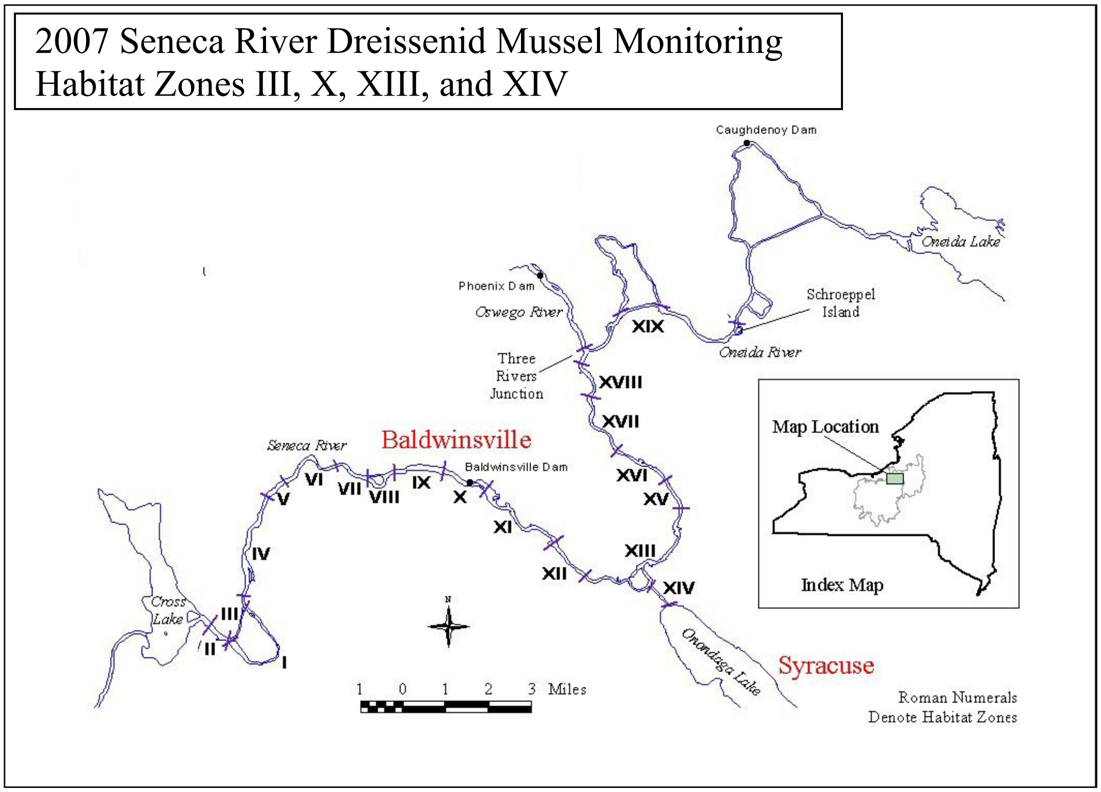


Figure 5-6. Dreissenid mussel monitoring locations in the Seneca River.
In 2007 zones III, X, XIII, and XIV were sampled.

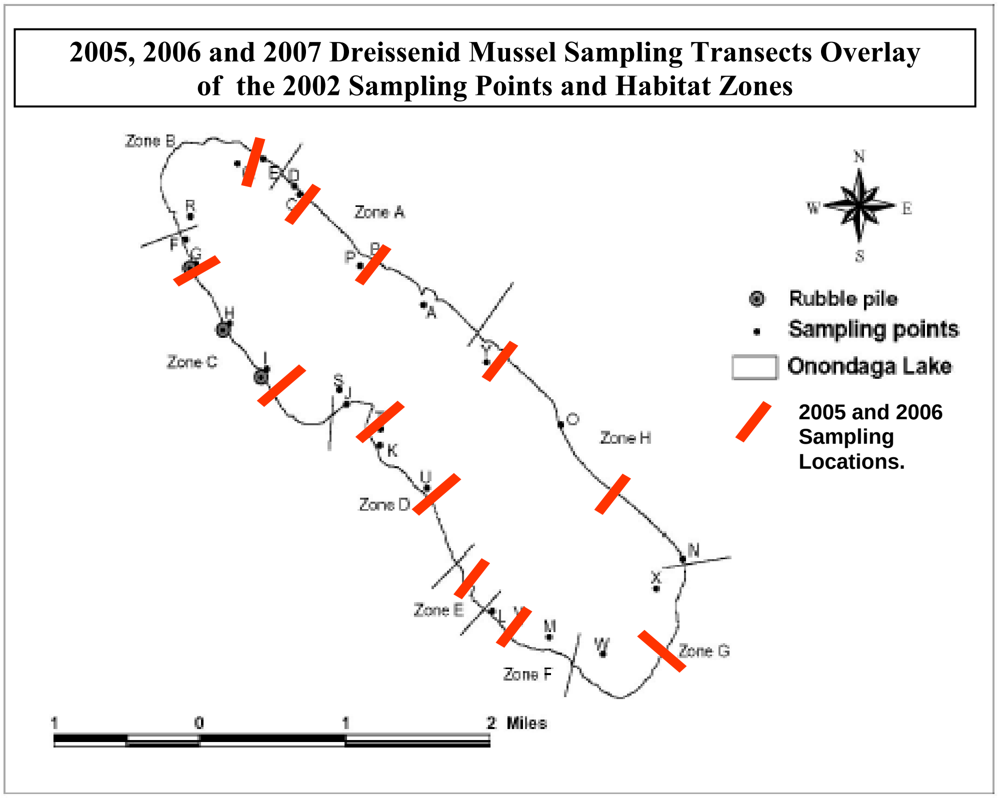


Figure 5-7. Dreissenid mussel sampling locations in Onondaga Lake.

5.3.1 Seneca River

In 2007, quagga mussels were identified in four of the eleven Seneca River transects (IIIA, XB, XIIIA, and XIIIE) and in both Lake Outlet locations (XIVA and XIVB). The quagga mussels represented 6% of the Seneca River and nearly 15% of the Lake Outlet dreissenid mussels sampled.

Abundance of dreissenid mussels in the Seneca River and Onondaga Lake outlet are variable over time. Both abundance and biomass of mussels declined in 2007 as compared with previous years (**Table 5-4**) at most sampling locations. In contrast, abundance and biomass increased substantially in 2007 at the lake outlet.

Table 5-4. Dreissenid mussel biomass and density estimates from the Seneca River since 2004.

Zone	Mean Weight (g/m^2)				Mean Estimated Number of Mussels per m^2			
	2004	2005	2006	2007	2004	2005	2006	2007[a]
III	2662	178	670	27	13179	11030	6282	2530 (74)
X	331	154	182	3	1064	810	388	35 (15)
XIII	461	288	263	152	2156	867	1643	681 (133)
XIV	2287	73	1007	3207	11801	398	6547	22944 (870)

[a]The 2007 results are expressed as "N zebra mussels (N quagga mussels)" when quagga mussels are present.

5.3.2 Onondaga Lake

In 2007, quagga mussels were identified in three zones (A, C and D) in water depths ranging from 0 to 4.5 meters; the greatest densities were in the 3-meter to 4.5-meter depth range. Quagga mussels represented 3.5% of the Onondaga Lake dreissenid mussels sampled.

Zebra mussel density and biomass increased in 2007 (**Table 5-5**). Estimated density increased by a factor of five from 2038 mussels/m^2 in 2006 to 10,470 mussels/m^2 in 2007. Similarly, biomass increased from 130 g/m^3 in 2006 to 994 g/m^3 in 2007. The 2007 numbers were the highest measured to date in the lake.

Zone C (NW Shore above Ninemile Creek), Zone D (Wastebeds 1-8), Zone F (Wastebed B) and Zone G (Southern End/Metro) had the greatest increase in the number of zebra mussels compared to the 2006 data.

Table 5-5. Dreissenid mussel biomass and density estimates in Onondaga Lake.

Zone	Mean Weight (g/m^2)				Mean Estimated Number of Mussels per m^2			
	2002	**2005**	**2006**	**2007**	**2002**	**2005**	**2006**	**2007**[a]
A	2008	42	717	1150	1834	1187	5465	14559 (229)
B	0	6	47	338	0	133	4803	12148
C	256	58	74	1748	514	1040	1991	12396 (2522)
D	542	45	70	1261	1356	907	774	18791 (281)
E	1458	17	27	348	1460	752	1549	7806
F	1688	133	7	2586	1141	3319	59	13211
G	0	0	0	65	0	15	0	2383
H	1201	23	94	457	1102	789	1667	2463
Lake Average	***894***	***40***	***130***	***994***	***926***	***1018***	***2038***	***10470 (379)***

[a]The 2007 results are expressed as "N zebra mussels (N quagga mussels)" when quagga mussels are present.

5.4 FISH COMMUNITY

The AMP fish program evaluates the structure and function of the fish community by sampling multiple life stages and habitats. Detailed methods, data summaries and trends are included in **Appendix 1 (Methods) and Appendix 8 (data summaries)**. For additional information, a baseline analysis of the fish community was completed in the 2002 Annual AMP Report, and is available on the Onondaga County web site www.ongov.net/WEP/wepdf/we15e.pdf

5.4.1 Community Structure

Onondaga Lake supports a diverse assemblage of predominantly warmwater fish species including largemouth bass and sunfish. Some coolwater species such as yellow perch and walleye also maintain populations in the lake. Overall, about 70% of the taxa in the lake are classified as warmwater and 30% as coolwater. Although a few individual coldwater species are

AMP Hypotheses To Be Tested:

- Implementation of nutrient load reductions at Metro and nonpoint sources including CSO remediation will indirectly increase the number of fish species present in Onondaga Lake

captured in the lake each year, the anoxic hypolimnion precludes the year-round residence of coldwater taxa.

A total of 26 fish species were collected via all sampling methods during the 2007 monitoring effort. One species new to the AMP program, spotfin shiner (*Cyprinella spiloptera*), was collected during the juvenile seine effort. This species was captured in the lake in the 1990s (**Tango and Ringler 1996**). The total number of fish species captured in Onondaga Lake since the inception of the AMP program in 1999 is now 44.

The primary method of collecting adult fish in Onondaga Lake is by nearshore electrofishing. In 2007 the electrofishing effort collected a total of 22 species, with 11 of those accounting for about 97% of the total catch of 2800 individuals (**Figure 5-8**). As in recent years the fish community is dominated by two species of clupeid (herring): gizzard shad (*Dorosoma cepedianum*) and alewives (*Alosa pseudohoharengus*). The abundance of these two species tends to be highly variable in New York because they are near the northern edge of their range and can experience high winter mortality. Shad are more susceptible to over winter mortality as they are closer to the northern edge of their range. Extremes in recruitment also play a role in the variability in abundance of these species. Both species may periodically produce very strong year classes that dominate the catch for years. Year classes can persist for a long period of time as both species can live upwards of 10 years. Other fish popular with anglers are common in Onondaga Lake.

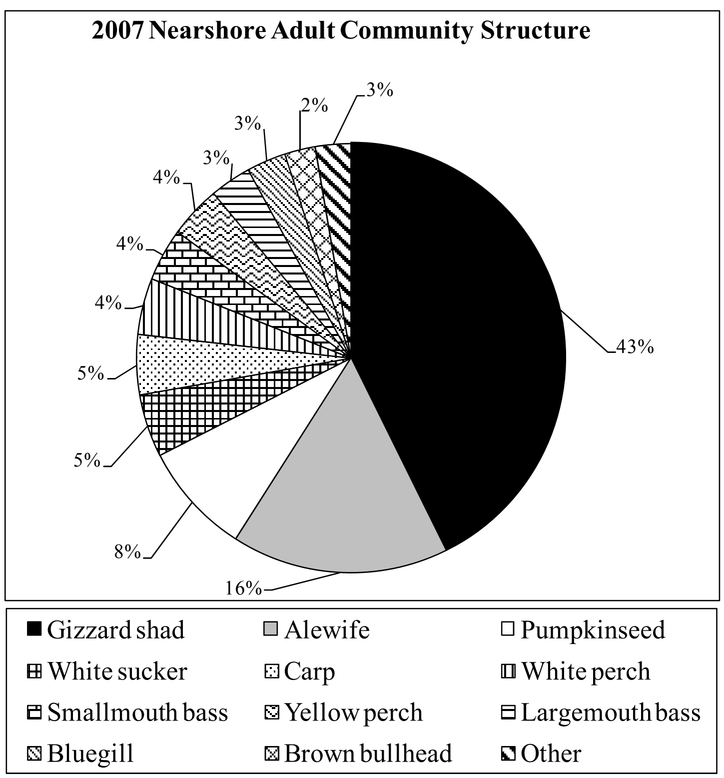


Figure 5-8. Relative abundance of fish species captured in AMP nearshore electrofishing efforts in Onondaga Lake in 2007.

These species include smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochirus*), yellow perch (*Perca flavescens*) and common carp (*Cryprinus carpio*).

5.4.2 Community Trends

5.4.2.1 Population Size

Many factors can create shifts in a lake's fish community. Improvements in water quality and habitat can affect reproductive success and survival. Relatively small changes in reproductive success and survival of young can gradually change population and community dynamics. Strong year classes can result in abrupt changes that may remain evident in the population and community for years.

As a result of the multiplicity of factors affecting the fish community, changes in populations of individual species resulting from improving water quality and habitat conditions may not be immediately evident. Water quality conditions and lower trophic levels will respond on a much more rapid time scale.

Only indirect measures of the population size of fishes in Onondaga Lake are available. A reasonable surrogate of population is catch per unity effort (CPUE) of the adult electrofishing effort. The trends in square root-normalized catch rates since 2000 were calculated for 20 species that are routinely caught as adults in the electrofishing efforts. Five species show statistically significant positive trends (percent change per year) in population size, and two had statistically significant negative trends (**Table 5-6**). The catch rates of the remaining ten species either did not have a strong trend, indicating that their populations are relatively stable, or the variability in annual abundance was high enough to preclude determination of significance.

Several important gamefish species are included in this analysis, such as smallmouth and largemouth bass. Both species have shown an increasing trend in catch rates since 2000 (**Figure 5-9A and B**), although only the smallmouth bass trend was statistically significant (**Table 5-6**). On average the smallmouth bass catch rates have increased by about 8% per year and those of the largemouth bass have increased by 4%.

Another species that has shown a dramatic abundance increase in recent years is the brown bullhead (*Ameiurus nebulosus).* Abundance of this species remained nearly constant from 2000 to 2003. Since 2003 the catch rates have increased almost six-fold (**Figure 5-9C**).

> <u>AMP Hypotheses To Be Tested:</u>
>
> - Implementation of point and nonpoint nutrient load reductions will indirectly increase the number of fish species that are sensitive to pollution present in Onondaga Lake

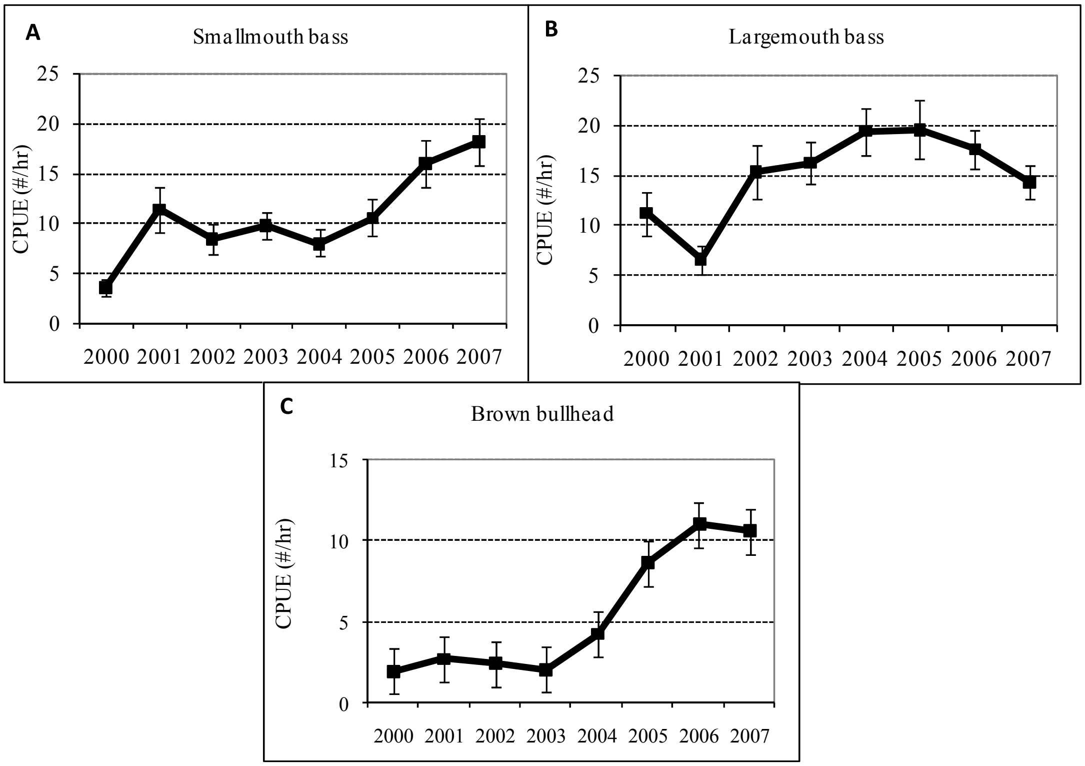


Figure 5-9. Catch per unit effort from electrofishing of smallmouth bass, largemouth bass, and brown bullhead in Onondaga Lake from 2000 to 2007.

Table 5-6. Eight-year trend analysis (percent change per year) and level of significance of square root-normalized catch per hour from electrofishing results of commonly captured species.

Species	Mean CPUE	Trophic Guild	Pollution Tolerance	Thermal Guild	Trend	Level of Significance
Golden shiner	1.0	Planktivore/ Invertivore	Tolerant	Cool	**21%**	**0.09**
Alewife	547	Planktivore	Moderate	Cool	**19%**	**0.37**
Brown bullhead	5.4	Invertivore/ Piscivore	Tolerant	Warm	**14%**	**0.01**
Bowfin	0.9	Piscivore	Tolerant	Warm	**11%**	**0.03**
Smallmouth bass	11	Piscivore	Moderate	Cool	**8%**	**0.01**
Longnose gar	0.8	Invertivore/ Piscivore	Tolerant	Warm	**8%**	**0.41**
Pumpkinseed	31	Invertivore	Tolerant	Warm	**7%**	**0.05**
Largemouth bass	15	Piscivore	Tolerant	Warm	**4%**	**0.11**
Freshwater drum	2.3	Invertivore/ Piscivore	Moderate	Warm	**4%**	**0.56**
Northern pike	0.2	Piscivore	Moderate	Cool	**3%**	**0.42**
Rock bass	0.6	Invertivore/ Piscivore	Moderate	Warm	**3%**	**0.82**
Gizzard shad	154	Detritivore	Moderately Tolerant	Warm	**3%**	**0.71**

Table 5-6. Eight-year trend analysis (percent change per year) and level of significance of square root-normalized catch per hour from electrofishing results of commonly captured species.

Species	Mean CPUE	Trophic Guild	Pollution Tolerance	Thermal Guild	Trend	Level of Significance
White perch	49	Invertivore/ Piscivore	Tolerant	Warm	**2%**	**0.34**
Yellow perch	18	Invertivore/ Piscivore	Moderately Tolerant	Cool	**-2%**	**0.28**
White sucker	20	Benthic Invertivore	Moderately Tolerant	Cool	**-2%**	**0.27**
Channel catfish	1.6	Invertivore/ Piscivore	Moderately Tolerant	Warm	**-2%**	**0.49**
Walleye	1.0	Piscivore	Moderately Tolerant	Cool	**-3%**	**0.60**
Bluegill	26	Invertivore	Tolerant	Warm	**-8%**	**0.16**
Shorthead redhorse	2.2	Benthic Invertivore	Moderately Tolerant	Cool	**-9%**	**0.02**
Carp	30	Benthic Invertivore	Tolerant	Warm	**-11%**	**0.03**

Notes: Table is sorted first by trend, then by significance level. Trends that are statistically significant at the alpha< 0.10 level are shaded.

5.4.2.2 *Trophic Guilds*

Because some of the most important lake improvements relate, directly or indirectly, to changes in trophic structure, examining trends in trophic guilds (functional feeding groups) is useful. This has the benefit of reducing variability from individual fish.

Planktivorous (plankton-eating) species have shown the greatest increase in population size since 2000, due largely to a very strong alewife year class in 2002. However, the high annual variability in the size of the planktivore population results in a non-significant trend (**Table 5-7**).

Piscivorous (fish-eating) species have increased, on average, about 5% per year since 2000. This result is largely controlled by the increase in the abundance of largemouth and smallmouth bass. The increase in bass population is likely related to improved habitat and feeding opportunities associated with the expansion in macrophyte coverage of the littoral zone (see **section 3.2.4.5**).

Benthic (bottom-feeding) species have decreased at a rate of about 7% per year since 2000. By comparison, in Oneida Lake benthic fish species have increased in recent years; the increase is considered to be a consequence of dreissenid mussel activity (**Irwin 2006**). Although present in Onondaga Lake since 1991, zebra mussels did not become prevalent until 1999 when ammonia concentrations declined (**Spada et al. 2002**). The reason for the decline in relative abundance of benthic species in Onondaga Lake is not known.

Table 5-7. Eight-year trend analysis (percent change per year) and level of significance of trophic guilds based on square root-normalized catch per hour from electrofishing.

Trophic Guild	Trend	Significance
Planktivore	19%	0.37
Planktivore/Invertivore	19%	0.11

Table 5-7. Eight-year trend analysis (percent change per year) and level of significance of trophic guilds based on square root-normalized catch per hour from electrofishing.

Trophic Guild	Trend	Significance
Piscivore	5%	<0.01
Detritivore	3%	0.71
Invertivore	0.0%	0.99
Invertivore/Piscivore	-0.2%	0.89
Benthic Invertivore	-7%	0.03

Notes: Table is sorted first by trend, then by significance level. Trends that are statistically significant at the alpha< 0.10 level are shaded. See Table A8-1 in Appendix 8 for list of species in each trophic guild.

5.4.2.3 Relative Weights of Bass

Relative weight (Wr) is the ratio of the actual weight of a fish to what an average healthy fish of the same length should weigh (called standard weight). Fish with high Wr (>100) are fatter than the standard weight of a fish of the same length, while those with low Wr (<100) are thinner.

Prior to 2003 the Wrs of largemouth and smallmouth bass were similar, typically around 100. Beginning in 2004 these species diverged; largemouth bass Wr began increasing and that of smallmouth bass decreased (**Figure 5-10**). This change has been noticed by anglers who have contacted OCDWEP to inquire why smallmouth bass are becoming increasingly "thin" (David Snyder OCDWEP personal communication 7/25/08).

The divergence in bass Wr is coincident with a large increase in alewife abundance and subsequent decrease in young *Lepomis* sp. that began in 2003 and continued through 2007. Catch rates (# per seine haul) of young *Lepomis* sp. have decreased from an average of 88 from 2000 through 2002 to only 6 in 2006 and 2007. Alewives are known to sometimes prey heavily on larval fish, which could account for the decline in *Lepomis* sp. young (**Brooking et al. 1998, Mason and Brandt 1996**). Young of *Lepomis* sp. are believed to be a primary food source for the lake's piscivores (**Gandino 1996**). A large decline in young *Lepomis* sp. could account for the decrease in Wr of smallmouth bass. However, the large alewife population in the lake would seem to provide an excellent forage base capable of ameliorating any negative impacts to growth rates. For example, alewives have been stocked in the past to improve largemouth bass growth (**Lars Rudstam Cornell University personal communication 8/20/08).** This appears to be the case with largemouth bass in Onondaga Lake but not smallmouth bass. It seems that alewives should be at least as, if not more, susceptible to predation by smallmouth bass as they are to largemouth bass because they tend to prefer the deeper water habitats where smallmouth bass are common (**Randy Jackson Cornell University personal communication 7/29/08**). It is possible that the smallmouth bass are more oriented towards the bottom and alewives in the open water (**Lars Rudstam Cornell University personal communication 8/20/08).** Thus the divergence in Wr between the bass species is somewhat counterintuitive. It is possible, but unlikely, that gape (mouth) size is playing some role in this relationship. Largemouth bass are capable of preying upon fish approximately half their size, smallmouth bass about one-third their size (**Lars Rudstam Cornell University personal communication 7/28/08**). Adult alewives in Onondaga

Lake average about 130 to 140 mm in length meaning smallmouth bass greater than about 400mm (15.5 inches) should be able to utilize them as prey. Smallmouth bass of this size are not uncommon in the lake. Smallmouth bass should also have been able to readily prey upon young alewives which presumably have been abundant in recent years. The exact cause of the declining smallmouth bass Wr is not known at this time. Because of the importance of this species to lakes fisheries further research into this issue may be warranted.

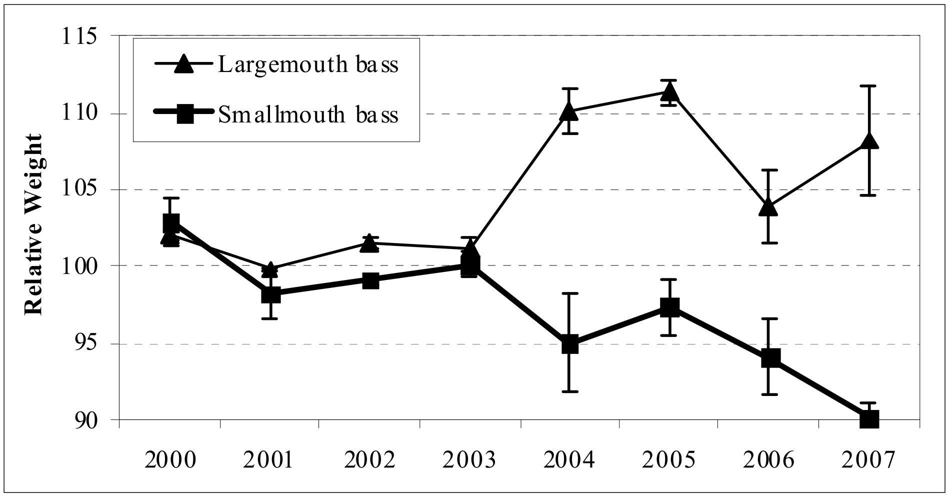


Figure 5-10. Relative weight trends for largemouth bass and smallmouth bass in Onondaga Lake from 2000-2007**.** *Note: error bars are standard error.*

5.4.3 Alewife

Since 2004, the AMP has included special surveys to estimate alewife abundance. The alewife monitoring program has been conducted by Dr. Lars Rudstam from the Cornell Biological Field Station. Dr. Rudstam uses small-mesh pelagic gill nets and hydroacoustics (70 kHz split beam) to estimate the density (abundance) of the clupeid.

The results of the 2007 alewife monitoring effort indicate that the density of alewife in Onondaga Lake in June was about 30% lower than in past years (**Figure 5-11**). The population consists of at least two age classes, the 2002 and 2004 year class. This indicates that the initial strong 2002 year class was not an isolated occurrence. Alewife recruitment is generally highly variable (**O'Gorman et al. 2004**). Densities of over 2000 fish/ha were documented and are considered high for age 1 and older alewife across the Finger Lakes region (Dr. Lars Rudstam personal communication; May 2007).

Alewife will likely continue to be abundant in Onondaga Lake and go through periods of strong recruitment that will continuously affect both lower trophic levels and recruitment of other fish species. Consequently, the influence of the alewife must be considered when evaluating improvement in Onondaga Lake. Several of the metrics used to track changes in trophic state are directly affected by alewife abundance, including water clarity, algal blooms, and presence of early life stages of target fish species.

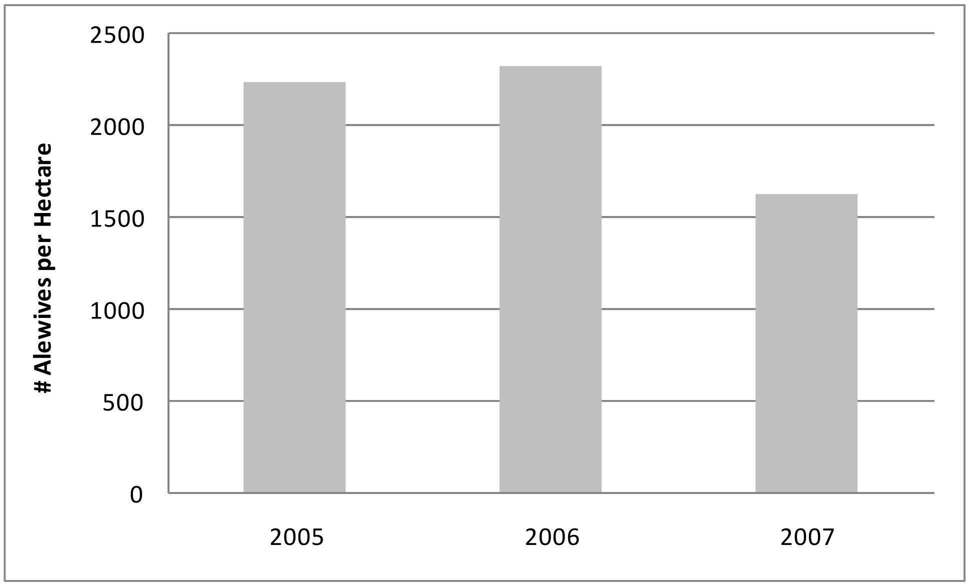


Figure 5-11. Estimated alewife density in Onondaga Lake 2005 – 2007, using hydroacoustical sampling.

Notes: Density is calculated from areal back scattering using the average target strength of alewife found during the survey.

5.4.4 Trends in DELTFM

OCDWEP tracks the occurrence of Deformities, Erosions, Lesions, Tumors, Fungus, and Malignancies (DELTFM) on fish captured during AMP sampling. The percent of adult fish with DELTFM has increased in recent years (**Figure 5-12**). From 2000 to 2004 the percent of adult fish with DELTFM averaged 0.9%; from 2005 to 2007 that number increased to 2.8%. The overall increase appears to be mostly related to increases in deformities (including injuries) and lesions (likely bacterial, fungal or viral infections). The species contributing to the most individuals to the DELTFM total in 2007 were: brown bullhead (49% of total), channel catfish (16%), and largemouth bass (12%). The species with the highest proportion of individuals with DELTFMs were: northern pike (100%, 2 of 2), channel catfish (50%, 8 of 16), walleye (27%, 3 of 11), and brown bullhead (24%, 24 of 101). The cause of the recent increase in DELTFM is not understood.

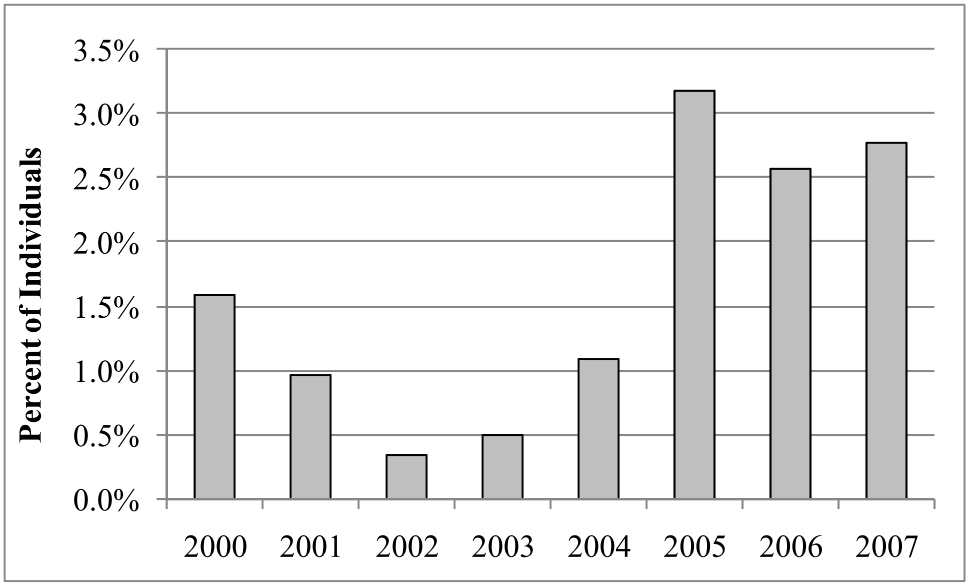


Figure 5-12. Percent of adult fish captured during AMP sampling with DELTFM abnormalities noted.

5.4.5 Reproductive Success

The ACJ requires Onondaga County to monitor the reproductive success of bass, sunfish and walleye. Since 2000, the AMP has included intensive annual sampling of the number and distribution of fish nests, and abundance of larvae and young-of-the-year (YOY) to meet this requirement.

> AMP Hypotheses To Be Tested:
>
> - Implementation of point and nonpoint nutrient load reductions will increase the reproductive success of fish in Onondaga Lake

Since the AMP began, most fish nests in Onondaga Lake have been documented in the north basin (average 83%, range 66% to 100%), presumably because of better habitat conditions there (refer to **Appendix 8 Figure A8-13, and Table A8-20** for additional detail on the 2007 nest survey results). This is consistent with the spatial pattern documented by **Arrigo** (**1998**) in the early 1990s when about 75% of nests documented in that study were found in the north basin. The fish species observed guarding nests are mostly combinations of sunfish (*Lepomis* sp.), largemouth bass, and smallmouth bass. Sunfish nests have typically been most abundant, with largemouth bass nests also common. The ability to document species guarding nests has been difficult in recent years because of the dense macrophyte beds now present in the lake. The presence of nests in combination with young is a strong indicator of successful reproduction occurring in the lake.

To date, there is no evidence of successful walleye reproduction in the lake or its tributaries. This is most likely due to limited availability of suitable habitat in tributaries (where walleye typically spawn) than in-lake conditions. In addition the presence of a large alewife population in the lake since 2003 would likely eliminate any walleye larvae. Dense adult alewife populations can eliminate entire year classes of both walleye and yellow perch in New York lakes through predation on open water larvae (**Brooking et al. 1998, Mason and Brandt 1996**).

Bass and sunfish (*Lepomis* sp.) have successfully reproduced in the lake since at least the early 1990s (**Arrigo 1998**). When the AMP began in 2000, sunfish were the most common species in nearshore seine hauls. Over the intervening eight years, the relative abundance of sunfish YOY in seine hauls has decreased and that of largemouth bass has increased. In 2007, these taxa each represented almost 50% of the YOY captured (**Figure 5-13**). The increase in largemouth bass young is likely due to corresponding increases in aquatic vegetation that bass use as nursery and rearing habitat (see **Section 5.5.2.2**). The decline in sunfish young may be related to the presence of large numbers of adult alewives in the lake beginning in 2003. Alewives are primarily planktivorous fish, and will feed on larval fish when available. Species known to reproduce in the lake but with poor recruitment in Onondaga Lake since 2003 include species with pelagic larvae (sunfish, white perch, and yellow perch).

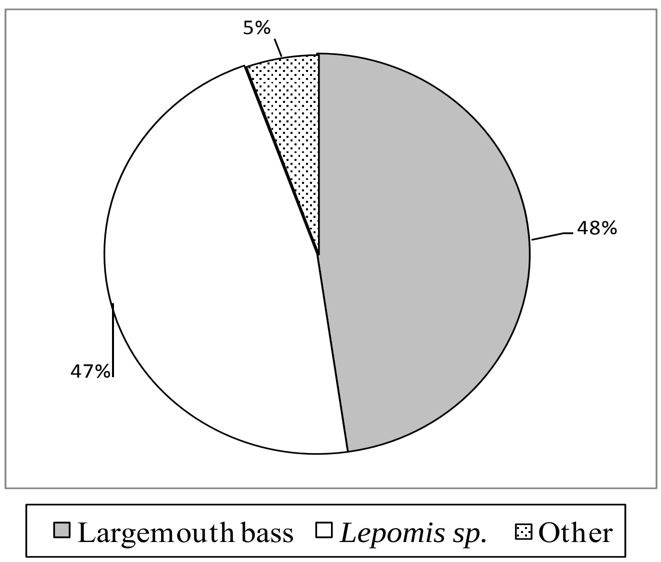


Figure 5-13. Fish species identified in nearshore seine hauls of YOYs in 2007.

Of the 26 species captured via all the sampling methods used in the lake in 2007, 11 (42%) showed some evidence of successful reproduction. Successful reproduction is inferred from catch of larvae and/or presence of young-of-the-year (YOY). For several species (four in 2007), successful reproduction was inferred by the presence of small individuals difficult to identify as YOY (**Table 5-8**). Since 2000, about 40% to 50% of species captured as adults in Onondaga Lake show evidence of successful reproduction in any given year. Since the intensive monitoring program on the lake is unique in the area, it is not known if this percentage is higher or lower than other regional lakes. It is likely that other species did in fact reproduce in the lake but that the numbers of young produced were low or were located in areas of the lake not sampled.

Table 5-8. Life stages present in Onondaga Lake for each species captured in 2007.

Species	Life Stages Present
Bluegill	L/Y/A
Pumpkinseed	L/Y/A
Alewife	L/A
Banded killifish*	Y/A
Brown bullhead	Y/A
Spotfin Shiner*	Y/A
Golden shiner*	Y/A
Largemouth bass	Y/A
Smallmouth bass	Y/A
Tessellated darter*	Y/A
Carp	Y/A
Gizzard shad	A
Bowfin	A
Brown trout	A
Channel catfish	A
Freshwater drum	A
Longnose gar	A
Northern hog sucker	A
Northern pike	A
Rock bass	A
Rudd	A
Shorthead redhorse	A
Walleye	A
White perch	A
White sucker	A
Yellow perch	A

Note: A= Adult stage present, L= Larvae present (captured during larvae sampling), Y= YOY present (captured during YOY seining). * Indicates species whose adult sizes are small and difficult to differentiate from YOY; presence of adults of these species likely indicates a reproducing population.

5.4.5.1 Growth and Relative Weight

The AMP tracks the size and relative weights of key species of YOY in the lake. The size of YOY has been remarkably consistent from year to year, with the exception of the year 2000 when YOY were smaller, but heavier, than other years (**Figure 5-14**). The summer of 2000 was cooler than normal which may have affected growth of fish in the lake during that year (**EcoLogic 2001**). The consistency in size and relative weight are indications that food resources are generally not limiting for these species in Onondaga Lake despite large annual fluctuations in population size.

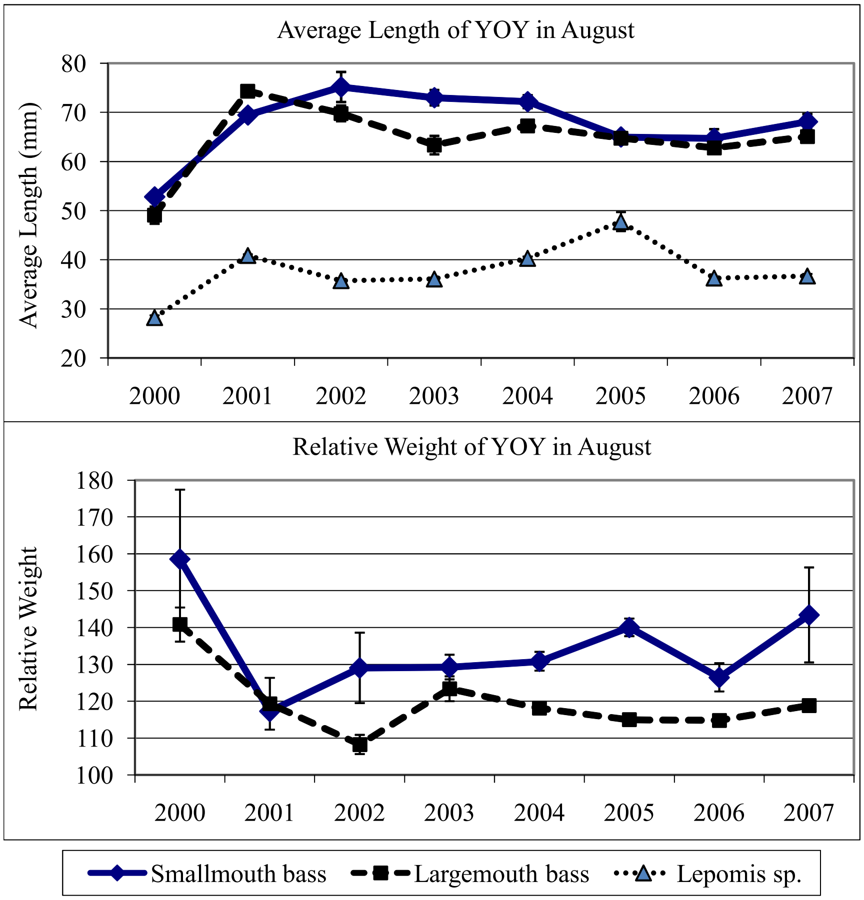


Figure 5-14 Average size and relative weight of smallmouth and largemouth bass, and *Lepomis* sp. in Onondaga Lake from 2000 to 2007.

Note: relative weight of YOY Lepomis is not calculated because no standard weight is published. Error bars are standard error.

5.4.6 Angler Success

Onondaga Lake is a popular destination for angler fishing for smallmouth and largemouth bass, and has the reputation as one of the best bass fishing lakes in the state. Many amateur and professional bass tournaments are held on the lake each year. As such, bass continued to be the most frequently targeted species in the lake.

Angler catch rates are estimated from a diary program where select anglers keep track of their catch during the year. The smallmouth bass catch rates in Onondaga Lake have been relatively consistent since 2003, varying annually between about 0.55 and 0.75 fish per hour (**Figure 5-15**). This is comparable to catch rates in Oneida Lake from 2002 to 2006 of about 0.70 fish per hour. The catch rates of largemouth bass in Onondaga Lake have increased in the last two years and are now generally comparable to the catch of smallmouth bass. The consistency in the catch rates in Onondaga Lake indicates that the fishery can withstand increased fishing pressure.

Catch rates of both bass species in Onondaga Lake in the past have been comparable or slightly less than the Seneca and Oneida Rivers. In 2007 only smallmouth bass in the section of the Seneca River downstream of Onondaga Lake had higher catch rates than the lake itself. This is due to the effect of slightly higher catch rates in Onondaga Lake combined with generally lower catch rates in the other bodies of water.

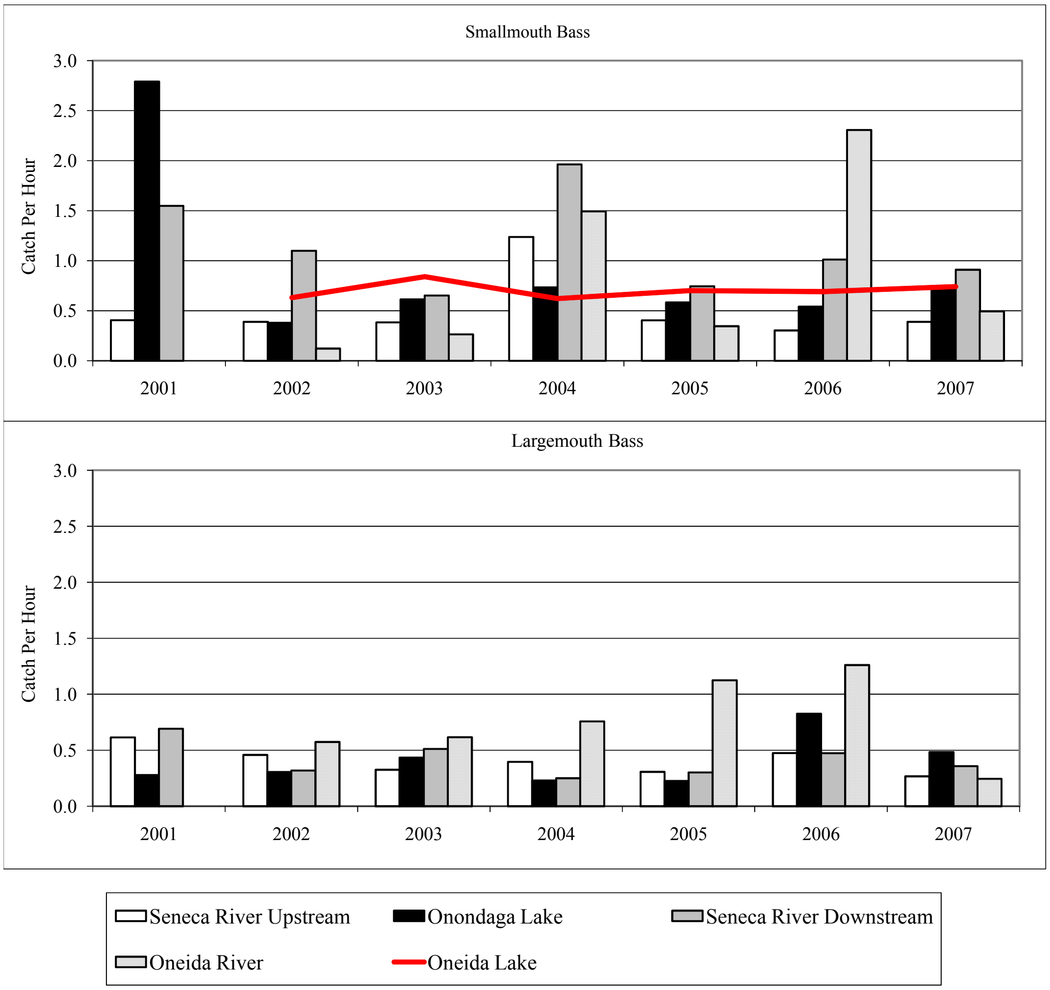


Figure 5-15. Angler catch per hour for largemouth and smallmouth bass in Onondaga Lake, the Seneca River, and Oneida River from 2001 to 2007 based on reported catch in angler diaries.

**Note that Oneida Lake data are from creel surveys (Scott Krueger, Cornell University, Personal Communication) which tend to estimate catch rates lower than diary programs.*

5.4.7 Index of Biotic Integrity

5.4.7.1 Background

The concept of using measures of the composition of aquatic communities to assess the water quality or biotic integrity of aquatic ecosystems has been realized and practiced since the early 20th century (**Cairns and Pratt 1993**). Early applications of biological monitoring were almost exclusively developed for and applied to lotic communities (flowing waterbodies). **Karr** (**1981**) was the first to apply this approach to fish in developing a biological monitoring system that used fish community attributes related to species composition and ecological structure to evaluate the quality of the greater aquatic community and the environment supporting it. This work put forth the building blocks for development of an Index of Biotic Integrity (IBI, **Karr et al. 1986**) based on fish community attributes.

Development and application of IBI for lentic waters (non-flowing) has advanced much more slowly than similar methodologies for lotic environments. Reasons for the lag in development of lentic IBI include greater research activity in the field of stream ecology versus lake ecology in recent decades, streams being easier to sample than lakes, stream impairment being more widespread than lake impairment, and possibly lotic pollution being viewed as more of a problem than lentic pollution (**Resh and Jackson 1993**). In the past 20 years, development of IBI for lentic waters has begun to advance, and indices have been developed for a variety of lentic biota, including periphyton (**McNair and Chow-Fraser 2003**), zooplankton (**Lougheed and Chow-Fraser 2002**), benthic macroinvertebrates (**Wilcox et al. 2002**), and fish (**USEPA 1993; Minns et al. 1994; Hickman and McDonough 1996; Shulz et al. 1999; Seilheimer and Chow-Fraser 2006**). Development and testing of IBI-type measures based on fish communities has continued to evolve, and the ability and efficacy of such tools to consistently characterize levels of ecological degradation over various spatial scales and environmental gradients will ultimately determine the widespread applicability of this approach to characterizing environmental quality.

> AMP Hypothesis To Be Tested:
>
> - Implementation of point and nonpoint nutrient load reductions will improve the lake's IBI

OCDWEP was interested in identifying an IBI-based approach that could be applied to the extensive Onondaga Lake fish dataset to help track changes in environmental quality over time associated with ongoing efforts to improve municipal wastewater treatment and aquatic habitat within the lake. **Seilheimer and Chow-Fraser** (**2006**) have recently developed fish community-based indices for evaluating the level of impairment of near-shore and wetland fish communities (and hence ecosystem health) of the Great Lakes. Their indices utilize a combination of abundance, pollution tolerance values and niche breadth to provide a means of evaluating water quality and habitat conditions in littoral habitats of the Great Lakes. The Seilheimer and Chow-Fraser Wetland Fish Index (WFI) was developed for use over a wide range of environmental conditions in nearshore areas and wetlands from three Great Lakes.

The WFI was considered suitable for this exercise given the location of Onondaga Lake within the Great Lakes basin and its proximity to Lake Ontario. In addition, the sampling program focused on the littoral fish community in much the same way as the sampling programs used to develop the WFI. The WFI was also attractive because it had been shown to be able to detect intra-wetland degradation between two sites in an urban wetland and detect a gradient in wetland quality within Green Bay, WI (**Seilheimer and Chow-Fraser 2006**). The WFI was also shown to be significantly related to water quality degradation and wetland condition (**Seilheimer and Chow-Fraser 2006**).

This section presents a summary of results for the WFI calculated from Onondaga Lake fish data. The WFI is actually composed of two separate, but very similar, equations: one based on presence/absence, and one on abundance. The results of the two equations were almost identical spatially and temporally. This section only presents a summary of the presence/absence (WFI P/A) results.

5.4.7.2 Results

The newly created Integrated Biological Database was used to query catch data for each species, in each electrofishing transect since the monitoring program began in 2000.

5.4.7.2.1 Spatial Pattern

The nearshore biological sampling program collects data within five spatial strata that were designated based on a combination of wave/wind energy and sediment characteristics. The strata begin in the northwest end and proceed around the lake in a counterclockwise manner ending in Stratum 5 in the northeast end (**Figure 5-16**). Spatial patterns have been observed in other biological datasets collected in the lake such as; macrophyte cover and NYSDEC macroinvertebrate indices (a type of IBI) (**EcoLogic 2006**). There appears to be a north to south gradient in the lake so that when graphed a "U"-shaped pattern is evident. The WFI P/A shows a similar pattern; greatest impact is indicated at the south end (Stratum 3), while least impact is indicated in the north end (Strata 1 and 5) (**Figure 5-17**). This gradient had been assumed to be present prior to implementation of the AMP due to the presence of sources or conduits for water and sediment quality impacts (Metro, three tributaries, industrial contaminants, and the wastebeds) in the southern end. The replication of the observed pattern in three separate biological community indices confirms existence of the gradient.

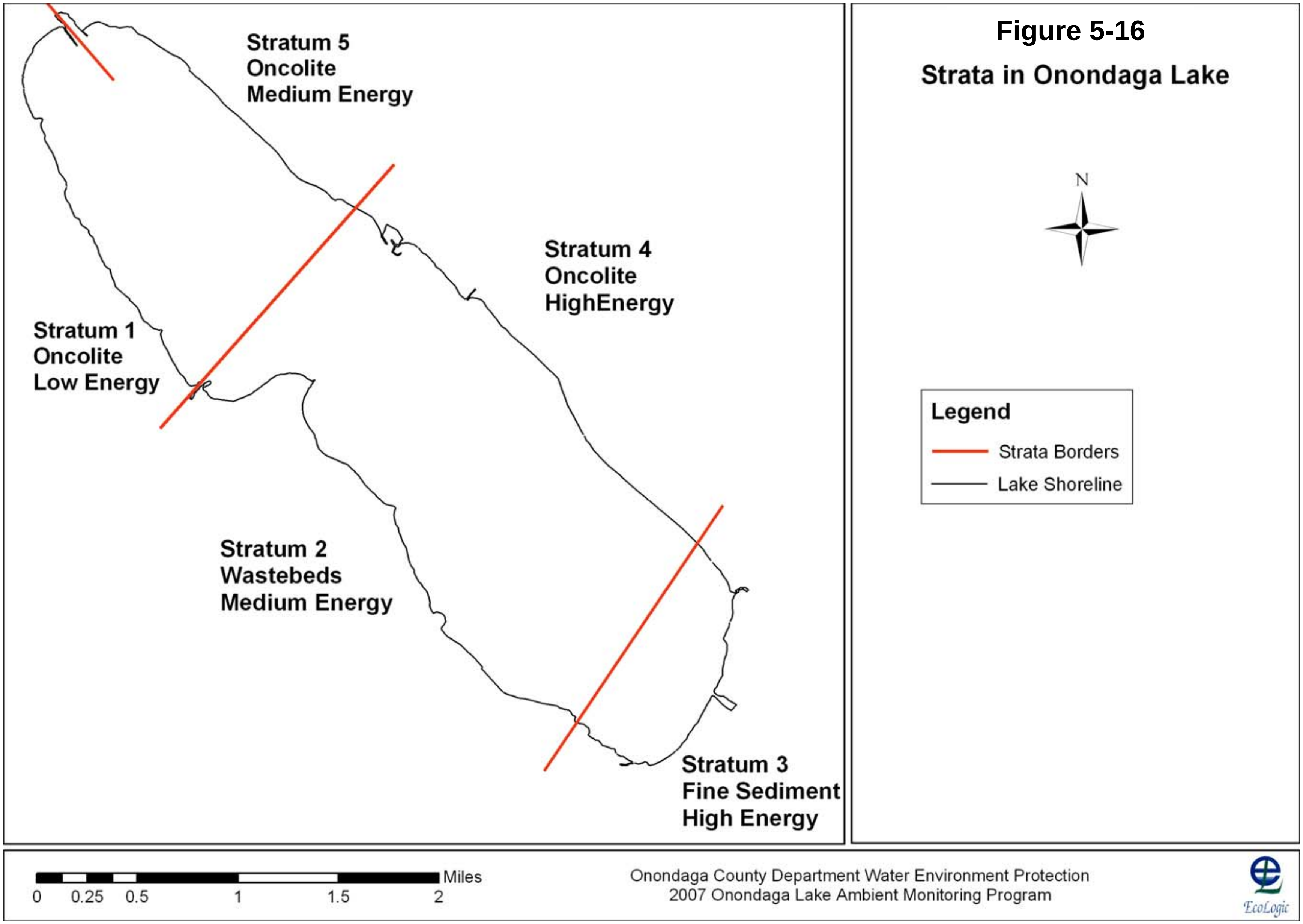


Figure 5-16
Strata in Onondaga Lake
Stratum 5
Oncolite
Medium Energy
Stratum 4
Oncolite
HighEnergy
Stratum 1
Oncolite
Low Energy
Stratum 2
Wastebeds
Medium Energy
Stratum 3
Fine Sediment
High Energy
N
Legend
Strata Borders
Lake Shoreline
0 0.25 0.5 1 1.5 2 Miles
Onondaga County Department Water Environment Protection
2007 Onondaga Lake Ambient Monitoring Program
EcoLogic

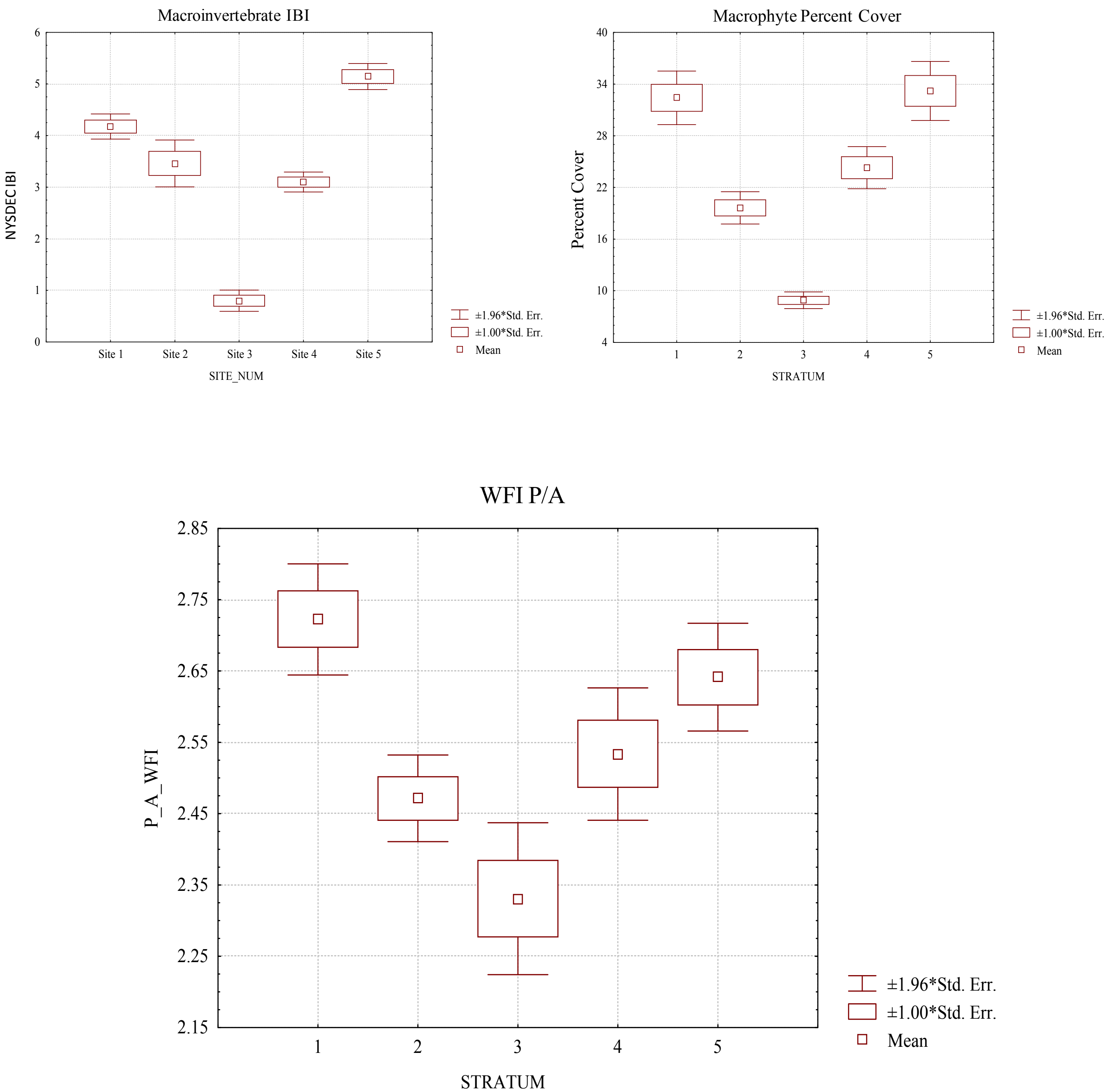


Figure 5-17. Spatial pattern of WFI P/A compared to those of a macroinvertebrate IBI and macrophyte cover.
Note: macroinvertebrate and macrophyte results are combined from year 2000 and 2005 data and WFI P/A are combined 2000-2007 data.

5.4.7.2.2 Temporal Trend

There appear to be two distinct groupings when the annual average WFI P/A values are plotted; one of lower values (2000-2002) and one with higher (2004-2007), with a transitional year in between (2003) (**Figure 5-18**). These timeframes seem to coincide with the startup of the BAF, designed to treat ammonia, which went on-line in January 2004. In fact, plots of annual average ammonia concentration in the lake and WFI P/A show a striking correlation (**Figure 5-19**). The correlation is suggestive, but not proof, of a causal relationship.

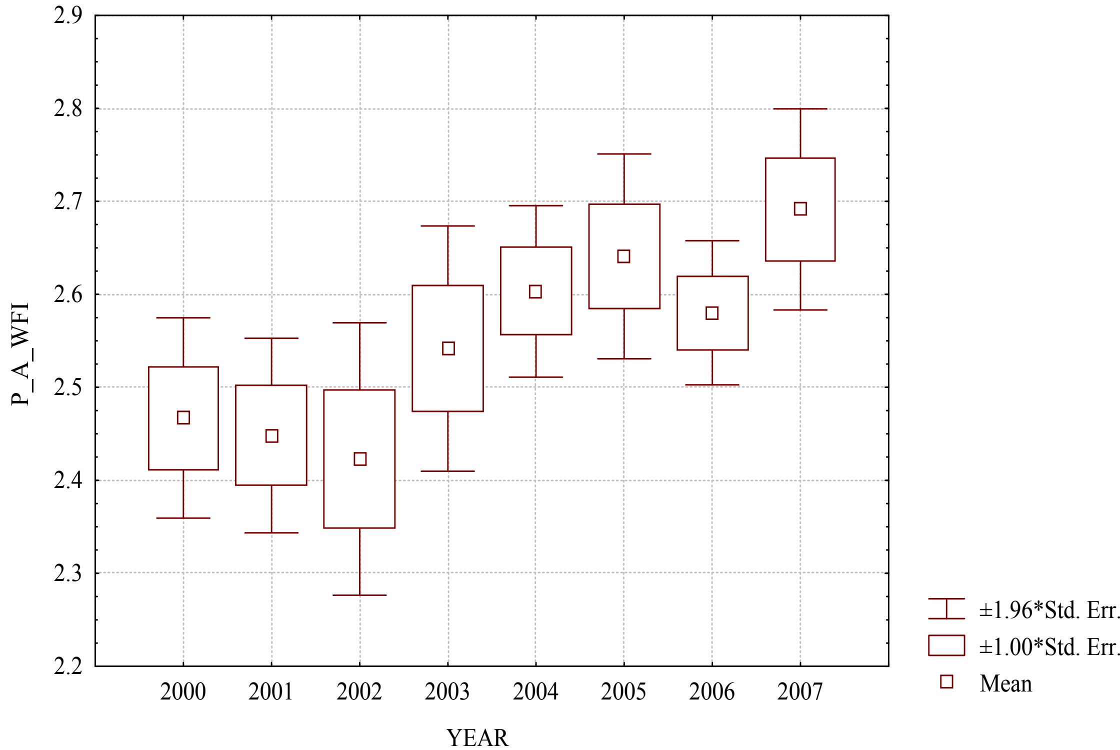


Figure 5-18. Annual average WFI P/A in Onondaga Lake from 2000-2007.

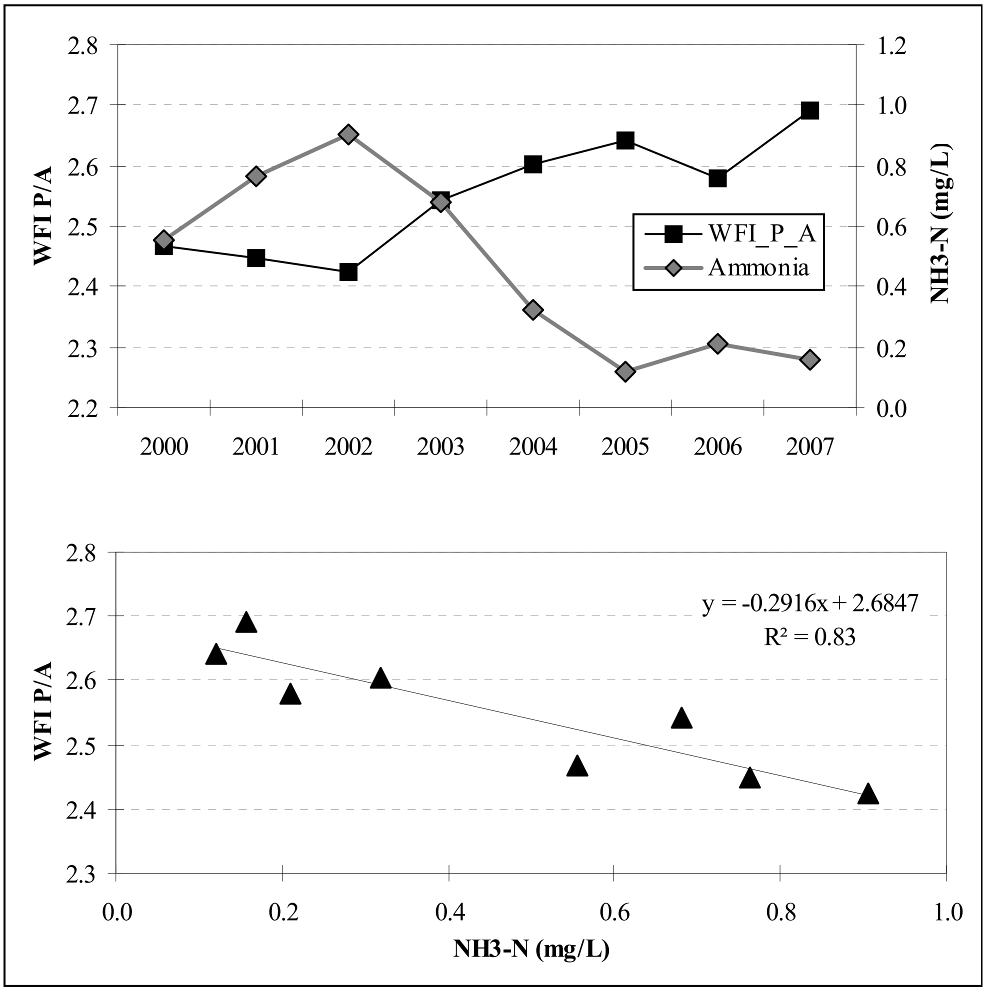


Figure 5-19. Correlation between annual average ammonia concentration and annual average WFI P/A in Onondaga Lake from 2000-2007.

5.4.7.2.3 Relationship to other Waterbodies

Seilheimer and Chow-Fraser (**2006**) presented WFI/P/A results for 39 waterbodies. Their results indicated that WFI P/A values were evenly spread amongst the sampled areas ranging from 1.9 to 3.8. The range in annual average values from 2000 to 2007 in Onondaga Lake was relatively narrow, from 2.4 to 2.7 (**Figure 5-20**). This range is within approximately the lower one third of the range found in Great Lakes near-shore and wetland fish communities, indicating that although there appears to have been improvement in recent years, the fish community in Onondaga Lake would still likely be considered impacted based on the WFI P/A calculations.

5.4.7.2.4 Utility of the WFI in Onondaga Lake

The ability of the WFI to integrate data from the entire fish community into a single value that not only detects both spatial and temporal patterns, but also appears to be correlated with remedial actions is highly valuable to the AMP. It is recommended that The Wetland Fish Index be incorporated into the AMP and reported on an annual basis.

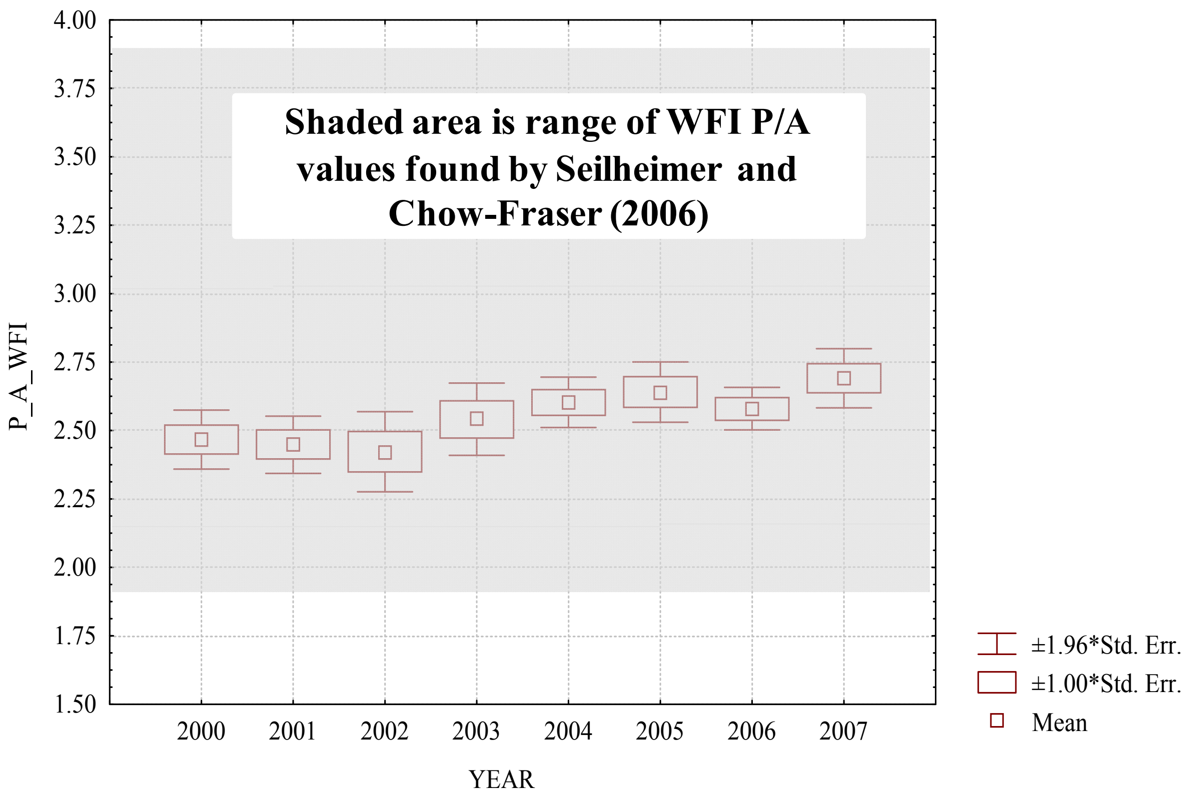


Figure 5-20. Annual mean WFI P/A values in Onondaga Lake from 2000 to 2007 in relation to the range of WFI P/A values found by Seilheimer and Chow-Fraser (2006) in nearshore and wetland communities of the Great Lakes.

Table 5-9. Progress towards water quality improvement: Fish Community. AMP 2007 Annual Report. (Assessment Measure)

AMENDED CONSENT JUDGMENT GOAL

Expand habitat for fish community and promote water quality conditions that support diverse warmwater fish community. Achieve conditions to support a self-sustaining sport fishery, and achieve desired use of the lake for recreation.

Hypotheses to be tested:	**Status:**
Implementation of nutrient load reductions at Metro and nonpoint sources including CSO remediation will indirectly increase the number of fish species present in Onondaga Lake	• Number of species captured per year is currently stable.
Implementation of point and nonpoint nutrient load reductions will indirectly increase the number of fish species that are sensitive to pollution present in Onondaga Lake	• Standard pollution tolerance metric does not show significant change. Fish IBI (WFI) based on tolerance values shows improvement since 2003.
Implementation of point and nonpoint nutrient load reductions will increase the reproductive success of fish in Onondaga Lake	• Largemouth bass reproduction has increased, probably due to increased macrophytes. Other species have decreased (sunfish, perch) likely due to predation of larvae by alewives.
Implementation of point and nonpoint nutrient load reductions will improve the lake's IBI. (Effects may be more evident in Strata 2, 3, and 4)	• Wetland Fish Index indicates improvement beginning in 2003.
Implementation of point and nonpoint nutrient load reductions will increase the habitat available for the coolwater fish community	• Habitat available to coolwater fish is highly variable. Controlled by summer temperature and intrusion of anoxia into metalimnion.

Current Conditions with Historical Comparison	
Number of fish species *(Average Annual Total & Standard Deviation)*	2000-2003: 22.5 (2.4) 2004-2006: 25.3 (0.6) 2007: 22
Percent of species that are pollution-sensitive *(Average Annual Relative Abundance & Standard Deviation)*	2000-2003: 5.9% (5.1%) 2004-2006: 6.7% (2.5%) 2007: 5%
Number of fish species reproducing in the lake	2001-2003: 16-20 2004-2006: 13-17 2007: 11
Index of Biotic Integrity *(Annual Average & Standard Deviation of WFI P/A)*	2000-2003: 2.47 (0.05) 2004-2006: 2.61 (0.030 2007: 2.69
Cool water habitat *(Annual Average Percent of Habitat Available and Standard Deviation)*	2000-2003: 74% (3.6%) 2004-2006: 79% (1.7%) 2007: 87%
Forcing Functions	Extent of aerobic habitat, water temperature, abundance of preferred food sources, habitat for spawning and juveniles, predation of larvae by alewives, abundance of macrophytes

Table 5-9. Progress towards water quality improvement: Fish Community. AMP 2007 Annual Report. (Assessment Measure) (continued).

Monitoring and Assessment Program	
Lake Monitoring *(Annual County monitoring program)*	Annual monitoring, beginning in 2000 to assess reproductive success and community structure • Number and distribution of littoral nests • ID and enumerate larval fishes • ID and enumerate juvenile and YOY stages • ID and estimate (CPUE) of adult community using electrofishing, gillnets, and angler diaries Assess and record DELT-FM anomalies
Tools for Decision Making	
Quantitative and Qualitative Analyses	Data collection techniques and data analysis comparable to standard procedures used throughout New York.

5.5 LAKE TROPHIC INTERACTIONS AND HABITAT

5.5.1 Trophic Interactions

Size structure of zooplankton communities can be influenced by the relative degree of planktivory, which can cause a distinct shift favoring survival of smaller species as planktivorous fish prefer to graze on the larger organisms (**Wetzel 1983**). Mean zooplankton size in Onondaga Lake exhibited a substantial decline in 2003 and has continued to remain below historical measurements. However, the average size appears to be gradually recovering (**Figure 5-21**).

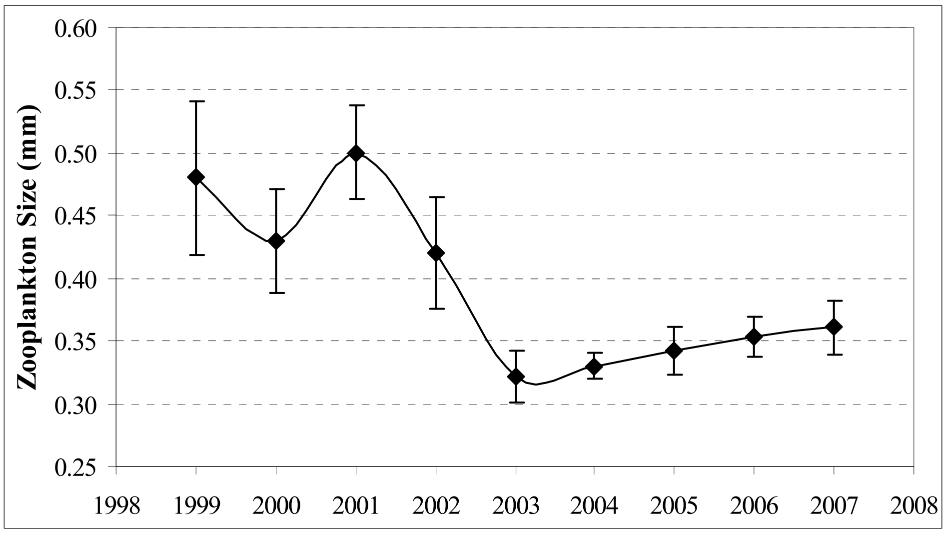
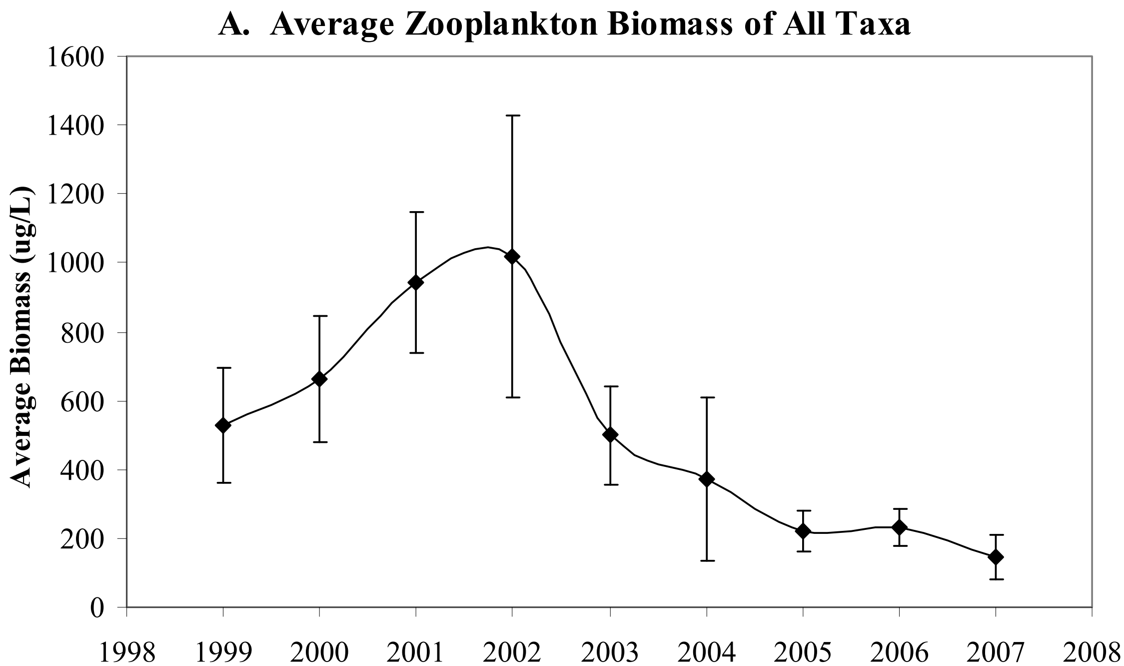


Figure 5-21. Average size of zooplankton (all taxa combined) in Onondaga Lake from April until October in 1999 to 2007.

This decline was due to the loss of the larger zooplankton, notably *Daphnia mendotae* and diaptomids, from the community. The loss of the larger plankton is attributed to the dramatic increase in the planktivorous alewife in these same years (see **Section 5.4.3**). The reduction in population of these larger zooplankton taxa was evident in late summer 2002 when young-of-the-year alewife biomass increased. Prior to late summer young-of-the-year alewives were abundant but did not have sufficient biomass or gape size to effectively reduce the *Daphnia* population. The extirpation of larger zooplankton by the alewife caused a decline in total zooplankton biomass from 2003 to 2007 (**Figure 5-22**).

Other taxa once prevalent in Onondaga Lake have also become scarce since the influx of alewives. *Diacyclops thomasi* was scarce immediately after the alewife became abundant, rebounded in 2006, but then declined again in 2007. The biomass of *Bosmina longirostris* greatly increased in the years following the alewife proliferation, probably in response to decreased competition with other once prevalent species. However, there has been a decline in this species since 2005 from the level documented immediately after the influx of alewives (**Figure 5-22)**. Declines in *Bosmina sp.* related to predation by *Cercopagis pengoi* has been documented in Lake Ontario (Benoit et al. 2002). The periods of decreased dominance by

Bosmina longirostris in 2007 coincide with *Cercopagis pengoi* detection in the lake, indicating that they may be playing at least some role in the decline in *Bosmina* sp. in Onondaga Lake (**Appendix 3**).



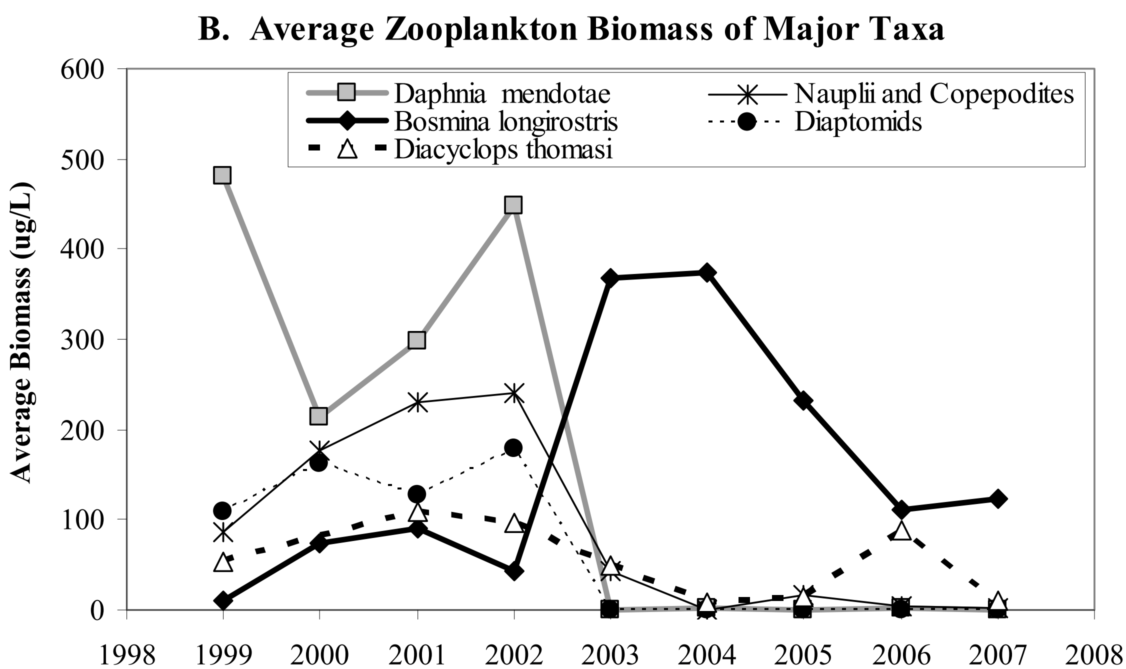


Figure 5-22. Average biomass of zooplankton (all taxa combined) and major taxa in Onondaga Lake April – October, 1999 – 2007. Error bars are standard errors.

The loss of larger zooplankton from Onondaga Lake has considerable implications for the future of the phytoplankton community and water clarity. Phytoplankton will grow as long as environmental conditions such as temperature and light are favorable, and nutrients are available. In a balanced food web, maximum possible biomass is controlled, to a certain extent, by predation. In the aquatic environment, larger zooplankton are the most effective grazers of phytoplankton and exert a major control on the standing crop (**Mills et al. 1987**). The abundance of large species of *Daphnia* is generally considered the most important factor determining algal standing crop; this factor appears to exert greater influence than does the total biomass of all zooplankton present (**McQueen et al. 1986, Carpenter and Kitchell, 1993**). The Onondaga Lake data support this hypothesis; there is a strong relationship between mean zooplankton size and water clarity in Onondaga Lake from 1999-2007 (**Figure 5-23**). Note that years with abundant alewives consistently exhibit the smallest zooplankton and poorest water clarity.

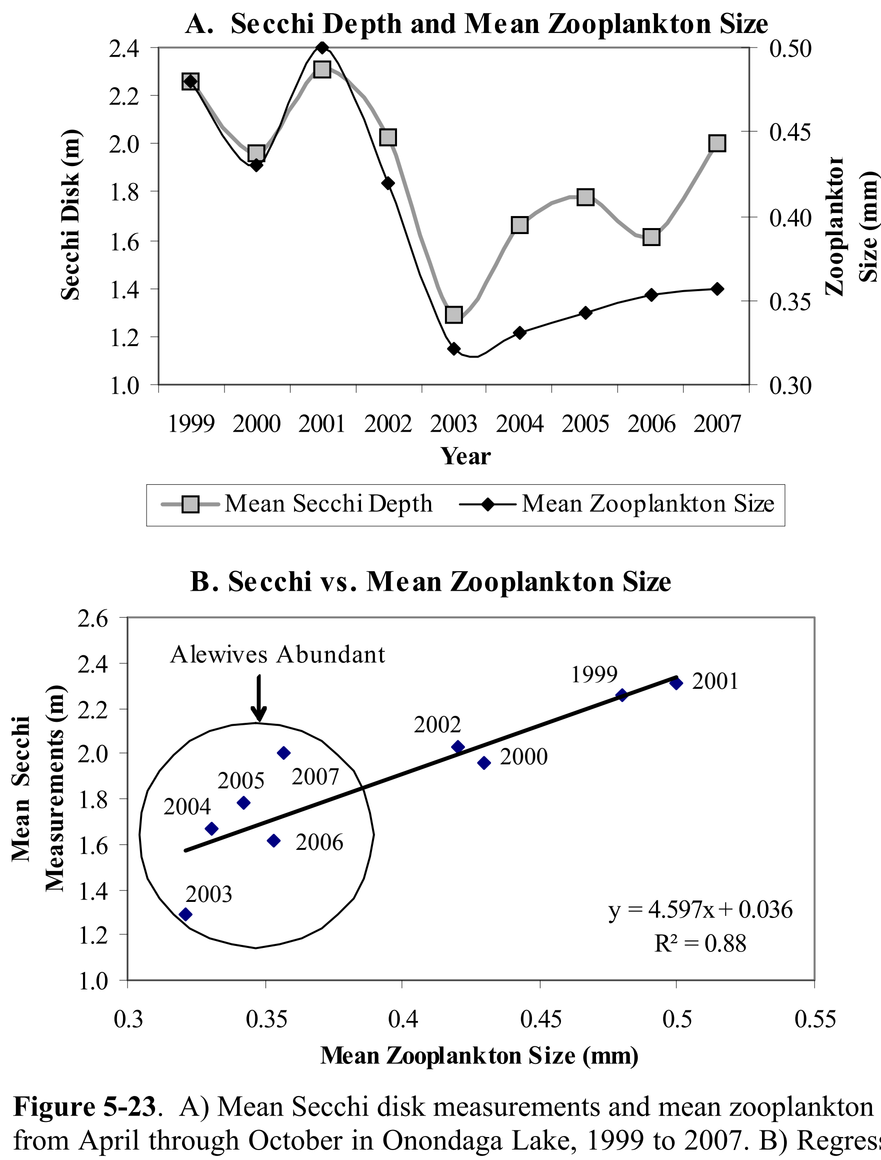


Figure 5-23. A) Mean Secchi disk measurements and mean zooplankton size from April through October in Onondaga Lake, 1999 to 2007. B) Regression of mean Secchi disk measurements and mean zooplankton size from April through October in Onondaga Lake 1999 to 2007, labels are the year.

The Onondaga Lake dataset also shows a poor correlation between zooplankton biomass and phytoplankton (**Figure 5-24**). Other interactions among the various trophic levels, including other grazing organisms such as zebra mussels and higher level interactions of the fish community may be affecting phytoplankton in addition to the effects of nutrients, lights, and temperature.

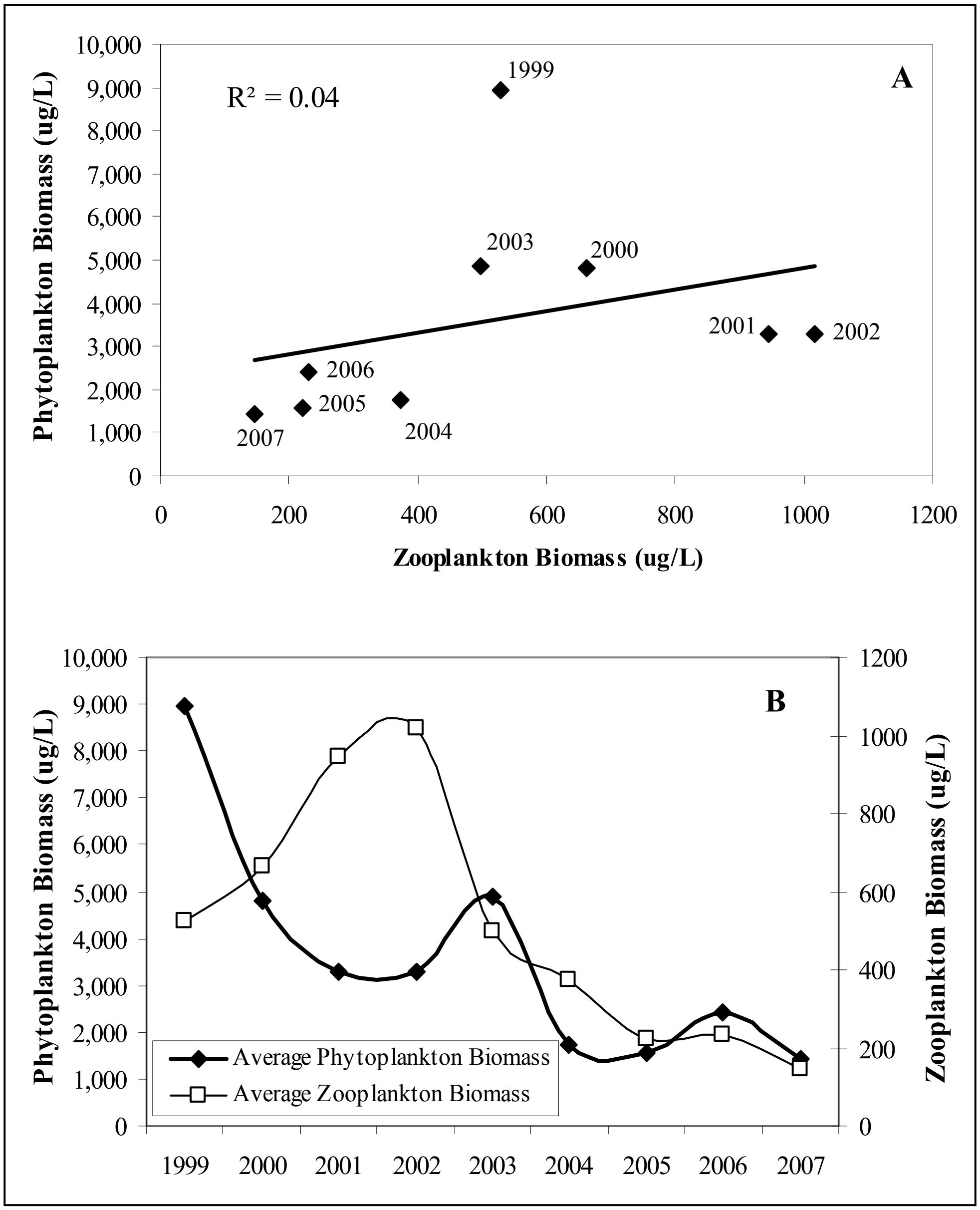


Figure 5-24. Phytoplankton biomass vs. zooplankton biomass (A) and plotted by year (B). Onondaga Lake, South Deep Station, 1999-2007.

5.5.2 Macrophytes

Habitat plays a critical role in structuring the Onondaga Lake biological community. Habitat can be divided into two general categories: physical attributes such as sediment type and macrophyte abundance, and chemical attributes such as water quality. Most of the physical habitat features of the lake are relatively constant (sediment type, large woody debris, artificial structures), although this could change significantly if proposed dredging of the littoral zone takes place. Aquatic macrophytes are the exception and vary annually.

Aquatic macrophytes are an important component of lake ecology; rooted plants have a major effect on productivity and biogeochemical cycles. Macrophytes produce food for other organisms, provide habitat areas for insects and fish, and help to stabilize sediments. The productivity, distribution, and species composition of submersed macrophyte communities are affected by a variety of environmental factors such as light, temperature, sediment composition, sediment stabilization (oncolites) by zebra mussels, nutrient status and wave energy.

Beginning in 2000, OCDWEP began intensive field surveys of the macrophyte community every five years. Aerial photographs of the entire lake are obtained each year to display the macrophyte distribution. For information regarding the OCDWEP macrophyte monitoring program, including detailed results of the 2000 and 2005 surveys, see **Appendix 10** of the **2005 Onondaga Lake Monitoring Report:** *http://www.ongov.net/WEP/wepdf/AMP_Report_Appendices_1-12_(Oct_2006).pdf*.

5.5.2.1 Changes in the Macrophyte Community

The macrophyte community continues to change. Species richness measured in the field surveys increased from 5 species in 1991 (**Madsen et al 1996**) to 10 species in 2000 (**EcoLogic 2001**), and 17 species in 2005 (**EcoLogic 2006**). An 18th species (long leaf pondweed (*Potamogeton nodosus*)) was identified in 2007.

There was a change in dominance from sago pondweed (*Stuckenia pectinatus*) to common waterweed (*Elodea canadensis*) between 2000 and 2005 (years of intensive field surveys). The cause of the change is not known.

The percent cover and biomass of macrophytes has also changed dramatically. The results of the 2005 survey indicate that, on average, there was an approximately three-fold increase in cover and biomass between 2000 and 2005. Average percent cover increased from 8% in 2000 to 26% in 2005 while average biomass increased from 16 g/m^2 dry weight to 51 g/m^2 dry weight. All areas of the lake showed at least a two-fold increase in percent cover between 2000 and 2005.

5.5.2.2 Effects of Changing Macrophyte Community on Bass

Many of the popular gamefish species will likely benefit from increased abundance and diversity of the macrophyte community. In particular, production of one the most important gamefish species in the lake, largemouth bass, is correlated with macrophyte cover (Wiley et al. 1987). Macrophyte coverage has expanded in recent years and is now within an ideal range for largemouth bass production. There is a strong correlation between the amount of macrophyte coverage in any given year and year class strength of largemouth bass as judged from catch rates in seine hauls (**Figure 5-25**). Smallmouth bass year class strength is only slightly correlated with macrophyte coverage. Smallmouth bass tend to be found further off shore where macrophytes are less abundant (Edwards et al. 1983). This increasing trend in the number of young bass appears to be translating into greater abundance of adult bass, as evident from catch rates of adults (**Figure 5-26**). This is a strong indication that the bass population is self-sustaining.

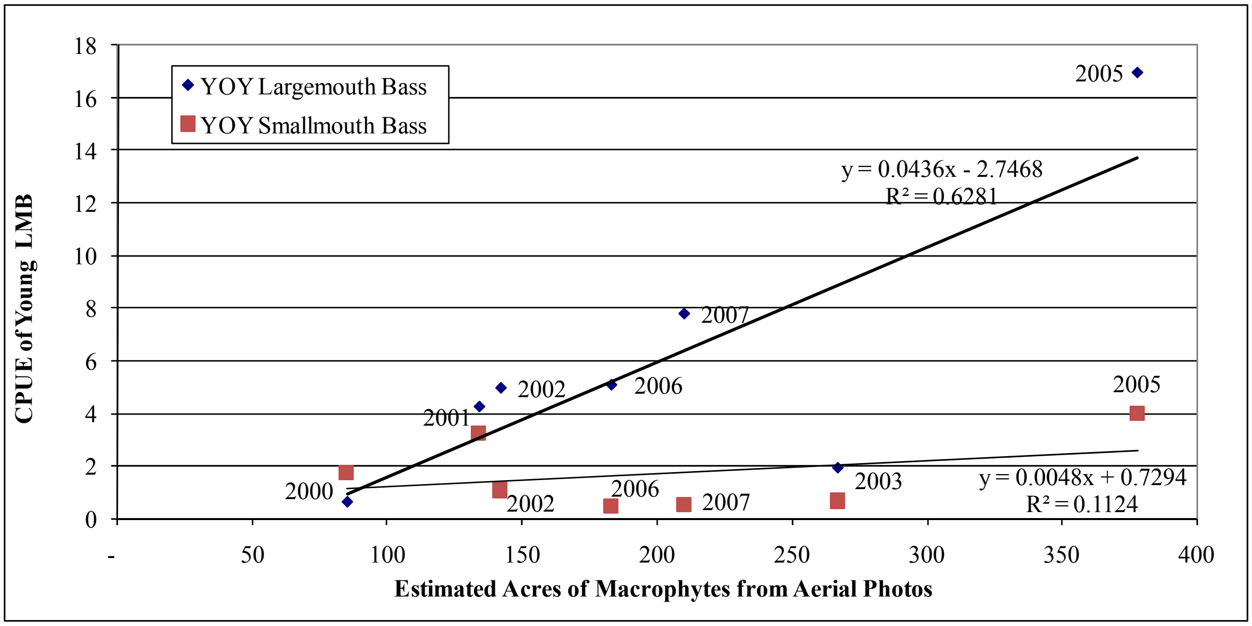


Figure 5-25. Correlation of largemouth bass YOY CPUE and acres of macrophytes delineated in aerial photographs from 2000 to 2007.

Note: 2004 data are omitted because no macrophyte aerial photographs were collected in that year. 2006 and 2007 macrophyte photos were taken in August while photos from other years were collected in late June/early July.

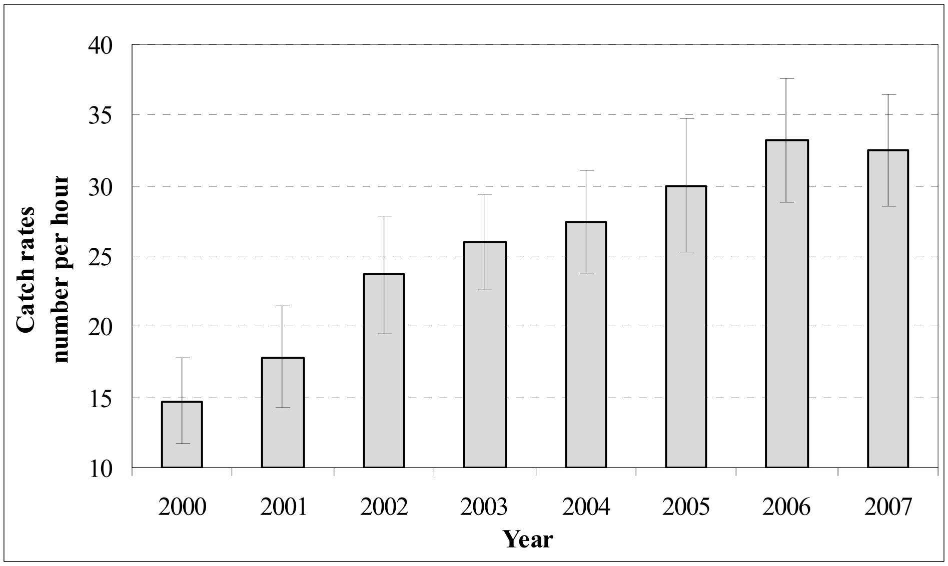


Figure 5-26. Combined catch rates from electrofishing of adult largemouth and smallmouth bass in Onondaga Lake

5.5.3 Habitat Availability Based on Water Temperature and Dissolved Oxygen

> <u>AMP Hypothesis To Be Tested:</u>
>
> - Implementation of point and nonpoint nutrient load reductions will increase the habitat available for the coolwater fish community

Until recently, low DO in the fall throughout the water column was a major factor affecting aquatic habitat. This condition has improved. Oxygen depletion in the lower waters remains typical of this and other stratified productive lakes; the lack of well-oxygenated cold water precludes a year-round resident coldwater fish community

A customized data visualization tool (DVT) was developed by QEA to represent "fish space," i.e., habitat requirements of different fish species. For details regarding the methods and assumptions of the Fish Space DVT calculations refer to **Chapter 3** of the **2006 AMP Annual Report**. The fish space metric is useful for tracking changes in habitat based on DO and temperature, two variables that are necessary, but not sufficient, to maintain a self-sustaining population. The metric should not be interpreted as an indicator of whether populations are sustainable. A sustainable population requires additional elements such as forage base and reproductive habitat that are not reflected solely by DO and temperature conditions.

Two metrics illustrate Fish Space DVT:

(1) <u>Coldwater Fish Habitat</u>. Default values are: temperature ≤ 22° C <u>and</u> dissolved oxygen ≥ 5 mg/L between May 15 and November 15.

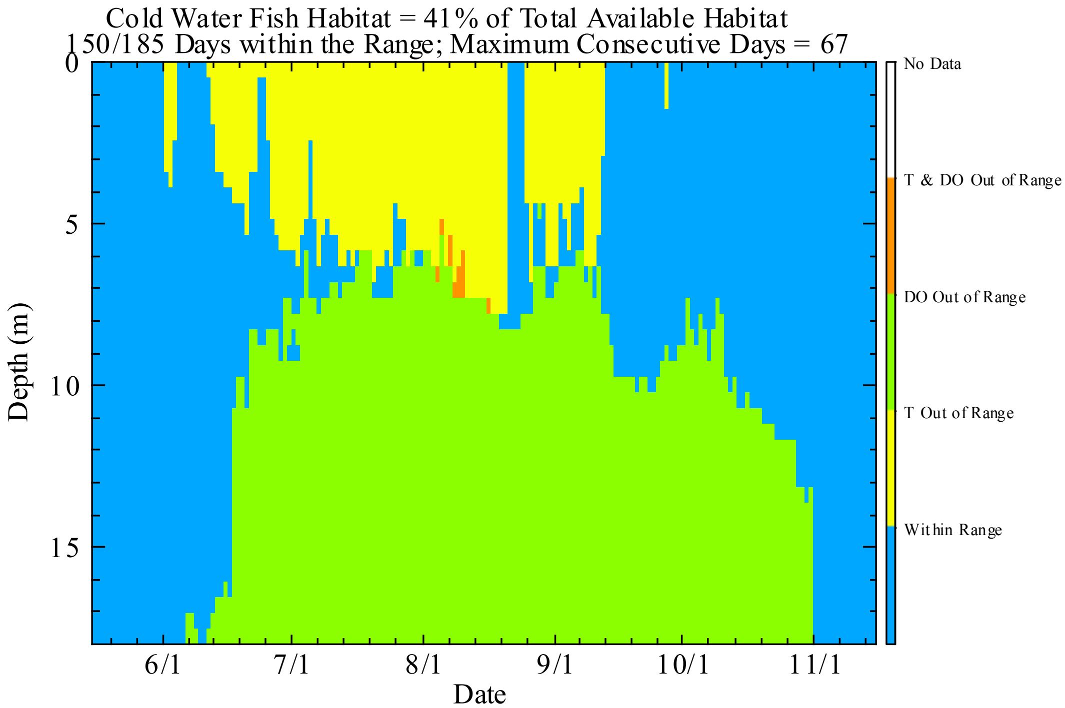


Figure 5-27. Coldwater fish habitat in Onondaga Lake in 2007.
<u>Note:</u> Water temperature <22 deg. C and dissolved oxygen >5 mg/L between May 15 and November 15.

Conditions in 2007 were comparable to previous years. The DO was less than 5 mg/l in the deeper cool waters beginning in mid-June through October, and water temperatures were above 22° C throughout much of the upper oxygenated layer from July through early-September (**Figure 5-27**). The percent of available habitat (41%) was similar to recent years (**Table 5-10**). The total number of days within range (150) and number of consecutive days in range (67) were also consistent with previous years. These data suggest that, although there could be areas of refugia in the lake for coldwater species, there is generally insufficient dissolved oxygen in waters with temperatures capable of supporting a significant population.

Table 5-10. Habitat availability for coldwater fishes in Onondaga Lake from 2000 to 2007 based on default DVT criteria.

Year	Coldwater Habitat		
	% Available Habitat[1]	Total # Days In Range[2] (max 185 days)	# Consecutive Days In Range[2] (max 185 days)
2000	40	161	72
2001	39	140	72
2002	35	112	50
2003	34	129	51
2004	40	175	71
2005	37	124	59
2006	42	132	80
2007	41	150	67

1 Assumes entire volume of the lake from May 15 to November 15 is available.

2 Number of days where temperature and DO are within range in at least a one meter vertical section of the lake.

(2) **Coolwater Fish Habitat Metric. Default values are: temperature between 18º - 25º C and dissolved oxygen ≥ 6 mg/L between May 15 and November 15.**

The percent of total available habitat for coolwater fish has remained high since the AMP fish monitoring began in 2000 varying from 69% (2003) to 87% (2007) (**Table 5-11**). Once surface waters warmed to temperatures within the ideal range for coolwater fish (late May) in 2007, ideal conditions existed in at least a one meter deep layer throughout the summer until temperatures cooled to levels less than ideal in mid-October (**Figure 5-28**). The percent of total available habitat for coolwater species in a given year appears to be mostly controlled by UML water temperature and to a lesser extent the intrusions of low DO water into the UML from the LWL. Warmer years provide less coolwater habitat and cooler years provide more.

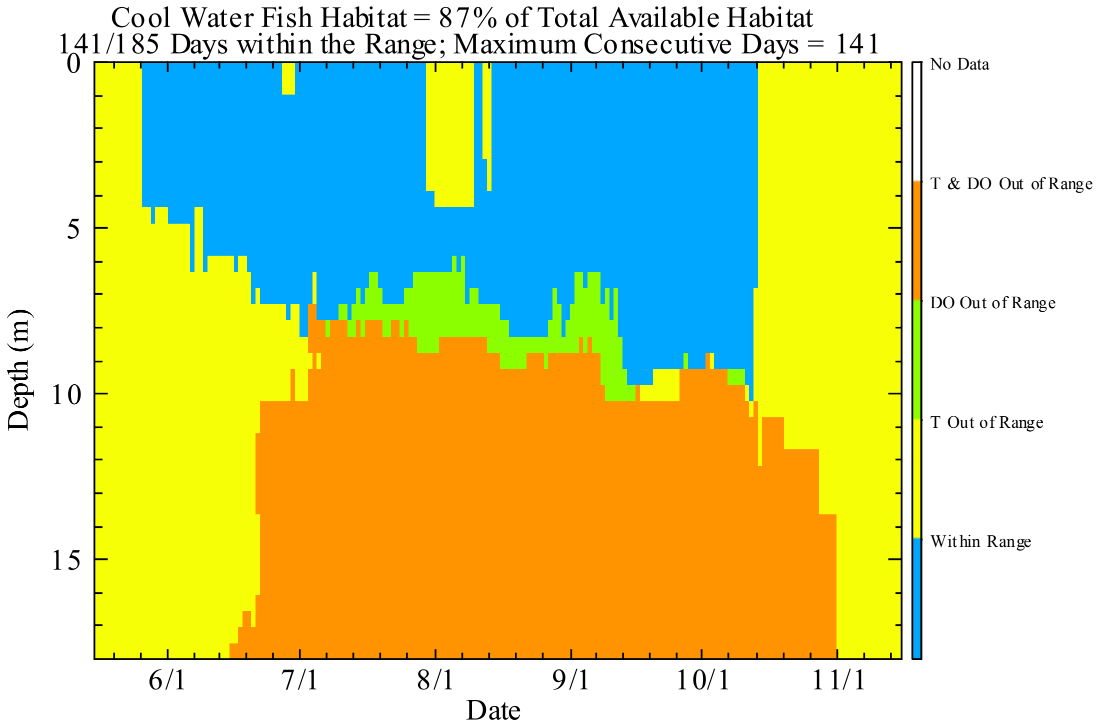


Figure 5-28. Coolwater fish habitat in Onondaga Lake in 2007.
Note: Water temperature between 18-25 deg. C and dissolved oxygen >= 4 mg/L between May 15 and November 15, total 185 days.

Table 5-11. Habitat availability for cool water fishes in Onondaga Lake from 2000 to 2007 based on default DVT criteria.

	Coolwater Habitat		
Year	**% Available Habitat**	**Total # Days In Range[1] (max 185 days)**	**# Consecutive Days In Range[1] (max 185 days)**
2000	77	114	109
2001	76	117	114
2002	75	101	47
2003	69	102	61
2004	80	134	124
2005	77	115	52
2006	80	116	50
2007	87	141	141

1 Number of days where temperature and DO are within range in at least a one meter vertical section of the lake.

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CHAPTER 6: SENECA RIVER CONDITIONS

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CHAPTER 6. SENECA RIVER CONDITIONS

As outlined in the 2007 AMP workplan, OCDWEP conducted three water quality surveys of the Seneca River during the summer of 2007, when river flows were generally low. The surveys were designed to assess current water quality status with respect to ambient water quality standards and to support the river modeling effort being carried out by Quantitative Environmental Analysis, LLC (QEA). The AMP calls for annual water quality monitoring at Buoy 316; this sampling and analysis has been incorporated into the three full river surveys. The water quality survey study area spans the Seneca River from Cross Lake to Three Rivers Junction (TRJ), as well as portions of the Oneida and Oswego Rivers (**Figure 6-1**).

River sampling in 2007 occurred on July 12th, August 9th and September 26th. During each survey, grab samples of "bottom" and "top" waters (1m above the channel bottom and 1m below the water surface, respectively) were collected and analyzed for several water quality parameters at numerous locations (defined by navigational buoys) throughout the study area. To further characterize the extent of stratification and variations in water quality with depth at Buoy 269, grab samples were also collected from a point halfway between the top and bottom samples at this location. In addition to the grab sampling, depth profiles of in-situ water quality parameters (dissolved oxygen (DO), salinity, redox potential, pH, and temperature) were collected at each sampling location during the AMP surveys.

Furthermore, YSI data sondes were deployed over the summer at three locations to evaluate changes in water quality conditions over the course of a day, as suggested by the river modeling peer review panel (**QEA 2005, Appendix M**). The sondes were placed at Cross Lake (Buoy 409), Buoy 316 in Baldwinsville, and the Onondaga Lake Outlet. In-situ temperature, DO, salinity and chlorophyll (Buoy 409 only) were recorded at 15-minute intervals for both top and bottom waters. This effort resulted in more than 117 days of data to characterize the diurnal variation in water quality conditions. Additional details regarding the river sampling, in-situ depth profiles, and YSI sonde data can be found in **Appendix 9**.

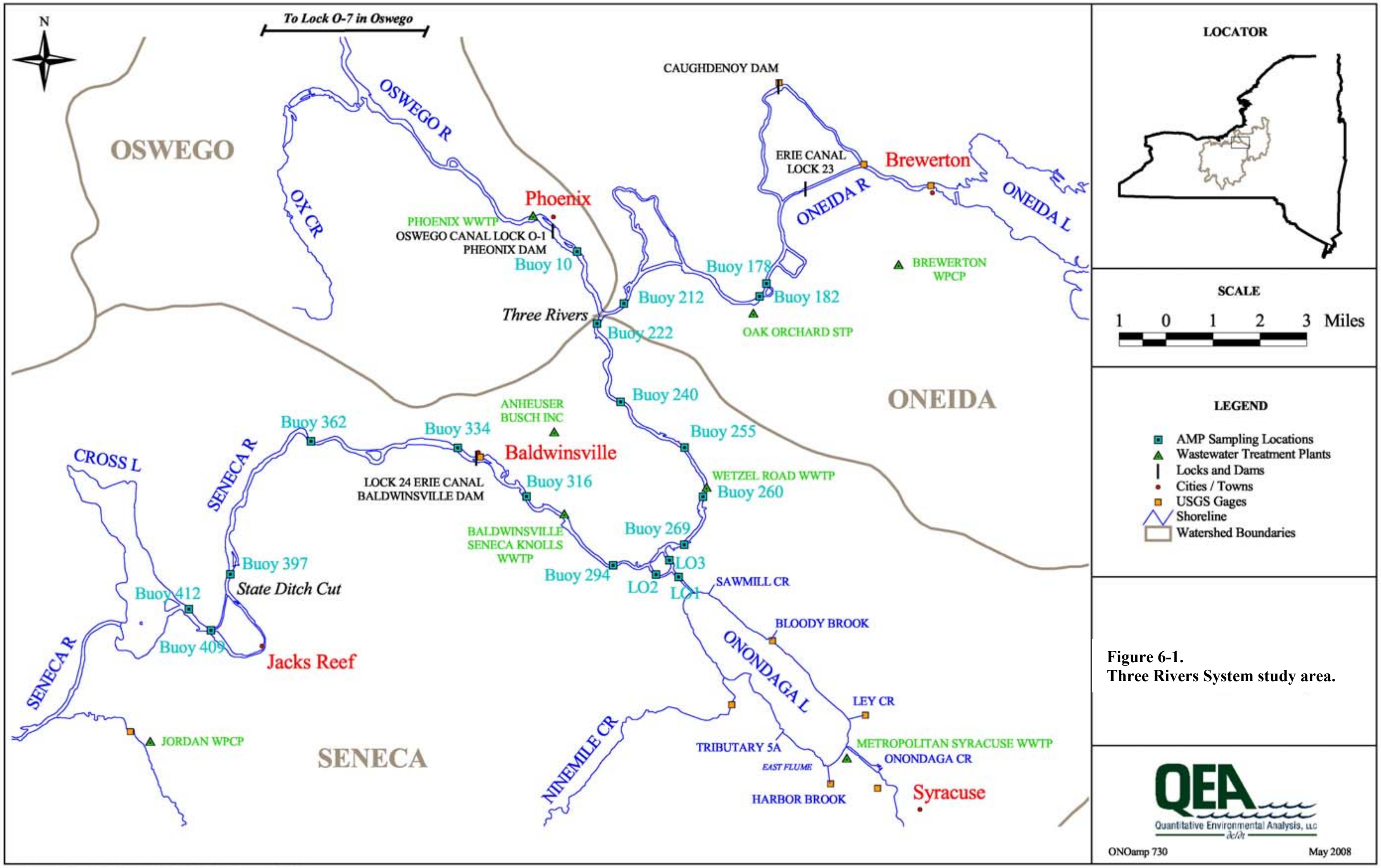

Figure 6-1.
Three Rivers System study area.

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6.1 RIVER FLOW CONDITIONS 2007

River flow conditions in 2007 can be characterized by high flows in the spring (April to mid May) due to runoff and release from the Finger Lakes, and a period of sustained low flow during the summer and early fall (late May to mid October). There was one moderate flow period at the end of July (**Figure 6-2**). The flow rates in the Seneca River were low during all three water quality surveys (684 cfs on 7/12/07; 716 cfs on 8/9/07 and 654 cfs on 9/26/07). The 2007 average flow rates between July and September were 774 cfs in the Seneca River and 569 cfs in the Oneida River. These average flow rates are about 50% lower than the long-term summer averages in these systems (1,696 cfs in the Seneca River 1950-2007; 1,043 cfs in the Oneida River 1950-2007). In 2007 the flow rates in the Seneca River dropped below the 7Q10 value of 350 cfs (**QEA, 2000**) on five occasions - once at the very end of August, three times in early September, and once more in early October (ranging from 141 to 275 cfs), although flow rates in the neighboring days precluded a seven-day average from being below the 7Q10 value.

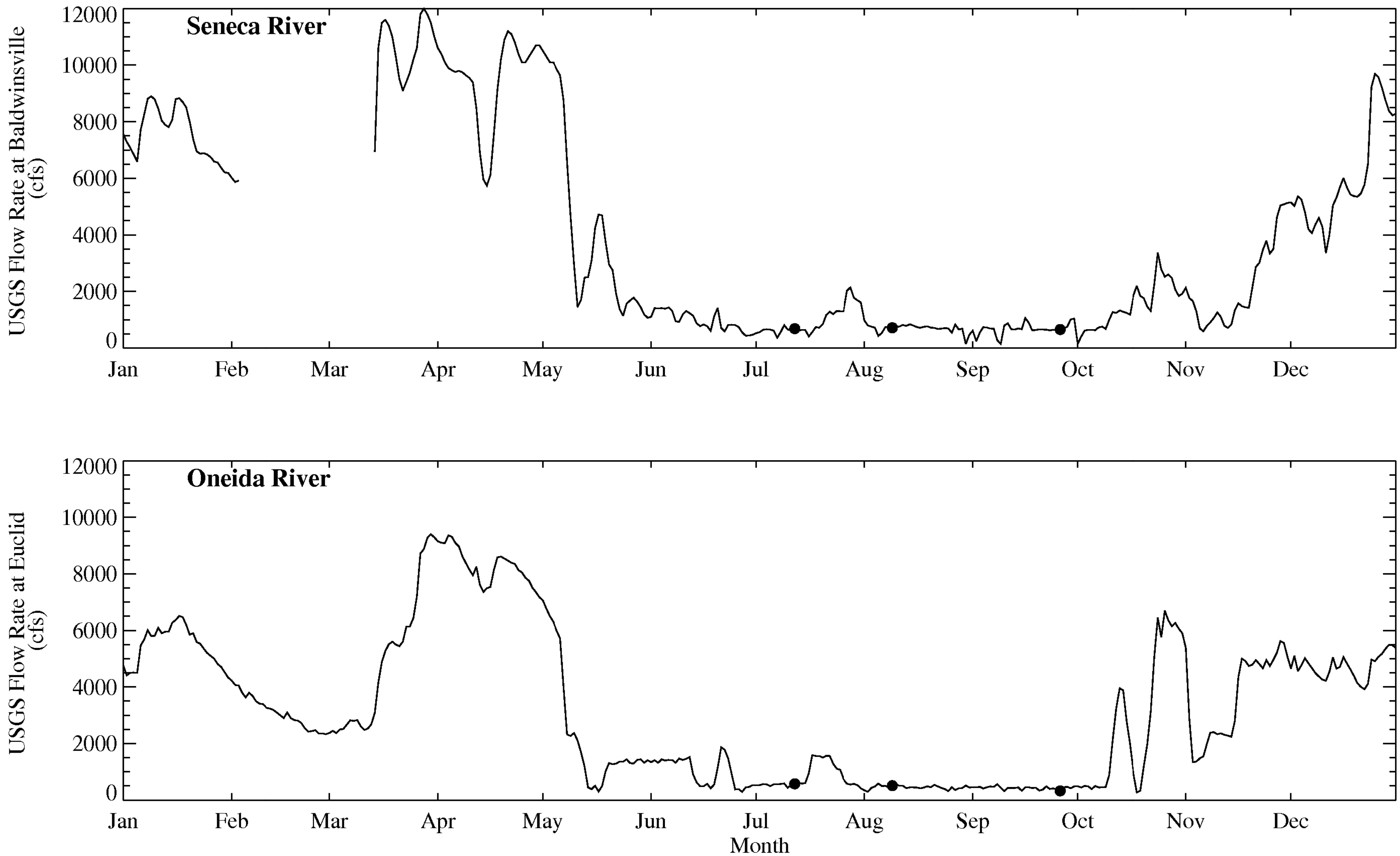

Figure 6-2. USGS flow rate and OCDWEP AMP sampling dates for year 2007.
Note: Points represent OCDWEP water quality sampling dates.

6.2 SENECA RIVER WATER QUALITY CONDITIONS 2007

As in past years, Seneca River water quality in 2007 can be understood in light of several major factors: the loading of algal biomass from Cross Lake, flow rates, time of year, phytoplankton and zebra mussel activity, effects of inflow from the more saline and eutrophic Onondaga Lake, and the presence of an anomalous region of the Seneca River downstream of the lake outlet called the "Deep Hole," which may be influenced by groundwater discharge (**QEA, 2005**). Water quality conditions in the Seneca River are discussed below for six selected parameters: DO, SRP, chlorophyll-*a*, NH3-N, NO2-N, and NO3-N measured during the three 2007 sampling surveys. Spatial profiles of the full suite of water quality constituents (i.e., DO, organic and inorganic forms of nitrogen, phosphorus, and carbon, as well as solids, chlorophyll-*a*, salinity, and temperature) are provided in **Appendix 9** (**Figures A9-2 to A9-11**).

6.2.1 Phosphorus

In 2007, as in previous years, soluble reactive phosphorus (SRP) concentrations increased between Cross Lake and the Onondaga Lake outlet as a result of zebra mussel activity (**Figures 6-3a to 6-3c**). This increase was generally small during the July and September surveys (e.g., from 5 µg/l to 10 to 15 µg/l), perhaps due to the slow growth of the zebra mussel population in July and diminished zebra mussel activities by late September. In contrast, the August survey exhibited a much larger increase in SRP concentrations (e.g., from 5 µg/l to approximately 50 µg/l), likely due to zebra mussel activity reaching its peak. SRP concentrations between Cross Lake and Baldwinsville dam were generally similar between the top and bottom waters. Because the surface SRP in the river just upstream of the lake outlet was consistently higher than the surface (UML) SRP concentration of the lake throughout the summer, the river may have contributed some SRP to the lake's upper waters during periods of river inflow in 2007 (**Figure 6-3b**).

The surface SRP concentrations downstream of the Onondaga Lake outlet remained relatively constant during the July and September surveys, probably due to the balancing of algal production with filtration of the remaining algae by zebra mussels. During the August survey, surface SRP concentrations decreased between the lake and Three Rivers Junction, likely due to mixing between lake and river water and uptake by algae as evidenced by the concomitant increase in chlorophyll-*a* concentrations. The relatively higher SRP concentrations measured in the bottom layer of the river downstream of the Onondaga Lake outlet are likely due to limited mixing of the relatively stagnant water layer, perhaps coupled with some flux of SRP from the limited areal extent of anoxic sediments, within the "Deep Hole." Although there were no data specifically collected to measure SRP flux from sediments in this area, it is reasonable to expect that some SRP would be released to the overlying water during diagenesis reactions. The cooler water and higher salinity levels limit mixing of this water stratum Overall, the SRP patterns observed in 2007 were consistent with patterns observed in previous years.

6.2.2 Chlorophyll-a

Since the early 1990's a decrease in chlorophyll-*a* has been observed in the river between Cross Lake and Baldwinsville Dam due to zebra mussel filtration. Such a trend was again observed in the July and August 2007 surveys, but was not observed in the September 2007 survey, when the chlorophyll-*a* concentrations in the surface waters between Cross Lake and Baldwinsville Dam stayed approximately constant at ~30 µg/l (**Figures 6-3a to 6-3c**). The relatively constant nature of the chlorophyll-*a* concentration in this stretch of the river suggests decreased zebra mussel activity during the September 2007 survey, perhaps due to die-offs at the end of the growing season. In 2007 the data suggest that both the #/m^2 and the g/m^2 were significantly less than the previous years in this area (see **Section 5.3.1**). Although no actual observations of die-offs were observed the October 2007 mussel survey from this area of the River was comprised of relatively small (median and mean about 3-4 mm) YOY zebra mussels. This could suggest some recovery of the population following a die-off in the prior months. In general, chlorophyll-*a* concentrations in 2007 increased downstream of the Onondaga Lake outlet likely due to nutrient inputs from the lake, with the maximum concentration of about 60 µg/l being measured at Three Rivers Junction during the September survey (**Figure 6-3c**).

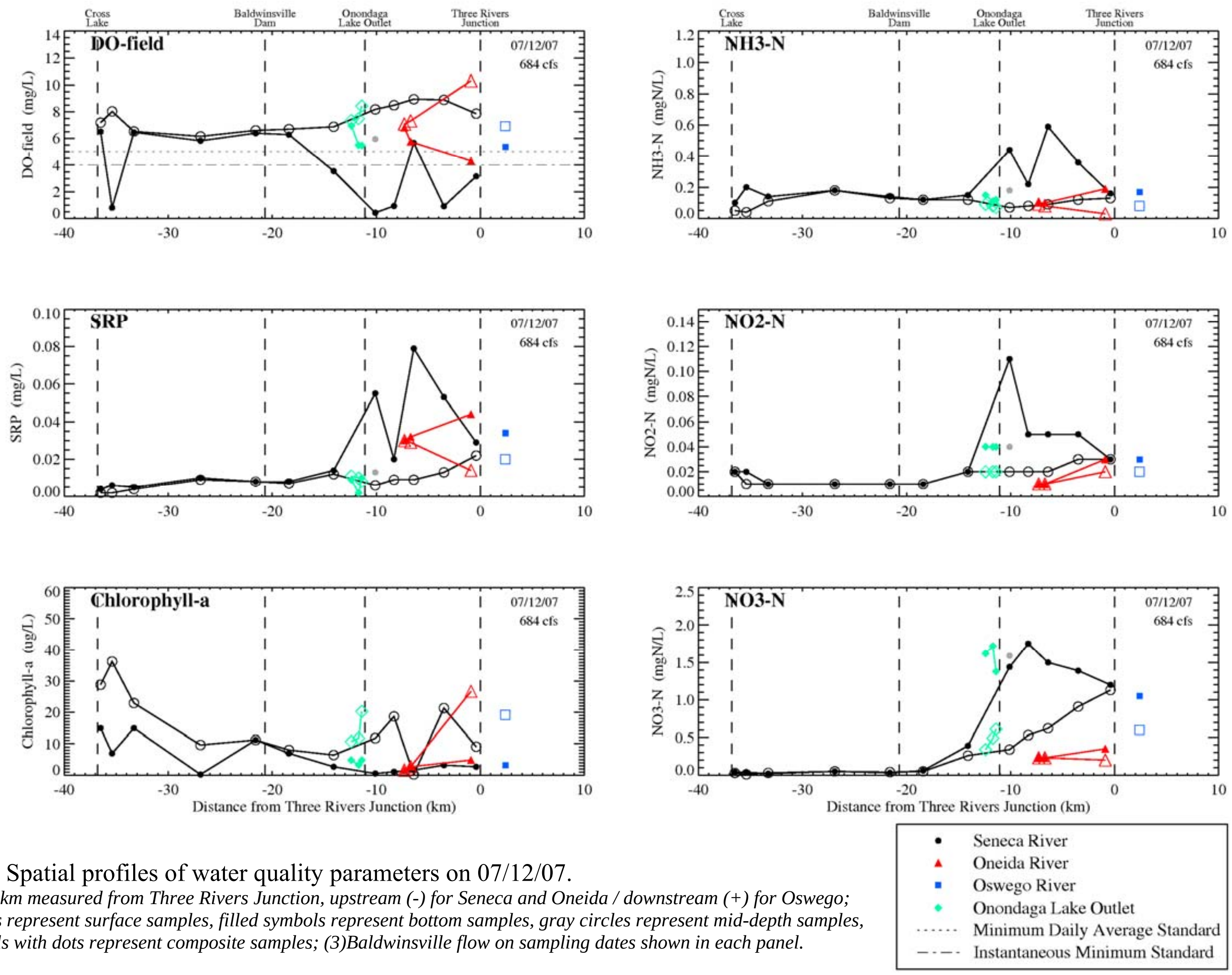

Figure 6-3a. Spatial profiles of water quality parameters on 07/12/07.

Notes: (1) River km measured from Three Rivers Junction, upstream (-) for Seneca and Oneida / downstream (+) for Oswego; (2)Open symbols represent surface samples, filled symbols represent bottom samples, gray circles represent mid-depth samples, and open symbols with dots represent composite samples; (3)Baldwinsville flow on sampling dates shown in each panel.

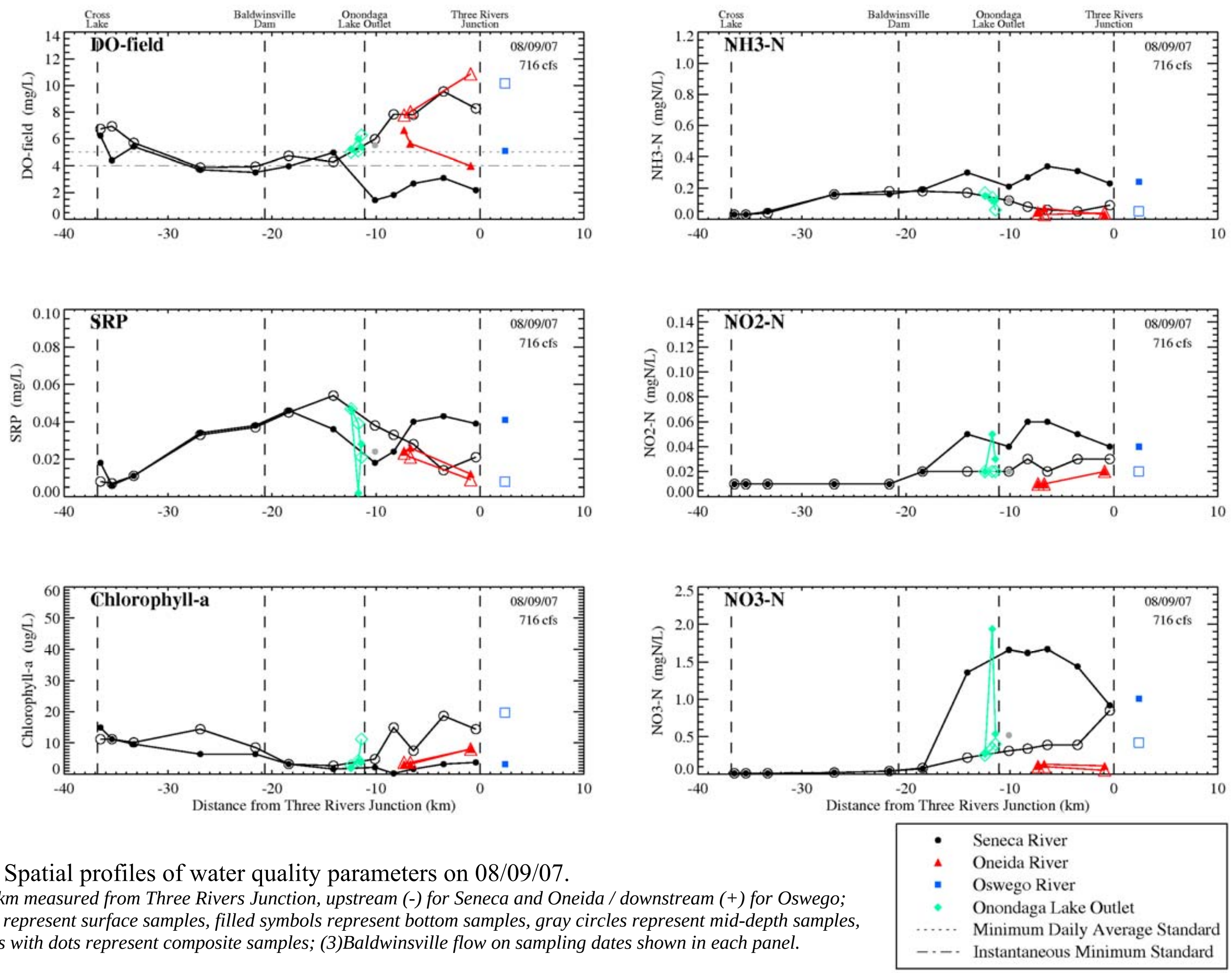

Figure 6-3b. Spatial profiles of water quality parameters on 08/09/07.
Notes: (1) River km measured from Three Rivers Junction, upstream (-) for Seneca and Oneida / downstream (+) for Oswego; (2)Open symbols represent surface samples, filled symbols represent bottom samples, gray circles represent mid-depth samples, and open symbols with dots represent composite samples; (3)Baldwinsville flow on sampling dates shown in each panel.

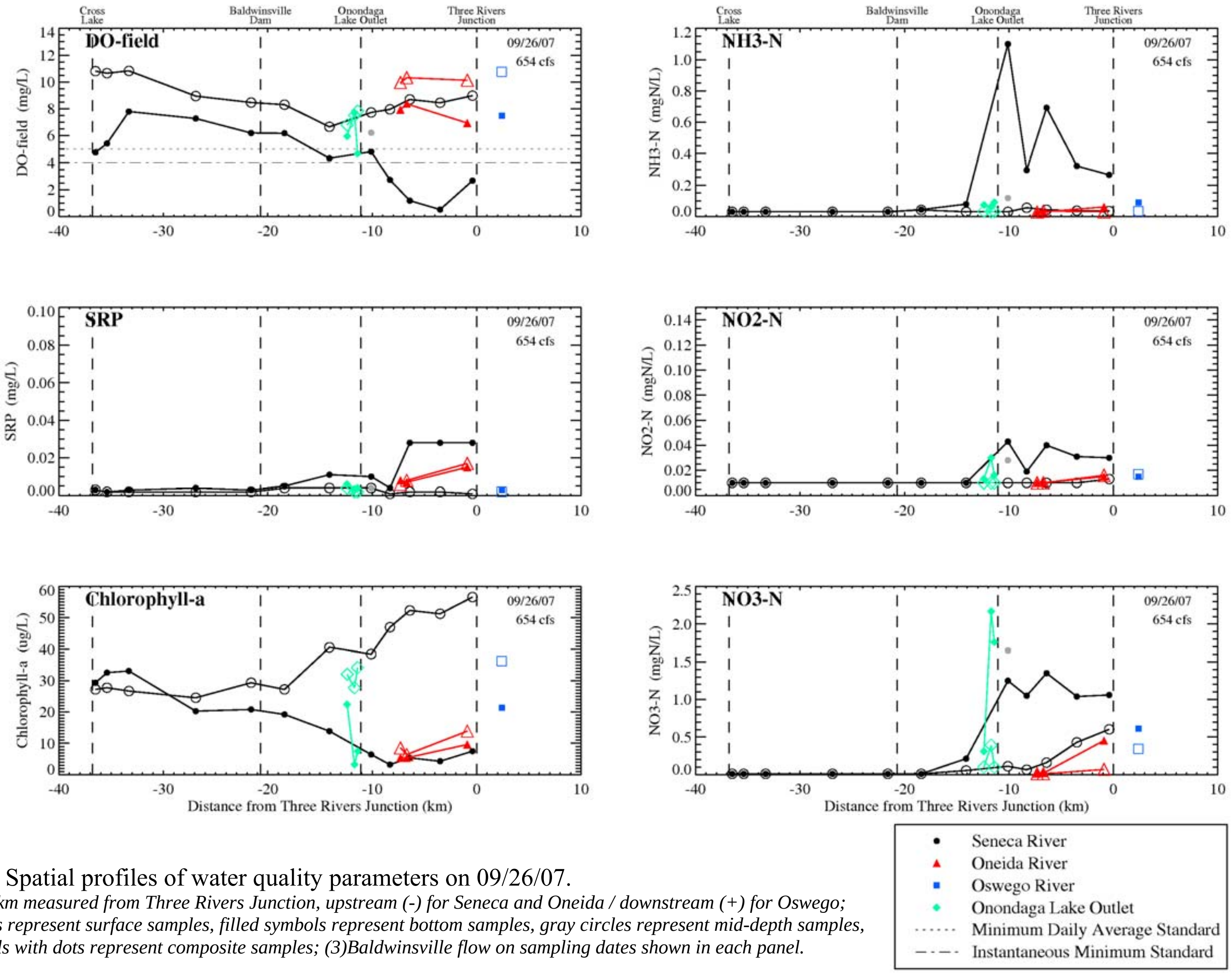

Figure 6-3c. Spatial profiles of water quality parameters on 09/26/07.
Notes: (1)River km measured from Three Rivers Junction, upstream (-) for Seneca and Oneida / downstream (+) for Oswego; (2)Open symbols represent surface samples, filled symbols represent bottom samples, gray circles represent mid-depth samples, and open symbols with dots represent composite samples; (3)Baldwinsville flow on sampling dates shown in each panel.

6.2.3 Dissolved Oxygen

DO concentrations during the three 2007 surveys generally demonstrated similar patterns, except during the September 2007 event, for which the data exhibited more pronounced stratification of DO between top and bottom waters. Overall the DO concentrations measured between Cross Lake and Baldwinsville dam showed gradual decreases, which continued to the Onondaga Lake outlet. This decrease was likely caused by zebra mussel respiration and sediment oxygen demand and was more prevalent in the bottom waters than at the surface, especially for the September 2007 event. Downstream of the Onondaga Lake outlet DO concentrations in the top waters increased due to reaeration and inflow from the lake, while the bottom water DO concentrations remained low or decreased (e.g., < 2 mg/l) as a result of the anomaly caused by the existence of the "Deep Hole" in this portion of the river (discussed further below). In all three 2007 surveys, the low flow conditions led to a number of bottom water DO violations downstream of Onondaga Lake, where concentrations were below the NYSDEC instantaneous minimum standard of 4 mg/L, particularly in the area of the "Deep Hole." This is in contrast to 2006, when the flow conditions throughout the summer were relatively high and very few DO violations were observed.

In-situ DO data were collected during 2007 using YSI sondes deployed at Buoys 409, 316, and at Onondaga Lake outlet near Long Branch Road. Temporal profiles of the in-situ DO data at Buoys 409 and 315 are provided in **Figure 6-4.** Plots of all parameters measured by the data sondes at all three locations are provided in **Appendix 9** (**Figures A9-12 to A9-16**). The influence of photosynthesis and respiration of phytoplankton and macrophytes can be observed in the diurnal DO variations recorded by the YSI data sondes deployed at Buoys 409 near Cross Lake and Buoy 316 downstream of the Baldwinsville dam (**Figure 6-4**). DO is produced via photosynthesis during day time and gradually reaches its peak concentration around late afternoon. DO is consumed at night, and reaches its minimum concentration before sunrise.

Similar to previous years, Buoy 409 exhibited more DO variability than Buoy 316 likely due to algal inputs from Cross Lake at that location. The magnitude of the diurnal DO fluctuations recorded by Buoy 409 was between 1 and 10 mg/l while during the same time period, the magnitude of the diurnal DO fluctuations at Buoy 316 was between 1 and 6 mg/l (**Figure 6-4**). The daily average DO concentrations measured at the bottom of Buoys 409 and 316 were much lower than the DO measured at the top. Overall, the sonde data suggest that DO concentrations in 2007 appeared to be relatively low with larger diurnal DO variations than past years. This is in contrast to 2006, when the higher flow conditions resulted in stronger vertical mixing and reaeration in the river which in turn contributed to much more favorable DO conditions.

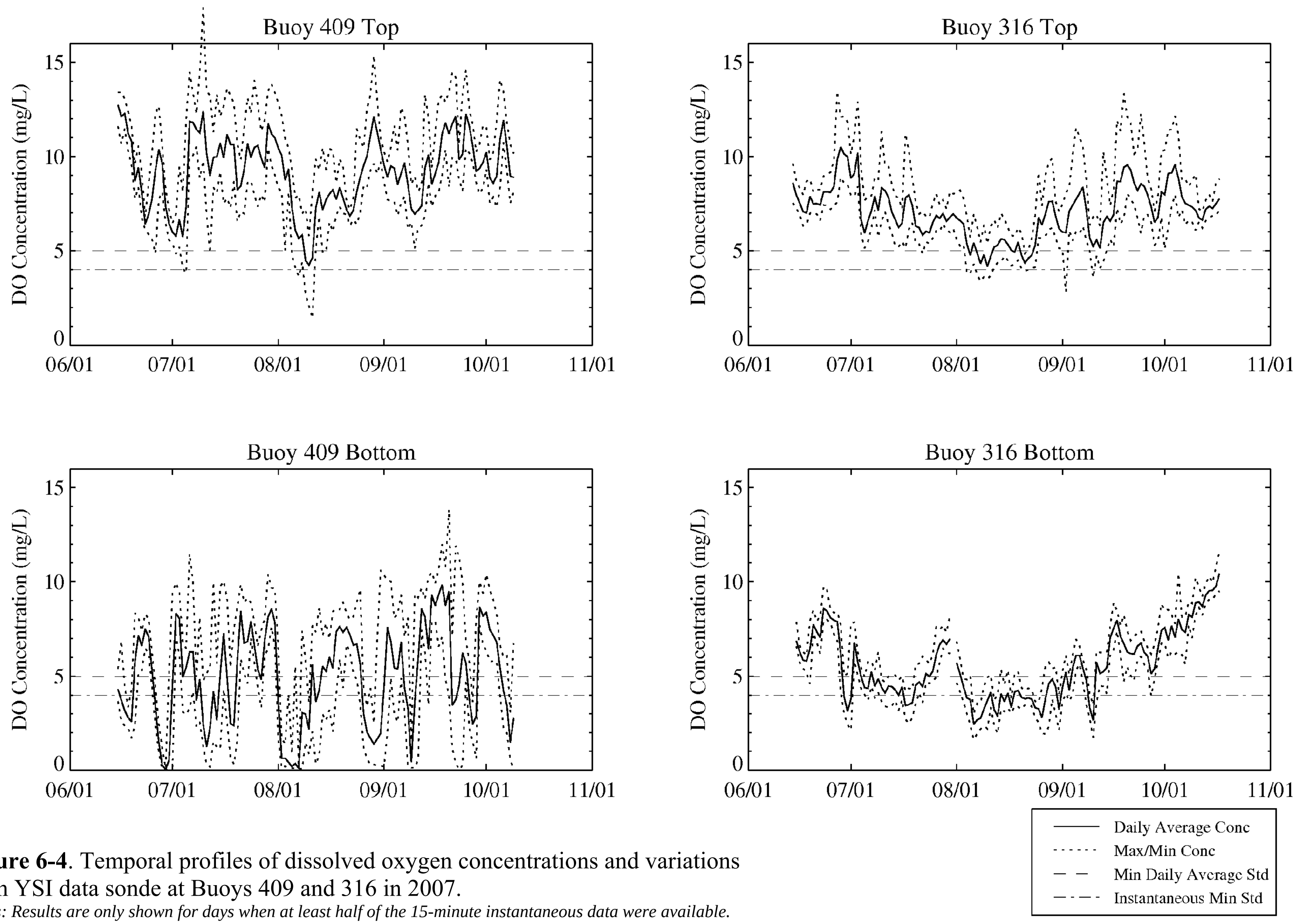

Figure 6-4. Temporal profiles of dissolved oxygen concentrations and variations from YSI data sonde at Buoys 409 and 316 in 2007.
Notes: Results are only shown for days when at least half of the 15-minute instantaneous data were available.

6.2.4 Nitrogen

In 2007 ammonia-N (NH3-N) concentrations in the Seneca River exhibited spatial patterns generally similar to those observed in recent years (**Figures 6-3a to 6-3c**). In the July and August surveys, there was a slight increase in NH3-N concentrations (~0.2 mgN/l) between Cross Lake and Baldwinsville. Such increase has been traditionally associated with zebra mussel activity in this area. The ammonia-N concentrations observed during the September 2007 survey were much lower, likely due to a decrease in zebra mussel activity. The top and bottom concentrations of nitrogen species between Cross Lake and the Onondaga Lake outlet were generally similar for all three surveys.

As in previous years, the concentrations of nitrogen species in the lower waters increased significantly in the vicinity of the Onondaga Lake outlet and then decreased somewhat downstream toward Three Rivers Junction due to vertical mixing and algal uptake. During the September 2007 survey, the bottom NH3-N concentration at Buoy 269 just downstream of the Onondaga Lake outlet was 1.1 mgN/l; this is significantly higher than the NH3-N measured in both the river upstream and the lake outlet (both ~0.1 mgN/l). Elevated NH3-N concentrations in the deeper waters of the river downstream of the lake outlet were also observed in the July and August surveys, but were far less pronounced. The high NH3-N concentrations at the bottom water downstream of the lake outlet were likely influenced by the presence of the "Deep Hole" as well as limited mixing due to the prolonged low flow conditions during summer 2007. Similar to recent years, the bottom waters of the river downstream of the lake outlet are characterized by elevated NO3-N concentrations, which reflect inputs from the lake.

6.2.5 Stratification in the "Deep Hole"

Similar to previous years, elevated salinity and lower temperatures were observed in the river downstream of the lake outlet (**Appendix 9**, **Figures A9-9 and A9-11**), likely reflecting the influx of stratified lake water and groundwater from the "Deep Hole" both of which have higher salinity than the river. During the July and August surveys the salinity measured in the bottom waters downstream of the Onondaga Lake outlet was on the order of 1 ppt, which is consistent with that of the lake (**Appendix 9**, **Figure A9-9**).

However, during the September sampling event, the bottom samples collected in this area exhibited extremely high salinities (11.2 ppt and 8.3 ppt at Buoys 269 and 260, respectively), which were much higher than the salinity of the lake (approximately 1 ppt). These data suggest that water in the "Deep Hole" region was affected by recharge of high salinity groundwater in this area, which has been observed in previous years (see **Appendix G of QEA 2005**), but not at such high salt concentrations. In addition, elevated salinity was also observed in the bottom waters of the lake outlet (4 ppt at LO3) during the survey, suggesting that the spatial extent of the high salinity bottom water layer was greater in 2007. The higher levels and greater spatial extent of this saline groundwater region in the river in 2007 was likely caused by the sustained periods of low river flow; it does not appear that other events occurred in 2007 that would explain these high salinities. The presence of a relatively stagnant water layer influenced by saline groundwater influx can explain the low DO concentrations (~0.5 mg/L) measured at Buoys 255 and 240, which were much lower than the DO measured at the lake outlet (4-8 mg/L).

6.2.6 Summary

In general the water quality data collected in 2007 during the three river surveys were comparable to the data collected in previous surveys (i.e., 1993 to 2006). The data measured during the individual surveys were reflective of the predominant processes occurring in the river at that time of the year (e.g. zebra mussel respiration slows down in the fall as the waters cool). Overall, 2007 can be characterized as a low flow year with decreased dilution, vertical mixing, and reaeration. Such conditions led to pronounced differences between upper and lower water layer concentrations, especially downstream of the Onondaga Lake outlet, on multiple occasions. The introduction of zebra mussels in the early 1990s resulted in dramatic changes in water quality in the river; since then, the dominant patterns and mechanisms do not appear to have changed significantly. The change in nutrient and chlorophyll-*a* concentrations between Cross Lake and Baldwinsville, suggest different levels of zebra mussel activities between July and September 2007. Finally, the sustained low flow conditions in the river appear to have contributed to an increase in the zone of influence from saline groundwater influx in the deep area of the river just downstream of the lake outlet.

6.3 SENECA RIVER REGULATORY COMPLIANCE 2007

Typically, samples collected during the low flow river surveys do not meet the ambient water quality standards for dissolved oxygen and nitrite-N at various locations and dates. The dry summer season of 2007 was no exception. While in 2006 there was just one DO standard violation observed in the river surveys, in 2007 the number of violations of water quality standards in the river was much higher. A summary of water quality violations observed during the three river surveys conducted in 2007 is shown in **Table 6-1**, where DO is compared to the NYSDEC instantaneous minimum standard[1] of 4 mg/l and nitrite-N concentrations are compared to the compliance criteria of 0.1 mgN/l.

[1] Sample collected during AMP river surveys s represents a single (i.e. instantaneous) sampling of each location

Table 6-1. Compliance summary of 2007 Seneca River data.

Parameter	Sampling Date	Location	Depth	Values below Standard (mg/l)
Dissolved Oxygen (Compliance criteria = 4 mg/l)	7/12/2007	BUOY-222	BOTTOM	3.16
		BUOY-240	BOTTOM	0.92
		BUOY-260	BOTTOM	0.93
		BUOY-269	BOTTOM	0.43
		BUOY-294	BOTTOM	3.55
		BUOY-409	BOTTOM	0.8
	8/9/2007	BUOY-222	BOTTOM	2.18
		BUOY-240	BOTTOM	3.09
		BUOY-255	BOTTOM	2.68
		BUOY-260	BOTTOM	1.82
		BUOY-269	BOTTOM	1.43
		BUOY-316	BOTTOM	3.97
		BUOY-334	BOTTOM	3.51
		BUOY-334	TOP	3.94
		BUOY-362	BOTTOM	3.71
		BUOY-362	TOP	3.87
	9/26/2007	BUOY-222	BOTTOM	2.67
		BUOY-240	BOTTOM	0.52
		BUOY-255	BOTTOM	1.18
		BUOY-260	BOTTOM	2.73
Parameter	**Sampling Date**	**Location**	**Depth**	**Values above Standard (mgN/l)**
Nitrite-N (Compliance criteria = 0.1 mgN/l)	7/12/2007	BUOY-269	BOTTOM	0.11

Table 6-1 shows that during the three 2007 Seneca River surveys DO was found below the NYSDEC instantaneous minimum DO standard of 4 mg/l on 20 separate occasions. In addition, on one occasion the nitrite-N compliance criteria of 0.1 mgN/l was exceeded, but the excursion was minor at 0.11 mgN/l. There were no violations detected in ammonia-N concentrations, for which the regulatory limit ranged from 0.83 to 1.81 mgN/l depending on pH and temperature.

The 2007 low flow patterns in the Seneca River (**Figure 6-2**) likely explain the greater extent of DO standard violations relative to previous years. DO standard violations were further assessed by comparing the 2007 DO data collected by the high frequency YSI sondes to the NYSDEC minimum daily average DO standard of 5 mg/l and to the NYSDEC instantaneous minimum DO standard of 4 mg/l. The data from the YSI sondes deployed at Buoys 409 and 316 showed that the 5 mg/l daily average DO standard was not met for over half of the days the sondes were deployed at the bottom depth and for about 10% of the days at the surface depth (**Figure 6-4**).

The counts of days during which sondes were in operation and the counts of days during which one or both of the DO standards were violated are summarized in **Table 6-2** below. These counts only includes days in which DO was measured for at least 12 hours within a day (down time occurred due to equipment issues and servicing).

Table 6-2. Summary of dissolved oxygen (DO) data collected by sondes**.**

Sonde Location	Operation (days) [(1)]	DO $\leq$ 5 mg/l (days) [(2)]	DO $\leq$ 4 mg/l (days) [(3)]
Buoy 409 (Top)	117	14	5
Buoy 409 (Bottom)	117	87	74
Buoy 316 (Top)	126	28	11
Buoy 316 (Bottom)	124	75	53

[(1)] *DO measured at least half of the time within one day*
[(2)] *NYSDEC minimum daily average DO standard*
[(3)] *NYSDEC instantaneous minimum DO standard*

6.4 ONEIDA RIVER WATER QUALITY CONDITIONS 2007

Water quality conditions in the Oneida River were monitored at Buoys 178 and 182 located upstream of the Oak Orchard STP and at Buoy 212 near Three Rivers Junction in 2007 (**Appendix 9**, **Figure A9-1**). Similar to the Seneca River, the low flow conditions in 2007 led to stratified water quality conditions in the Oneida River, as indicated by temperature data (~1.5^{o}C difference between top and bottom waters, **Appendix 9 Figure A9-11**). This section discusses the water quality conditions in the Oneida River for six selected parameters: DO, SRP, chlorophyll-*a*, NH3-N, NO2-N, and NO3-N monitored during the three 2007 surveys (**Figures 6-3a to 6-3c**). Spatial profiles of the entire suite of water quality constituents for all July, August and September river surveys can be found in **Appendix 9** (**Figures A9-2 to A9-11**).

In 2007 the SRP, chlorophyll-*a*, NH3-N, NO2-N, and NO3-N concentrations in the Oneida River were on average lower than those measured in the Seneca River, with the exception of SRP and chlorophyll-*a* during the July event, for which concentrations were similar (**Figures 6-3a to 6-3c**). As a result, the Oneida River contributed to the dilution of the Seneca River water quality parameter concentrations after the rivers join to form the Oswego River. Slight increases in SRP and nitrogen species in the Oneida River bottom waters between Buoy 182 and Three Rivers Junction were observed during the July and September events, while slight decreases were observed during the August survey. The increases in July and September may be associated with discharges from the Oak Orchard STP, as increases in chlorophyll-*a* concentrations over this stretch suggest that zebra mussel activity was not great.

In 2007 the differences in DO concentrations between surface and bottom waters within the Oneida River were less pronounced in the September survey than in the July and August surveys (**Figures 6-3a to 6-3c**). In all three surveys, the bottom DO concentrations decreased from upstream (Buoy 182) to downstream (Buoy 212), likely due to the discharge from the Oak

Orchard STP. The differences in chloride concentrations between Buoy 222 in the Seneca River and Buoy 212 in the Oneida River suggest that the Seneca River water had little impact on the water quality of the Oneida River (**Appendix 9 Figure A9-10**) on the days of sampling.

During the August survey of the Oneida River the NYSDEC instantaneous minimum DO standard of 4 mg/l was not met for the bottom water sample collected at Buoy 212, while no NO2-N and NH3-N violations were observed in the Oneida River during the 2007 surveys.

6.5 THREE RIVERS WATER QUALITY MODEL

The Three Rivers Water Quality Model (TRWQM) was developed by QEA, LLC to provide OCDWEP with a management tool to assist in decision making with respect to potential diversion of Metro effluent from the lake to the river (as required by the ACJ), the future development of Total Maximum Daily Loads (TMDLs) for oxygen demanding substances within the Seneca River, and permitting issues for the County's wastewater treatment plants that discharge to the system. This model was calibrated against water quality monitoring data collected between 1994 and 2000 and underwent a technical peer review in 2003 (**QEA, 2005**). TRWQM was applied to assist the County with assessing the water quality impacts of different TP effluent limits for Wetzel Road STP in 2005. In the future, the model is intended to be used to assist in TMDL development and in assessing the impact of the Oak Orchard STP discharge on the Oneida River.

As part of the current Onondaga Lake water quality modeling project (**QEA, 2006**), the TRWQM is being updated. These efforts include 1) an extension of the TRWQM calibration period through 2003 and 2) specification of boundary conditions at Onondaga Lake based on loadings predicted by the Onondaga Lake Water Quality Model (rather than the data-based approach used in the original TRWQM development), as recommended by the TRWQM peer review panel. The water quality data collected during the 2007 AMP survey, along with data collected between 2004 and 2006, will be used to perform a validation of the TRWQM in conjunction with validation of the lake model; over that same period. Both models' validation will be subject to a peer review, and together they will be used to assist with management decisions regarding potential diversion of effluent from the Metro plant, Total Maximum Daily Load (TMDL) allocations in the river and lake, as well as potential best management practices in the Onondaga Lake watershed.

6.6 REFERENCES

Quantitative Environmental Analysis, LLC, 2006. *Phase 1 Report: Modeling Work Plan -- Development of a Mechanistic Water Quality Model of Onondaga Lake*. Submitted to Onondaga County Department of Drainage and Sanitation. Syracuse, NY.

Quantitative Environmental Analysis, LLC, 2005. *Phase 2 Report – Three Rivers Water Quality Model.* Submitted to Onondaga County Department of Water Environment Protection. Syracuse, NY.

Quantitative Environmental Analysis, LLC, 2000. *Phase 1 Report – Water Quality Model of the Three Rivers System.* Submitted to Onondaga County Department of Drainage and Sanitation. Syracuse, NY.

CHAPTER 7: PROGRESS TOWARDS COMPLIANCE AND MEETING COMMUNITY GOALS FOR A REHABILITATED ECOSYSTEM

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CHAPTER 7. PROGRESS TOWARDS COMPLIANCE AND MEETING COMMUNITY GOALS FOR A REHABILITATED ECOSYSTEM

Each year, water quality and habitat conditions are reviewed in context of progress towards use attainment and compliance with ambient water quality standards. In this chapter, the 2007 data are compared with the metrics defined in Chapter 1 to assess progress toward use attainment and evaluate compliance with regulatory standards and/or guidelines.

7.1 Metrics for 2007

A series of metrics or indicators are used to summarize current conditions related to specific uses, as described in **Chapter 1**. These metrics share several specific properties: they relate directly to an impairment of the lake and watershed; they relate to a resource of interest; they correspond to a regulatory limit that, in turn, reflects the requirements of public health or the aquatic biota; and they can be measured and interpreted with relative ease. Indicators that help answer basic questions of the community – is the lake getting better, is it safe for my family to swim here, can we eat the fish – provide perspective on the benefits realized by the significant investment in lake rehabilitation.

Quantitative metrics are identified for four categories of use attainment:

(1) water contact recreation;

(2) aesthetics;

(3) aquatic life protection; and

(4) sustainable recreational fishery

Note that these categories describe human use of the resource as well as attributes of the ecosystem itself. These categories were defined to be consistent with public desires and regulatory determinations of use attainment.

Metrics for water contact recreation are straightforward: New York State Department of Health Sanitary Code, NYSDEC, and EPA have standards and guidance values for indicator bacteria and water clarity that are designed to be protective of human health and safety. Selecting metrics for aesthetics is slightly more judgmental, as they relate to perceived attributes such as water color and clarity, odors, and the visible extent of weed and algal growth.

Scientific information regarding how water quality conditions affect aquatic life is embodied in federal criteria and state standards. The metrics consider water quality conditions both throughout the year, and during critical periods for reproduction and early life stages. Also included are indices related to habitat quality for reproductive success of a warm-water fish community. Other indices related to recreational fishery include the number of nests and the presence and abundance of various life stages of warm-water fish. Evaluation of these metrics using the 2007 AMP data is presented in **Table 7-1**.

Table 7-1. 2007 Results from Onondaga Lake Water Quality and Habitat Metrics.

Issue: Water Contact Recreation		
Metrics (June 1 – September 30)	**Target**	**2007**
Percent of water clarity measurements > 4 ft (1.2 m); Class B stations	100%	83%
Percent of *E. coli* bacteria monthly geometric means* in compliance; Class B stations	100%	100%
Percent of fecal coliform bacteria monthly geometric means** in compliance; Class B stations	100%	100%
Metrics (April 1 through October 15)		
Percent of *E. coli* bacteria monthly geometric means* in compliance; Class B stations	100%	100%
Percent of fecal coliform bacteria monthly geometric means** in compliance; Class B stations	100%	100%
Issue: Aesthetics		
Metrics (June 1 – September 30)	**Target**	**2007**
Water clarity > 5 ft (1.5 m) at mid-lake station (South Deep)	100 %	70%
Algal abundance low in summer (chlorophyll-*a* < 15 µg/l in 85% of measurements)	>85%	91%
Lake is free of nuisance algal blooms 90% of time (nuisance algal bloom = chlorophyll-*a* > 30 µg/l)	>90 %	100%
Cyanobacterial abundance is low (< 10% of community biomass)	<10%	<1%
Issue: Aquatic Life Protection		
Metrics	**Target**	**2007**
Dissolved oxygen > 5 mg/l during turnover Oct 1-Dec 1 (daily average); > 4 mg/l (instantaneous minimum)	>5 mg/l; >4mg/l	7.99 mg/l; 7.82 mg/l
NH_3-N meets standards in 100% of measurements throughout the year	100%	100%
Nitrite meets standards in 100% of measurements throughout the year	100%	100%
Issue: Fish Reproduction		
Metrics	**Target**	**2007**
Reproduction of target species in the lake:		
• largemouth bass, smallmouth bass, and sunfish	• Occurring	• Occurring
• yellow perch	• Occurring	• No evidence
• black crappie	• Occurring	• No evidence
• rock bass	• Occurring	• No evidence
• walleye and northern pike	• Occurring	• No evidence
Percent intolerant or moderately intolerant species in Lake	>25%	8%
Percent macrophyte cover of littoral zone, based on optimal habitat for largemouth bass {percent based on aerial photograph interpretation}	40%	27%

Notes:
** The EPA criterion for E. coli for bathing beaches (126 cfu/100ml) is based on the geometric mean of a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period). Results from the Class B stations were compiled to calculate the monthly geometric means.*
*** §703.4 Water quality standards for coliforms - The monthly geometric mean, from a minimum of five examinations, shall not exceed 200 cfu/100ml during disinfection period Apr 1 to Oct 15. Results from the Class B stations were compiled to calculate the monthly geometric means.*

7.2 Water Quality Compliance Summary

Under the Amended Consent Judgment, the County is required to gather data on an adequate temporal and spatial scale to assess compliance with the applicable ambient water quality standards. These parameters are evaluated for compliance:

Tributaries

- pH
- Dissolved oxygen
- Indicator bacteria – fecal coliform bacteria
- Nitrogen – ammonia and nitrite
- Heavy metals (arsenic, cadmium, chromium, copper, cyanide, iron, lead, mercury, nickel, zinc)

Onondaga Lake

- pH
- Dissolved oxygen
- Dissolved solids
- Indicator bacteria – fecal coliform bacteria
- Nitrogen – ammonia and nitrite
- Heavy metals (arsenic, cadmium, chromium, copper, iron, lead, nickel, zinc, mercury)
- Phosphorus (guidance value)

7.2.1 Tributaries

Compliance of tributary waters with applicable ambient water quality standards is presented in **Table 7-2**. Water quality classifications of the tributaries are presented in **Chapter 1**. Of the eight tributaries assessed for compliance, the following were out of compliance for the parameters shown at some point during 2007:

East Flume	Trib 5A	Onondaga Creek	Ley Creek
pH	pH	nitrite	dissolved oxygen
dissolved oxygen	dissolved oxygen		cyanide
ammonia			
cyanide			
nitrite			

All eight of the tributaries were out of compliance at some point during 2007 with the ambient water quality standard for iron (300 mg/l) as well as the proposed standard (1000 mg/l). NYSDEC has recently proposed withdrawing the ambient water quality standard for iron in Class B and C waters.

Table 7-2. Compliance with ambient water quality standards, tributaries to Onondaga Lake, 2007

Parameter (units)	NYSDEC Standard (Class C)[1]			2007 measured concentrations[2]	Measurements in compliance
pH (standard units)	Shall not be less than 6.5 nor more than 8.5	NM :		7.58 - 8.04	100%
		OC :		6.97 - 8.10	100%
		LC :		6.78 - 7.98	100%
		HB :		7.12 - 8.25	100%
		5A :		7.47 - 8.52	96%
		EF :		7.35 - 8.89	77%
		BB :		7.70 - 7.85	100%
		SM :		7.60 - 7.72	100%
Dissolved Oxygen [3] (mg/l)	Minimum daily average 5.0 mg/l, at no time shall DO be < 4.0 mg/l	NM :		8.2 - 17.2	100% >4; 100% >5
		OC :		7.9 - 16.8	100% >4; 100% >5
		LC :		4.9 - 14.1	100% >4; 92% >5
		HB :		7.2 - 17.7	100% >4; 100% >5
		5A :		2.8 - 11.1	85% >4; 65% >5
		EF :		3.4 - 22.9	96% >4; 96% >5
		BB :		11.1 - 14.7	100% >4; 100% >5
		SM :		9.6 - 13	100% >4; 100% >5
Fecal Coliform [4] (cfu/100 ml)	The monthly geometric mean of a minimum of five measurements not to exceed 200 cfu/100 ml.	NM :		10 - 2100	Not assessed, minimum sample number not met
		OC :		2 - 5600	
		LC :		100 - 5100	
		HB :		10 - 60000	
		5A :	<	5 - 7100	
		EF :		10 - 5800	
		BB :		82 - 900	
		SM :	<	10 - 380	
Ammonia-N (mg/l)	Varies with pH and temperature.	NM :	<	0.03 - 0.6	100%
		OC :	<	0.03 - 0.16	100%
		LC :		0.09 - 0.58	100%
		HB :	<	0.03 - 0.24	100%
		5A :		0.1 - 0.33	100%
		EF :		0.04 - 1.28	77%
		BB :	<	0.03 - 0.12	100%
		SM :	<	0.03 - 0.17	100%
Arsenic [5,6] (µg/l)	150 µg/l	NM :	<	2 - 2.7	100%
		OC :	<	2.0	100%
		LC :	<	2 - 2.8	100%
		HB :	<	2.0	100%
		5A :	<	2 - 2.6	100%
		EF :	<	2 - 3.2	100%
		BB :	<	2.0	100%
		SM :	<	2.0	100%

Table 7-2. Compliance with ambient water quality standards, tributaries to Onondaga Lake, 2007 (continued).

Parameter (units)	NYSDEC Standard (Class C)[1]	2007 measured concentrations[2]			Measurements in compliance
Cyanide [6] (µg/l)	5.2 µg/l (Free CN)	NM :	<	3.0	100%
		OC :	<	3.0	100%
		LC :	<	3.0 - 17.0	75%
		HB :	<	3.0	100%
		5A :	<	3.0 - 5.0	100%
		EF :	<	3.0 - 7.0	50%
		BB :	<	3.0	100%
		SM :	<	3.0	100%
Nitrite-N (µg/l)	100 µg/l (Warm water fishery)	NM :	<	10 - 80	100%
		OC :	<	10 - 180	96%
		LC :	<	10 - 30	100%
		HB :	<	10 - 90	100%
		5A :		20 - 60	100%
		EF :		430 - 9,910	0%
		BB :	<	10 - 20	100%
		SM :		10 - 20	100%
Copper [6,8] (µg/l)	0.96 exp (0.8545 [ln (ppm hardness)] - 1.702)				
	Standard Range (µg/l):				
	NM : 36 - 71	NM :	<	3.1 - 7.4	100%
	OC : 21 - 42	OC :	<	3.1 - 10.0	100%
	LC : 27 - 37	LC :	<	3.1 - 4.1	100%
	HB : 47 - 69	HB :	<	3.1 - 4.3	100%
	5A : 26 - 33	5A :		9.8 - 18.8	100%
	EF : 29 - 31	EF :	<	3.1	100%
	BB : 16 - 37	BB :	<	3.1 - 12.5	100%
	SM : 15 - 24	SM :	<	3.1 - 4.0	100%
Mercury [6,7] (µg/l)	0.0007 µg/l	NM :	<	0.020	*See note*
		OC :	<	0.020	
		LC :	<	0.020	
		HB :	<	0.020	
		5A :	<	0.020 - 0.023	
		EF :		0.035 - 0.105	
		BB :	<	0.020	
		SM :	<	0.020	
Lead [6,8] (µg/l)	(1.46203 - [ln (hardness) 0.145712]) exp (1.273 [ln (hardness)] - 4.297)				
	Standard Range (µg/l):				
	NM : 21 - 46	NM :	<	2.0 - 2.1	100%
	OC : 11 - 25	OC :	<	2.0 - 3.6	100%
	LC : 15 - 22	LC :	<	2.0 - 4.3	100%
	HB : 29 - 45	HB :	<	2.0	100%
	5A : 14 - 19	5A :	<	2.0 - 4.8	100%
	EF : 16 - 18	EF :	<	2.0	100%
	BB : 8 - 21	BB :	<	2.0 - 3.9	100%
	SM : 8 - 13	SM :	<	2.0	100%

Table 7-2. Compliance with ambient water quality standards, tributaries to Onondaga Lake, 2007 (continued)

Parameter (units)	NYSDEC Standard (Class C)[1]	2007 measured concentrations[2]			Measurements in compliance
Cadmium [6,8]	0.85 exp (0.7852 [ln (ppm hardness)] - 2.715)				
(µg/l)	Standard Range (µg/l):				
	NM : 8 - 14	NM :	<	0.80	100%
	OC : 5 - 9	OC :	<	0.80	100%
	LC : 6 - 8	LC :	<	0.80	100%
	HB : 10 - 14	HB :	<	0.80	100%
	5A : 5 - 7	5A :	<	0.80	100%
	EF : 6 - 7	EF :	<	0.80	100%
	BB : 4 - 8	BB :		1.0 - 2.1	100%
	SM : 3 - 5	SM :	<	0.80	100%
Zinc [6,8]	exp (0.85 [ln (ppm hardness)] + 0.50)				
(µg/l)	Standard Range (µg/l):				
	NM : 331 - 648	NM :	<	6.3 - 9.1	100%
	OC : 190 - 380	OC :	<	6.3 - 11.6	100%
	LC : 250 - 339	LC :		11.5 - 15.3	100%
	HB : 430 - 634	HB :	<	6.3 - 15.7	100%
	5A : 235 - 301	5A :		6.3 - 9.5	100%
	EF : 267 - 285	EF :		7.1 - 28.3	100%
	BB : 150 - 334	BB :		13.7 - 39.8	100%
	SM : 143 - 218	SM :	<	6.3 - 19.4	100%
Chromium [6,8]	0.86 exp (0.819 [ln (ppm hardness)] + 0.6848)				
(µg/l)	Standard Range (µg/l):				
	NM : 282 - 539	NM :	<	2.5	100%
	OC : 165 - 322	OC :	<	2.5	100%
	LC : 215 - 289	LC :	<	2.5	100%
	HB : 363 - 528	HB :	<	2.5	100%
	5A : 203 - 257	5A :		9.2 - 32.8	100%
	EF : 230 - 245	EF :	<	2.5	100%
	BB : 131 - 285	BB :	<	2.5	100%
	SM : 125 - 189	SM :	<	2.5	100%
Iron	300 µg/l	NM :		253 – 5,420	4% <300
(µg/l)	(proposed for deletion)	OC :		192 – 19,800	19% <300
		LC :		512 – 2,470	0% <300
		HB :	<	50 – 19,200	73% <300
		5A :		322 – 3,420	0% <300
		EF :		62 – 5,940	81% <300
		BB :		468 – 1,450	0% <300
		SM :		472 – 1,140	0% <300

Table 7-2. Compliance with ambient water quality standards, tributaries to Onondaga Lake, 2007 (continued)

Parameter (units)	NYSDEC Standard (Class C)[1]	2007 measured concentrations[2]	Measurements in compliance
Nickel [6,8]	0.997 exp (0.846 [ln (ppm hardness)] + 0.0584)		
(µg/l)	Standard Range (µg/l):		
	NM : 207 - 368	NM : < 3.8	100%
	OC : 119 - 237	OC : < 3.8	100%
	LC : 157 - 205	LC : < 3.8	100%
	HB : 268 - 395	HB : < 3.8	100%
	5A : 147 - 188	5A : 59.8 - 118.0	100%
	EF : 168 - 179	EF : < 3.8	100%
	BB : 94 - 209	BB : < 3.8	100%
	SM : 90 - 137	SM : < 3.8 - 3.9	100%

Notes:

[1] 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.

[2] 2007 data are reported for each tributary. Samples were obtained at several sites on certain streams. Tributary abbreviations:

NM = Ninemile Creek at Lakeland Route 48, OC = Onondaga Creek at Kirkpatrick Street and Dorwin Avenue;

LC = Ley Creek at Park Street; HB = Harbor Brook at Velasko Road and Hiawatha Boulevard;

HB(H) = Harbor Brook at Hiawatha Boulevard; HB(V) = Harbor Brook at Velasko Road; 5A = Tributary 5A;

EF = East Flume; BB = Bloody Brook at Onondaga Lake Parkway; SM = Sawmill Creek at Onondaga Lake Recreation Trail

Unless otherwise noted, measured concentrations shown reflect the range from minimum to maximum for samples collected throughout the year. Where a single value is shown with a "<" beside it, results did not exceed the minimal reportable limit.

[3] Dissolved oxygen concentrations shown represent the results for individual samples for the period of measurement.

[4] Fecal coliform bacteria compliance in tributaries is not assessed. There are generally fewer than five samples collected at each location each month, therefore the geometric mean standard (which requires a minimum of 5 samples) cannot be applied.

[5] 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.

[6] 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.

[7] Mercury limit of detection 0.02 µg/l. Many results were below the laboratory's minimum reporting limit. Compliance cannot be evaluated on results reported as < MRL.

[8] The actual values for sample hardness were used to calculate compliance. Federal criteria for metals cap the hardness at 400 mg/l. 2007 average hardness for tributaries (calculated from database; units ppm):

NM - 756	OC - 369	LC - 425	HB - 799
5A - 398	EF - 399	BB - 350	SM - 243

7.2.2 Onondaga Lake

Compliance of Onondaga Lake's upper and lower waters with applicable ambient water quality standards is summarized in **Table 7-3**. Onondaga Lake is classified as B and C waters, as described in **Chapter 1.** The following parameters were out of compliance in South Deep some of the time in 2007:

Upper waters (UML)	Lower waters (LWL)
dissolved solids	dissolved oxygen
	dissolved solids
	nitrite-N

The NYSDEC standard for fecal coliform bacteria is defined as "the monthly geometric mean, from a minimum of five examinations, shall not exceed 200 cfu/100ml." This standard applies during the period of disinfection, which occurs from April 1 to October 15. Taken together, the monthly geometric means of the monitoring stations within the Class B segment – Willow Bay, Maple Bay, Onondaga Lake Park, Bloody Brook, North Deep, and Wastebeds – met this standard for the monitoring period May 3 to September 25; there were no samples collected at the nearshore stations in April or October.

Ammonia-N levels were consistently within compliance throughout the water column during 2007. Compared with past years, this represents the culmination of a gradual improvement at the South Deep monitoring station over time since 2000 (shading indicates less than 100% compliance):

Depth (m)	*Percent measurements in compliance, NYS standard*							
	2000	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*
0	86	95	68	96	100	100	100	100
3	90	90	68	96	100	100	100	100
6	90	95	73	100	100	100	100	100
9	90	95	73	100	100	100	100	100
12	90	81	50	80	100	100	100	100
15	57	52	41	56	80	100	100	100
18	52	38	32	48	75	95	95	100

This improvement is reflective of the water quality response to reductions in ammonia loading from Metro, specifically the BAF system that went on-line in 2004.

Nitrite-N concentrations in the upper waters consistently met the compliance standard for warm-water fishery in 2007, an improvement over previous years. In lower waters, nitrite-N concentrations occasionally exceeded the standard (81% compliance), consistent with percent compliance over the past 6 years which ranged from 40% to 91%.

The NYSDEC guidance value for total phosphorus (20 µg/l at 1 m depth, mid-lake sample, biweekly average from June 1 to September 30) was not met in 2007. However, the summer average value in 2007 was 25 µg/l– the lowest summer average concentration to date in Onondaga Lake and the narrative standard for phosphorus was met. The guidance value is assessed as a long-term average.

Table 7-3. Compliance with ambient water quality standards, Onondaga Lake, 2007

Parameter (units)	NYSDEC Standard (Class B&C)[1]		2007 measured concentrations[2]	Measurements in compliance
pH	Shall not be less than 6.5	UML:	7.4 - 8.2	100%
(standard units)	nor more than 8.5	LWL:	7.1 - 7.9	100%
Dissolved Oxygen [3]	Minimum daily average 5.0 mg/l, at no time	UML:	7.5 (Daily)	100% >5
(mg/l)	shall DO be < 4.0 mg/l		6.7 (15-min.)	100% >4
	(15-min buoy data, 2m and 12m depths)	LWL:	0 (Daily)	45% >5
			0 (15-min.)	47% >4
Dissolved Solids	Shall be kept as low as practicable to	UML:	897 - 1314	0%
(mg/l)	maintain the best usage of waters but in no	LWL:	950 - 1473	0%
	case shall it exceed 500 mg/l			
Fecal Coliform [4]	The monthly geometric mean, from a minimum	0 m - Apr:	N = 2	100%
(cfu/100ml)	of five examinations, shall not exceed	May:	8 (5)	
	200 cfu/100ml during disinfection period	Jun:	33 (7)	
	Apr 1 to Oct 15.	Jul:	11 (5)	
		Aug:	9 (7)	
	showing monthly geometric mean with number	Sep:	N = 4	
	of measurements used in geometric mean.	Oct:	N = 1	
		Nearshore (Class B five stations) - Apr:	no data	100%
		May:	5 (24)	
		Jun:	18 (31)	
		Jul:	8 (25)	
		Aug:	6 (35)	
		Sep:	7 (20)	
		Oct:	no data	
Ammonia-N	Standard varies with pH and temperature	0 m:	0.04 - 0.04	100%
(mg/l)		3 m:	< 0.03 - 0.45	100%
		6 m:	0.06 - 0.43	100%
		9m:	0.03 - 0.46	100%
		12 m:	0.1 - 0.76	100%
		15 m:	0.29 - 1.34	100%
		18 m:	0.34 - 1.74	100%
Arsenic [5,6]	150 µg/l	UML:	< 2.0	100%
(µg/l)		LWL:	< 2.0	100%
Nitrite-N	100 µg/l (warm-water fishery)	UML:	20 - 60	100%
(µg/l)		LWL:	< 10 - 240	81%
Copper [6,7]	0.96 exp (0.8545 [ln (ppm hardness)] - 1.702)	UML:	< 2.0	100%
(µg/l)	Standard Range (µg/l): 30 - 33	LWL:	< 2.0	100%
Lead [6,7]	(1.46203 - [ln (hardness) 0.145712]) exp (1.273 [ln (hardness)] - 4.297)			
(µg/l)	Standard Range (µg/l): 17 - 19	UML:	< 2.0 - 3.6	100%
		LWL:	< 2.0	100%

Table 7-3. Compliance with ambient water quality standards, Onondaga Lake, 2007 (continued).

Parameter (units)	NYSDEC Standard (Class B&C)[1]	2007 measured concentrations[2]	Measurements in compliance
Cadmium [6,7] (μg/l)	0.85 exp (0.7852 [ln (ppm hardness)] - 2.715) Standard Range (μg/l): 6.3 - 6.9	UML: < 0.80 LWL: < 0.80	100% 100%
Zinc [6,7] (μg/l)	exp (0.85 [ln (ppm hardness)] + 0.50) Standard Range (μg/l): 272 - 303	UML: < 6.3 - 7.5 LWL: < 6.3	100% 100%
Chromium [6,7] (μg/l)	0.86 exp (0.819 [ln (ppm hardness)] + 1.561) Standard Range (μg/l): 234 - 259	UML: < 2.5 LWL: < 2.5	100% 100%
Iron (μg/l)	300 μg/l (proposed for deletion)	UML: < 50 - 213 LWL: < 50 - 229	100% <300 100% <300
Nickel [6,7] (μg/l)	0.997 exp (0.846 [ln (ppm hardness)] + 0.0584) Standard Range (μg/l): 171 - 189	UML: < 3.8 - 4.2 LWL: < 3.8	100% 100%
Total Phosphorus[8] (μg/l)	(narrative standard) None in amounts that will result in growths of algae, weeds, and slimes that will impair the waters for their best usages. (Guidance value) 20 μg/l summer average. *1 m, biweekly, June 1 – Sept 30 average*	1 m: 25	

Notes:

[1] 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.

[2] South Deep sample locations: UML = upper mixed layer; LWL = lower water layer; m = meters depth of a sample. Nearshore sample locations: Metro = mid-south near Metro/Outfall; Ley Crk = near mouth of Ley Creek; Bloody Brk = near mouth of Bloody Brook; Onondaga Lake Park = east side; Willow Bay = Willow Bay; Maple Bay = Maple Bay; Ninemile Crk = Ninemile Creek; Wastebeds = near Wastebeds on west side; Harbor Brk = Harbor Brook. Unless otherwise noted, measured concentrations shown reflect the range from minimum to maximum for samples collected throughout the year. Where a single value is shown with a "<" beside it, results did not exceed the minimal reportable limit.

[3] Dissolved oxygen concentrations shown represent the minimum daily average ("daily") and the instantaneous reading ("15 min") for the period of measurement throughout the year.

[4] Fecal coliform compliance was assessed as the geometric mean of a minimum of 5 samples a month during the period of disinfection from April 1 to October 15. NYCRR Part 895. Class B monitoring stations include North Deep, Bloody Brook, Onondaga Lake Park, Willow Bay, Maple Bay and Westside Wastebeds.

[5] Standard applies to dissolved fraction, though currently only acid soluble, total recoverable fraction is measured within the monitoring program. Standards for all other metals apply to acid soluble, total recoverable fraction.

[6] 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.

[7] Actual sample results for hardness were used to calculate compliance. Federal criteria for metals cap the hardness at 400 mg/l. 2007 average hardness for Onondaga Lake South Deep was 439 ppm.

[8] Guidance value of 20 ug/l from New York State Ambient Water Quality Standards and Guidance Values, June, 1998. TOGS 1.1.1.

PART TWO:

CHAPTER 8: MASS BALANCES AND EMPIRICAL EUTROPHICATION MODEL UPDATE

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CHAPTER 8. MASS BALANCES AND EMPIRICAL EUTROPHICATION MODEL UPDATE

8.1 INTRODUCTION

The development and structure of a mass-balance modeling framework for Onondaga Lake is described in previous lake monitoring reports (EcoLogic et al., 2006). The framework 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 since 1986. Results provide a basis for:

1. Estimating the magnitude and precision of loads from each source;
2. Assessing long-term trends in load and inflow concentration from each source and source category (point, non-point, total);
3. Evaluating the adequacy of the monitoring program, based upon the precision of loads computed from concentration and flow data;
4. Developing and periodic updating of an empirical nutrient loading model that predicts eutrophication-related water quality conditions (as measured by nutrient concentrations, chlorophyll-a, algal bloom frequency, transparency, and hypolimnetic oxygen depletion) as a function of yearly nutrient loads, inflows, and lake morphometry (EcoLogic et al, 2006).
5. Developing simple input/output models for other constituents; and
6. Developing data summaries to support integration and interpretation of monitoring results in each yearly AMP report.

This chapter updates the mass-balance framework to include data through 2007. Computations are linked directly to the AMP long-term water quality and hydrologic database (**Figure 8-1**). Recent mass balances for key water quality components are summarized. Long-term trends in total loads (point, non-point), inflow concentrations, and outflow concentrations are documented using revised statistical methods.

With improvements to the monitoring program made since initiation of the AMP in 1999, the accuracy and precision of the load estimates and power for detecting trends has steadily improved. In this update, nine out of the ten years in the base period typically used to evaluate recent trends (1998-2007) reflect AMP improvements.

With implementation of point-source phosphorus controls, non-point loads have become increasingly important as factors driving eutrophication-related water quality in the Lake. A separate section analyzes spatial and year-to-year variations in non-point loads of phosphorus and other constituents from the Lake tributaries, as they relate to land use and rainfall.

As discussed in the previous annual report (EcoLogic et al, 2007), the steady increase in precipitation over the past decade significantly complicates the interpretation of apparent trends in the tributary loading data. Since annual runoff and non-point source loads are correlated with precipitation, any decreases in long-term-average loads or improvements in lake water quality resulting from the control program would have been at least partially masked by increases in non-point load attributed to rainfall. Potential refinements in the trend analysis methodology to account for variations in rainfall are explored. These include using a longer period of record (vs. ten years) and statistical adjustment to remove rain-driven variations. The apparent decreasing trend in non-point total phosphorus load identified in the 2006 report (3.1 ± 1.2 % per year over 1990-2006) is further explored by applying the revised methods to data for other constituents and from individual tributaries. While the trend analysis is complicated by the increasing trend in rainfall, analysis of data from 1998-2007 indicates a significant decreasing trend in the combined phosphorus load from urban watersheds, an increasing trend in load from the lower subwatershed of Harbor Brook, but no trend in the combined non-point load from all tributaries.

The report updates the empirical eutrophication model that was initially developed based upon data thru 1999 (EcoLogic, 2001) and subsequently updated to include data through 2000 (EcoLogic et al, 2001) and 2005 (EcoLogic et al, 2006). Phosphorus and nitrogen balances are linked to empirical models for predicting eutrophication-related water quality variables (chlorophyll-a, transparency, organic nitrogen, oxygen depletion). Models for predicting the frequency of algal blooms (daily chlorophyll-a concentrations > 15 or 30 ppb) as a function of seasonal average chlorophyll-a concentration are recalibrated for use in the empirical model framework, as well as in the detailed mechanistic lake model being developed by QEA et al (2006) for OCDWEP. This linkage provides a basis for predicting the responses of summer-average lake concentrations and algal bloom frequencies to reductions in external phosphorus loads potentially resulting from future implementation of point-source and non-point-source control measures.

As further reductions in phosphorus loads from METRO were accomplished in 2006-2007 to achieve an average annual inflow concentration of 0.12 ppm, lake phosphorus concentrations decreased and algal productivity became increasingly phosphorus-limited (**Figure 8-2**). While declining trends in mixed-layer and hypolimnetic phosphorus concentrations indicate that the Lake had not fully responded to the recent load reductions and further reductions in non-point loads are planned, Lake water quality conditions in 2006-2007 were substantially closer to those likely to result from full implementation of planned control measures, as compared with at and before the beginning of the AMP. Adding data from these two years to the calibration dataset substantially improves the accuracy and precision of the model for use in evaluating the ultimate assimilative capacity and evaluating further control measures to achieve water quality goals. Further analysis of magnitudes and trends in non-point source loads also provides as improved basis for evaluating the load reductions potentially resulting from BMP’s and CSO controls.

8.2 HYDROLOGY

Yearly variations in precipitation and lake inflow volume are summarized in **Figure 8-3**. Over the 1990-2007 period, yearly runoff from the Onondaga Lake watershed varied from 31 to 75 cm and was strongly correlated with precipitation (r = 0.91). Runoff and precipitation were slightly above average in 2007. Runoff was 60 cm, as compared with the 18-year mean of 53 cm. Precipitation was 106 cm, as compared with a mean of 99 cm. Precipitation gradually increased from ~80 to ~110 cm/yr while runoff increased from ~30 to ~60 cm/yr over the 1998-2007 period. As discussed below, this complicates the interpretation of apparent trends in loading.

8.3 MASS BALANCES

Historical variations in the mass balances of primary water quality components over the 1990-2006 period are summarized in the following figures:

- **Figure 8-4** Total Inflow and Outflow Concentrations
- **Figure 8-5** Total Inflow and Outflow Loads
- **Figure 8-6** Total Non-point and Total Metro Loads

The time series start in 1990 because that was the first year in which total phosphorus measurements were made in the lake tributaries.

The following tables describe lake mass balances for various constituents in the most recent 5-year period (2003-2007), as provided in previous annual reports:

- **Table 8-1** Chloride
- **Table 8-2** Total Phosphorus
- **Table 8-3** Soluble Reactive Phosphorus
- **Table 8-4** Total Nitrogen
- **Table 8-5** Ammonia Nitrogen

Since chloride is expected to be conservative, the chloride balance provides a basis for testing the accuracy and completeness of the data and methods used to develop the mass balances. Outflow loads computed from 12-foot outlet samples considered most representative of net discharge from the Lake exceeded inflow loads by 3.6% ± 2.1% in 2003-2007 (**Table 8-1**). This compares with 5.7 ± 2.1% in the previous 5-year interval and 0.4 ± 3.4% in last 2 years 2006-2007. An apparent increasing trend in the chloride load from the lower portion of Onondaga Creek (between the Dorwin and Kirkpatrick monitoring sites) may be responsible for the gradual convergence of the chloride balance, although the loading trend analysis is uncertain because of increases in precipitation (see below). In 2003-2007, the chloride load to this reach accounted for 34% of the total load to the Lake (**Table 8-1**). Chloride export from this subwatershed averaged 1,237 mt/km^2-yr, as compared with 144 mt/km^2-yr for all other subwatersheds combined. Trends in the sodium balance are similar (**Figure 8-5**). Salt springs enter the lower reach of Onondaga Creek between the Dorwin and Kirkpatrick sites (Kappel, 2003). Increases in road salt contributions associated with increasing precipitation may also contribute to increasing chloride and sodium loads.

As a consequence of treatment improvements, annual total phosphorus concentrations in the Metro discharge varied from 0.12 to 0.54 ppm in the 5-year mass balance period, but averaged 0.12 ppm in both 2006 and 2007. Supplemental total phosphorus balances for 2006-2007 and 1998-2007 are listed in **Tables 8-6** and **8-7**, respectively. The former is representative of point-source loads reflecting the current Metro treatment level. The latter reflects a wider range of precipitation and runoff concentrations that would be representative of average non-point loads in the past 10 years. That period is used below as a baseline for evaluating load reduction scenarios using the phosphorus mass-balance. Total phosphorus balances for each period are summarized below:

TP Load (metric tons / yr)	1998-2007	2006-2007	1998-2007*
Total Non-point	26.4	29.3	26.4
Industrial	0.4	0.2	0.2
Metro Discharge (Outfall 1)	27.5	10.7	10.7
Metro Bypass (Outfall 2)	2.3	1.5	1.5
Total	56.8	42.0	38.8

The 2006-2007 non-point load was above the 1998-2007 average because of high precipitation (**Figure 8-3**). The third column above (*) combines 1998-2007 non-point with 2006-2007 Metro and industrial loads. This is representative of the long-term average loads with the existing Metro treatment capabilities. The combined Metro discharge accounted for 31% of the total load, as compared with 52% in 1998-2007.

8.4 NON-POINT SOURCES

With non-point sources currently accounting for ~69% of the long-term average phosphorus load to the Lake, implementation of non-point source controls will be important to achieving further load reductions and improvements in Lake water quality. Spatial variations in runoff and non-point phosphorus loads from each subwatershed are shown in **Figure 8-7**. These results are based upon water and phosphorus balances for 1998-2007 listed in **Table 8-7**. Comparisons are made across subwatersheds with respect to drainage area, total flow, load, concentration, runoff (flow per unit watershed area), and export (load per unit watershed area).

As described in the previous annual report (EcoLogic et al, 2007), mass balances have been expanded to reflect runoff and non-point loads from different subwatersheds. Paired monitoring sites on Harbor Brook (upstream = Velasko, downstream = Hiawatha) and Onondaga Creek (upstream = Dorwin, downstream = Kirkpatrick) provide a basis for partitioning the load from each tributary into two components (Upper vs. Lower subwatersheds). In each case, the Upper subwatershed is generally representative of rural (undeveloped, agricultural) land uses, while the Lower subwatershed is generally representative of urban land uses. Similarly, the Ninemile Creek watershed is primarily rural and the Ley Creek watershed is primarily urban.

Total flows and loads from the Upper (~Rural) and Lower (~Urban) watersheds are included in the mass balance tables. A third category ("Net Urban") reflects the estimated Lower watershed contribution above that expected if the unit area export coefficient were equal to that measured in the Upper watershed (i.e. rural background load). The net load is estimated by applying the export coefficient (load per unit) from the Upper watersheds (total = 554 km^2) to the drainage area of the Lower basins (126 km^2). The net load from the Lower basins is thus computed as the measured load minus 0.23 times the measured load from the Upper basins. The same algorithm is used to compute subwatershed runoff volume.

The upper/rural and lower/urban watershed categories are also considered in the trend analyses described below. The lower watershed load estimates are less precise because they are computed by difference and thus reflect uncertainty in loads measured at both the upstream and downstream monitoring sites. The partitioning of Onondaga Creek is approximate because loads at the downstream site are computed from concentrations measured at Kirkpatrick Street and flows measured at Spencer Street since 1998. While the rural vs. urban classifications are simplifications because each subwatershed contains a mix of land uses, the framework provides approximate estimates of the total and net contributions from the urban watersheds that would potentially benefit from implementation of CSO and urban runoff controls in the lower watersheds. This information is useful for evaluating potential benefits of and responses to BMPs and CSO controls implemented in various locations.

As shown in **Figure 8-7**, runoff from individual subwatersheds varied from 20 to 68 cm/yr. Phosphorus export rate from the three urban watersheds averaged 60 kg/km^2-yr and ranged from 54 to 115 kg/km^2-yr, as compared with a mean of 31 kg/km^2-yr and range of 15 to 27 kg/km^2-yr for the rural watersheds. Considering the mix of land uses in each category, these export coefficients are reasonably consistent with values estimated for the Oneida Lake watershed by the EcoLogic (2007): 7 to 28 kg/km^2-yr for undeveloped areas, 40 to 70 kg/km^2-yr for medium-high density urban areas, 45 kg/km^2-yr for pasture, and 210 kg/km^2-yr for cropland. They are also similar to values tabulated by Coon and Reddy (2008). Similarly, the Onondaga Lake urban watersheds had higher runoff concentrations (mean = 98 ppb, range = 65–571 ppb), as compared with rural watersheds (mean = 60 ppb, range = 43–65 ppb). Overall, urban watersheds accounted for 29% of the total non-point load, rural watersheds accounted for 65%, and ungauged areas accounted for 6%. The net phosphorus load from the lower/urban watersheds (above rural background) accounted for 14% of the total non-point load.

Each of the three urban watersheds (Ley, lower Harbor, lower Onondaga) contributed equally to the total load (3.4-3.6 mt/yr), even though the lower Harbor watershed is about half the size of the others. Further investigation of potential causes for the unusually high P export from the lower Harbor watershed is recommended, particularly given the apparent increasing trend in load described below (**Table 8-10**, **Figure 8-10**). Similar non-point source breakdowns for other water quality components are listed in **Table 8-8**. In most cases, export coefficients are higher for the lower/urban watersheds. Excess fertilizer in agricultural runoff probably accounts for the similar rural and urban export coefficients for total and nitrate nitrogen.

8.5 TRENDS IN PHOSPHORUS

Data from the most recent ten-year period have typically been used to test AMP hypotheses regarding decreases in load or concentration resulting from implementation of control measures. As discussed above and in the previous annual report (EcoLogic et al, 2007), the increase in precipitation over the 1998-2007 period significantly complicates causal interpretation of trends in the tributary loading data (**Figure 8-3**). Precipitation and year are highly correlated in this period (r = 0.78). Similarly, total runoff and non-point load are each correlated with precipitation (r = 0.84 and r = 0.75), as well as with year (r = 0.74 and r = 0.58, respectively). Any decreases in long-term-average loads or improvements in lake water quality resulting from the control program could have been partially masked by increases in non-point load attributed to rainfall. As a consequence, tests of AMP hypotheses regarding load reductions and lake improvements over the1998-2007 period are weak and likely to be conservative; i.e. any improving trends might have been more pronounced had there not been an increasing trend in precipitation over this period. Power for detecting trends is improved by considering a longer base period (1990-2007) that includes precipitation cycles (**Figure 8-3**). Rainfall and year are less correlated over this period (r = 0.02), as compared with 1998-2007 (r = 0.78). One disadvantage of using a longer time frame is that apparent trends may vary within the 18-year period. Improvements in the monitoring program made over this period could also impact the trend analysis. As demonstrated in the previous annual report (EcoLogic et al, 2007), the power for detecting trends can also be increased by statistical adjustment of the data to account for rain-driven variations (Hirsch et al, 1982; Walker, 2000). A decreasing trend in the rainfall-adjusted phosphorus non-point load (-3.1 ± 1.2%/yr) over the 1990-2006 period was identified in the previous annual report. Similar results are obtained when the same methodology is applied to the 1990-2007 data (**Figure 8-8**).

The 2007 data fall on 1990-2006 regression lines relating load to precipitation and adjusted load year. As recommended in the previous report, the trend and methodology are further explored below by analyzing data from individual sources, other constituents, and other time frames.

Figure 8-9 applies a slightly different methodology to total non-point runoff, phosphorus load, and flow-weighted mean concentration over the 1990-2007 period. A multiple regression model relating the logarithm of the observed value to year and precipitation is fit to each time series. For each variable, the trend hypothesis is tested by determining whether the regression coefficient for year is significantly different from zero ($p < 0.05$ for one-tailed hypothesis). The regression models explain 80% of the variance in runoff, 72% of the variance in load, and 56% of the variance in concentration. Each variable is positively correlated with rainfall. There is no apparent trend in runoff volume, but decreasing trends in total non-point load (-3.1 ± 1.1 %/yr) and concentration (-3.7 ±1.0 %/yr). One limitation of the methodology is that the trends are assumed to be linear. This has the effect of reducing the power of the test for detecting sudden reductions in load potentially resulting from implementation of a control measure at a specific date. This may not be a major limitation, however, because of the time scales required for BMP's to be implemented and become fully effective, both at the mouths of the tributaries and in the outflow from the Lake.

The same methodology is applied to 1990-2007 data from individual sources and the Lake outflow in **Table 8-9**. Adjusted load time series are shown in **Figure 8-10**. In each case, the trend hypothesis is tested with and without adjusting for precipitation using the equations given in **Figure 8-9**. Because there is no net trend in precipitation during this period, conclusions regarding the presence or absence of trends are relatively insensitive to precipitation adjustment, although adjustment increases the power of the trend hypothesis test by decreasing variability in the time series. With precipitation adjustment, results indicate slight (~1%/yr) decreasing trends in flow at Harbor Brook and Onondaga Creek sites and an 8%/yr decreasing trend in Trib5A flow. Reductions in non-point P load and concentrations are indicated for most point and non-point sources and for the lake outflow. In contrast, increasing trends in phosphorus load and concentration are indicated for the lower portion of Harbor Brook (between the Velasko and Hiawatha monitoring sites).

Trends in phosphorus load over the 1990-2007 period are expressed both in percent per year and in kilograms/year (**Table 8-9**). The latter reveals the extent to which trends in individual sources contribute to trends in the total non-point and overall loads. The apparent trend in total non-point load (-1,012 ± 373 kg/yr) accounts for 20% of the trend in total inflow load (-4,880 ± 732 kg/yr), which primarily reflects reductions in Metro load over the 1990-2007 period. No trends in load are indicated for Ninemile Creek and the upper portion of Onondaga Creek. Most of the apparent trends in non-point load are attributed to urban subwatersheds (Ley Creek and lower portion of Onondaga Creek). The apparent increasing trend in phosphorus load from the lower Harbor Brook watershed (43 ± 8 kg/yr) offsets a portion of the decreasing trend in load from all nonpoint sources combined (-1,012 ± 373 kg/yr).

The analysis of non-point phosphorus loads for 1990-2007 is repeated for 1998-2007 in **Figure 8-11** and **Table 8-10**. Because of the increasing trend in precipitation during this period (**Figure 8-3**), conclusions regarding the presence or absence of trends in load for individual sources are sensitive to precipitation adjustment. Without adjustment, increasing trends in flow are indicated for most of the mass balance terms (**Table 8-10**). This is likely to be a consequence of the increasing precipitation. With adjustment, increasing trends in flow are indicated only for the Harbor Brook sites and a decreasing trend is indicated for Trib5A. Similarly, adjustment for precipitation removes most of the apparent trends in load. Exceptions include a decrease in load from Trib5A and increase in load from Harbor Brook, both of which are consistent with corresponding decreasing trends in flow. A decreasing trend in the adjusted total load from all urban watersheds combined is also indicated (-6.0 ± 2.5 %/yr). Rainfall adjustment removes most of the apparent trends in concentration, with the exceptions of decreasing trends for the total inflow, Ley Creek, and the combined inflows from the urban watersheds.

Results suggest that most of the apparent decreasing trend in total non-point P load over the 1990-2007 period occurred prior to 1998. Even with adjustments for precipitation, however, trend analysis results for 1998-2007 are uncertain because the increasing trend in precipitation causes the model regression coefficients to be correlated. While a trend in the total non-point load is not indicated for 1998-2007, decreasing trends in phosphorus load (6%/yr) and concentration (7%/yr) are indicated for the combined inflows from the urban subwatersheds. Lower Harbor Brook exhibits increasing trends in flow and load, but no apparent trend in phosphorus concentration. No trends in phosphorus load or concentration are indicated for the upper/rural watersheds.

Despite the fact that the lowest inflow phosphorus loads and concentrations occurred in 2006-2007 with the Metro discharge concentration reduced to 0.12 ppm, significant (linear) trends in the Metro load, total lake inflow load, and outflow loads are not indicated for the 1998-2007 period. This reflects the fact that Metro loads peaked in 2003-2004 and was closely tracked in the lake outflow (**Figures 8-5** and **8-6**). This "blip" in the load time series makes it difficult to identify long-term declining trends in point source and total loads within the 1998-2007 interval.

As compared with loads, flow-weighted mean concentrations tend to be less variable and less correlated with rainfall. As a consequence, the likelihood of detecting a trend of a given magnitude is greater for concentration than for load. The long-term flow weighted-mean concentrations can be used as a surrogate for the long-term-average load if the flow regime is assumed to be stable. Results of Seasonal Kendall Tests applied to concentration data from individual monitoring sites should also be considered in evaluating trends in the tributaries. While they are not flow-weighted and also confounded with trends in precipitation, they are likely to be more powerful because they are based upon the individual samples (vs. annual flow-weighted means), do not assume a linear trend, and are more robust to outliers in the data. Results of these tests for 1998-2007 indicate decreasing trends in phosphorus concentration at the Lake outflow and Ley Creek sites and increasing trends at the Dorwin (upper Onondaga Creek) and Hiawatha (total Harbor Brook) sites. These results are reasonably consistent with the observed trends in rainfall-adjusted load and flow-weighted mean concentration. There also indications of increasing trends in the adjusted load and flow-weighted mean concentration at the Dorwin site in 1998-2007, although they are not strong enough to be statistically significant.

The correlation between rainfall and non-point P loads developed from 1998-2007 data (**Figure 8-11**) can be used as a baseline for evaluating future measured loads relative to a management goal. Suppose, for example, that a goal of reducing the long-term average non-point load by 20% relative to the 1998-2007 were established. The load vs. rainfall regression model can be used to develop a confidence interval for the measured load in any future year that would be consistent with achieving the goal, considering the precipitation in that year. Similar methods are used to measure BMP performance in Florida agricultural watersheds (Walker, 2000). As compared with testing for linear trends in load or flow-weighted concentration, comparison of data from each year with 10-year baseline values may be more useful for evaluating responses to future load reduction measures. Adjusting for precipitation in each year increases the power of such comparisons. This concept is recommended for further development in the AMP statistical framework and/or future yearly reports.

8.6 TRENDS IN OTHER CONSTITUENTS

Ten-year trends in load and concentration for other nutrient and inorganic constituents are listed in **Tables 8-11** and **8-12**, respectively. Results are shown with and without adjustment for precipitation using the multiple regression technique described above (**Figure 8-9**). **Table 8-13** lists adjusted trends in load expressed in mass units (i.e. kg/yr vs. %/yr). Shaded cells indicate tests that are potentially impacted by detection limits for Ammonia N and Nitrite N at two sites with relatively low concentrations (Velasko and Dorwin). Trend analyses for BOD-5, TSS, and SRP in the lake tributaries are not shown because they are also potentially impacted by variations in analytical methods and detection limits. Similar to the results for phosphorus, many of the apparent trends in load and concentration are removed when adjustments are made for precipitation. Results of the latter tests are discussed below. While the multiple regression technique increases the power of the tests for trends in the long-term means, all results are subject to uncertainty because the technique does not necessarily eliminate the confounding effect of the trend in precipitation over the 1998-2007 period. Addition of data from future drought years to the time series will provide a basis for distinguishing between trends and variations driven by precipitation.

Decreasing trends in load and concentration are indicated for nitrogen species (TKN, Ammonia N, Nitrite N) in the Metro discharge, total inflow, and total outflow. Decreasing trends in ammonia concentration and/or load are also indicated for all of the non-point inflows to the Lake. At sites with relatively low ammonia concentrations (Velasko, Dorwin), these trends are likely to be artifacts of the decrease in the ammonia detection limit from 0.1 to 0.03 ppb over this period. Since these data are used to compute the net loads from the lower subwatersheds of Harbor Brook and Onondaga Creek, those results are suspect also. Results for other sites with concentrations in a higher range would not be impacted by the decrease in detection limit.

Both with respect to concentration and load, increasing trends in sodium and chloride are indicated for the total inflow and for the inflow from each tributary except for Ninemile Creek. On a mass basis, the trend in load from the lower Onondaga Creek watershed accounts for most of the trend in the total inflow load (**Table 8-13**). Despite the apparent trends in inflow loads for sodium and chloride, no trends in outflow loads are indicated.

Increases in flow are indicated at each Harbor Brook site. These are associated with increases in loads of total phosphorus, total nitrogen, nitrate, inorganic species (alkalinity, calcium, chloride, sodium) at the Hiawatha site. Similarly, decreases in Trib5A loads reflect an apparent decrease in flow.

Apparent increasing trends in silica concentration and load in the Lake outflow are not paired with corresponding trends in the lake inflow. This may be an indirect consequence of reduced algal productivity in the Lake resulting from decreases in phosphorus load. If diatom growth were increasingly limited by phosphorus levels, silica uptake by diatoms and subsequent sedimentation would also to decrease. Increases in lake nitrate concentrations would also be expected from this mechanism, although masked in Onondaga Lake by the decreases in nitrogen loads.

8.7 EUTROPHICATION MODEL

8.7.1 Introduction

This section updates empirical eutrophication model framework described in previous reports (EcoLogic, 2001; EcoLogic et al 2001 and 2005). The model structure is depicted **Figure 8-12**. Following the protocol established in previous updates, the model is re-calibrated to data from the last 5 water years (2003-2007) and tested against data collected prior to that (1991-2002). While small adjustments are made to a few model coefficients in this update, the overall calibration is not significantly different that based upon 2001-2005 data (EcoLogic et al, 2006). Lake conditions in 2006-2007 are successfully simulated using the model structure and calibrations developed in the previous update.

Models of this type are widely used for eutrophication assessment because of their limited data requirements and demonstrated ability to predict eutrophication-related water quality components within defined error distributions (Canfield and Bachman, 1981; Reckhow and Chapra, 1983; Wilson and Walker, 1989; Walker, 2006). While all mechanisms controlling lake phosphorus and algal response are not directly considered, effects of simplifying assumptions in the model structure are embedded in the calibrated coefficients and error distributions. Quantification of the latter allows characterization of the uncertainty associated with model forecasts and which is particularly useful in a TMDL context (Walker 2001, 2003). While a-priori calibrations are typically based upon data from collections of lakes, site-specific calibration reduces the potential impacts of simplifying assumptions and improves the accuracy and precision of model forecasts.

The latter features depend on the extent to which future scenarios differ from conditions under which the model was calibrated and tested.

Compared with previous model updates, calibration conditions are much closer those expected when the ultimate water quality goals are attained. **Figure 8-2** shows TP concentrations in the upper (0 – 3 m) and lower (9 – 12 m) layers at the Lake South station between 1990 and 2007. Declining trends were especially evident in the bottom layer, where concentrations peaked in late summer and subsequently declined in fall as the thermocline eroded and bottom waters became entrained in the upper layer. Peak lower-layer TP concentrations were 40-80 ppb in 2006 -2007, as compared with 100-300 ppb in 1990-2005. In the summer of 2007, the upper-layer TP concentration ranged from 21 to 44 ppb, the lowest in the 1991-2007 period of record.

8.7.2 Data Set Development

Average total phosphorus and nitrogen for the calibration period (2003-2007) are listed in **Tables 8-2** and **8-4**, respectively. Yearly loads and observed lake data used in model calibration and testing are listed in **Table 8-14**. The model is driven by water and mass balances formulated on a water year basis (October 1–September 30). Daily loads and flows are extracted from the AMP long-term database and summarized on a water- year basis.

Average lake nutrient concentrations in each summer have been computed using June-September samples collected at the Lake South station between 0 and 3 meters. Summer means and standard errors have been computed from the time series of daily means; i.e., the data are averaged first across depths on each date, then across dates in each year. Seasonal dynamics in lake TP and chlorophyll-a concentrations have been considered in selecting an averaging period for the lake responses (i.e. the definition of "summer"). Seasonal variations in upper-layer phosphorus, chlorophyll-a, and transparency over the 1998-2007 period are plotted in **Figure 8-13**. TP concentrations generally tend to decline from April to June due to algal uptake and sedimentation, then increase in late September and October as the thermocline erodes and phosphorus in the enriched hypolimnion is transported to the upper layer (**Figure 8-2**). The previous model version was calibrated to trophic state indicator data collected between June and August. That averaging period was used to reflect the summer stratified period and limit effects of lake mixing events in early fall on the phosphorus calibration. The latter events cause TP increases that have relatively little impact on summer-average algal productivity. June-August also corresponded to the averaging period typically used to assess lake condition relative to the state's guidance value for Total P (20 ppb).

Subsequent to the previous model update, June-September was adopted under the AMP as the official averaging period for assessing lake conditions relative to long-term water quality goals (EcoLogic et al, 2007). Accordingly, the model calibration period has been changed to reflect that period. Extension of the averaging period from June-August to June-September has the advantage of capturing that portion of the growing season occurring in September, as evident in elevated chlorophyll-a and low transparency levels (**Figure 8-13**). While phosphorus increases in late September are evident in some years, these occurred prior to the substantial decreases in bottom P concentrations in 2006-2007 (**Figure 8-2**). One exception is the September 30, 2003 sampling event, which has been excluded from the calibration dataset because of turnover impacts evident in a lake P concentration about twice those measured in all previous events that year.

Chlorophyll-a concentrations are based upon photic zone samples (1999-2007), epilimnion composites (1993-1998), and 0-3 meter average grab samples (1991-1992). Based upon paired data from 1999-2005, photic zone chlorophyll-a data collected during in June-September exceeded epilimnetic composites by an average of 10.2%. This reflects that the fact that epilimnion composites often extended below the photic zone, where algal densities may have been lower. Accordingly, the 1993-1998 epilimnetic values have been increased by 10.2% for consistency with the 1999-2007 values. No adjustment has been to the 1991-1992 grab-sample chlorophyll-a data because there are no paired photic zone measurements.

Aerial hypolimnetic oxygen depletion rates have been computed from oxygen and temperature profiles collected at 0.5 or 1.0 meter increments, as extracted from the AMP long-term water quality database (**Figure 8-1**). The rate reflects oxygen consumption below the thermocline between the first sampling date with thermal stratification and the last date prior to development of anoxic conditions (hypolimnetic mean < 2 ppm). Rates could not be computed for 1993 and 1994 because profile data prior to the onset of anoxia were not available. The areal rate is computed as the product of the mean hypolimnetic depth and the decrease in volume-averaged concentration divided by the number of days between sampling events. Rates have been computed for three assumed average thermocline levels (6, 9, 12 m). Results for the 9-meter depth have been used for model testing.

8.7.3 Assumptions

This section examines key assumptions in the phosphorus balance model with respect to vertical gradients, horizontal gradients, seasonal variations, and year-to-year variations. While simplifying assumptions have desirable effects of reducing data requirements and the number of calibrated parameters, they create a risk of bias in model forecasts, particularly if the model is applied under conditions that are significantly different from those present during the model calibration and testing periods. To some extent, effects of deviations from assumptions are embedded in the calibrated coefficients and reflected in the defined error distributions. Diagnostic checks (residuals analysis) provide a basis for evaluating model biases related to simplifying assumptions. Parallel application of the detailed Lake model (QEA et al, 2006) in evaluating management alternatives will be useful for evaluating the robustness of management decisions to modeling approach.

The model does not attempt to simulate the substantial vertical gradients in the water column P concentration evident in **Figure 8-2**. It does not assume that the water column is well-mixed vertically, but that net sedimentation of phosphorus per unit area is proportional to the upper-layer TP concentration. This is consistent with the notion that P uptake by algae and subsequent sedimentation is a primary mechanism for P removal. Effects of vertical gradients and mixing between the upper and lower layers are minimized by calibrating to data from the stratified period. Residual effects are embedded in the calibrated parameters (settling rate and ratio of summer to annual flow-weighted mean outflow concentration) and in the error distributions characterized by model calibration and testing datasets.

Figure 8-14 shows TP and chloride time series at the Lake South (0 -3 m), Lake North (0-3m), and Outlet (3.7 m) sites. There is good agreement across these sites for each variable and year. This supports the model's assumption that horizontal variations in water quality are small relative to seasonal and year-to-year variations. The occasional negative divergence of the outlet chloride from the lake values may reflect intrusion events from the Seneca River that penetrate to lower depths at the outlet.

Total phosphorus loads from the tributaries and point sources are assumed to have the equal impacts on the summer mixed-layer TP concentrations. There are three mechanisms that could decrease the relative impacts of the tributary loads:

1. Density currents transporting saline tributary inflows (Onondaga and Ninemile Creeks) below the upper mixed layer.
2. Differences in bio-availability related to phosphorus speciation; and
3. Seasonal variations in the relative magnitude of tributary and point-source loads.

To the extent that these mechanisms are important, the model will tend to under-estimate lake sensitivity to reductions in point-source loads and over-estimate sensitivity to reductions in non-point loads. While only the SRP fraction is immediately available for algal uptake, portions if not most of the dissolved organic and particulate P loads are eventually made available through decomposition processes occurring in the water column and recycling from bottom sediments occurring over various time scales. Model residuals (**Figure 8-17**) are reasonably independent of phosphorus load speciation, the fraction of load attributed to the Metro discharges, and the seasonal distribution of loads. This suggests that net effects of these mechanisms are small relative to other sources of variability in the model residuals.

Salinities measured in the lake thermocline tend to be slightly elevated relative to surface and bottom layers during the summer. This is evidence of "plunging inflows" from creeks with elevated salinity (Onondaga and Ninemile) and subsequent transport through the Lake as density currents below the mixed layer. The phosphorus load associated with these flows in June-September when density currents are evident averaged 18% of the total annual non-point load and 8% of the total load to the Lake in 1998-2007. Lake vertical profiles show that the summer thermocline salinity bulge is typically 10% above surface and bottom values, whereas the inflowing creek salinities typically exceed the lake mixed layer values by 200% in Onondaga Creek and 100% in Ninemile Creek. Considerable dilution of the saline inflows apparently occurs as they enter the lake before the density currents develop. There are no indications of positive divergence in the outlet chloride concentrations relative to the mixed layer values which would be expected if a significant fraction of the saline inflows passed through the Lake without mixing into the upper per layer (**Figure 8-14**). Similarly, positive divergence of the lake outlet over the upper mixed layer values is not evident in sodium or conductivity data. While density currents are evident in the profundal zone, it is possible that they are destroyed when reaching the littoral zone at the northern end of the lake and recycled back into the lake surface waters instead of passing directly to through the outlet.

Declining trends in inflow (**Figure 8-5**), lake surface, and lake bottom concentrations (**Figure 8-2**) may influence the calibration of the phosphorus balance model, which assumes that the Lake is at steady state with respect to the inflow loads in any given year. Peak fall-overturn concentrations declined from ~0.3 to ~0.04 ppm between 1995 and 2007 (**Figure 8-2**) which corresponds to an average trend of -2.8 metric tons / year in the phosphorus stored in the lake, assuming a total lake volume (128 x106 m^3). This is approximately 5% of the average inflow load and 7% of the average outflow load over the same period. Corresponding percentages for 2007 alone were 13% and 21%, respectively. This indicates that the Lake was still responding to the sharp reductions in load that occurred over the 2006-2007 period. As a consequence of this, the steady-state model calibration is likely to be conservative; i.e. over-estimate the long-term average Lake P concentration likely to result from a given loading regime.

Depletion of surface SRP concentrations in the summer is a sign that algal productivity is limited by phosphorus, a key assumption in the model components predicting mean chlorophyll-a and related trophic state indicators. Summer SRP concentrations in the upper layer were frequently at or below detection in 1998-2007, with exception of 2004, when loads from Metro were high relative to the other years (**Figure 8-5**). **Figure 8-15** plots summer mean SRP vs. TP concentrations in each year. Analytical detection limits varied from 1 to 3 ppb over this period. To allow comparison across years, the SRP concentrations have been constrained to a minimum value of 3 ppb before computing the summer averages. In the last decade, SRP concentrations generally averaged 3 ppb or less in years when the TP concentration averaged less than 40 ppb.

8.7.4 Model Structure and Calibration

The model structure is depicted in **Figure 8-12**. Major components and calibrations to 2003-2007 data are summarized below:

- Yearly flow-weighted mean outflow TP and TN concentrations are predicted from inflow loads and flows using a simple first-order model that assumes that the net nutrient removal per unit area is proportional to the mean concentration in the upper mixed layer (Vollenweider, 1969; Chapra, 1975). The calibrated coefficients (“effective settling rates”) are 22.9 m/yr for TP and 15.9 m/yr for TN.
- Summer lake TP and TN concentrations are assumed to be fixed percentages of the yearly flow-weighted mean outflow concentrations. The calibrated percentages are 59% for phosphorus and 100% for nitrogen.
- Chlorophyll-a is predicted using the Jones and Bachman (1976) regression equation for phosphorus-limited lakes. As expected, the model over-predicts chlorophyll-a and related trophic state indicators in years prior to ~1998 when phosphorus concentrations were above growth-limiting levels. Convergence between the data and predictions occurred as TP and SRP concentrations decreased in the recent decade (**Figure 8-15**).
- Other trophic response variables (Secchi Depth, organic nitrogen, utilized phosphorus (TP - SRP), and HOD rates) are predicted from predicted chlorophyll-a using empirical models derived from other lake and reservoir datasets, as extracted from the BATHTUB model (Walker, 1985; 2006).

- Bloom frequencies (% of daily chlorophyll-a concentrations exceeding 15 or 30 ppb, adopted AMP metrics (EcoLogic et al, 2007), are computed from predicted mean chlorophyll-a concentrations using a log-normal frequency distribution model (Walker, 1984; 2006) and calibrated temporal coefficient of variation (**Figure 8-18**).
- Frequencies of Secchi Depths less than 1.5 meters and 1.2 meters (also adopted AMP metrics) are predicted using a log-normal frequency distribution and a calibrated temporal coefficient of variation (**Figure 8-19**).

Updated model equations coefficients and equations are listed in **Table 8-15**. Observed and predicted time series for primary variables in the model network are shown in **Figure 8-16**. Prediction intervals in **Figure 8-16** are based upon residual standard errors computed from 1998-2007 data. For each sub-model, the 10-year residual standard error is less than or equal to the error for the 5-year model calibration period. Therefore, the calibrations hold up when applied to data from different periods.

The phosphorus balance model calibrated to 2003-2007 data performs reasonably well when applied to data from previous years. The calibrated net settling rate (22.9 m/yr) compares with a range of 19.9 to 22.9 m/yr in previous model updates. Residual standard errors (11% for outflow P and 14% for Lake P) reflect the combined effects of factors not considered in the model structure and uncertainty in the data related to limited precision of the yearly inflow loads, yearly outflow outflows, and summer-mean concentrations computed from the biweekly measurements. **Figure 8-17** indicates that phosphorus residuals (observed-predicted concentrations) are reasonably independent of several factors related to model assumptions, including year, areal water loading, phosphorus loading, average inflow concentration, ratio Metro load to total load, ratio of SRP to total P load, ratio of Total Dissolved P to Total P load, and fraction of the total annual load occurring between May and September. Any effects of variations in phosphorus speciation or differential response to Metro vs. tributary loading appear to be small relative to the inherent residual variations.

Effects of phosphorus releases from the lake bottom sediments are not directly considered in the model, but are embedded in the calibrated net settling rate. Non-steady state responses attributed to phosphorus releases from bottom sediments following external load reductions would be reflected in the model residual time series (**Figure 8-17**). Reasonable agreement between observed and predicted lake and outlet P time series over this period with significant reductions in external load (**Figure 8-16**) suggests that effects of net phosphorus releases from bottom sediments are small relative to variations in external loads. There is no evidence of a lagged response to changes in external P loads, as would be expected if net reflux of P from historical sediments were an important source.

While there is good agreement between observed and predicted outflow TN concentrations, summer TN concentrations are significantly under-predicted in 2007 (**Figure 8-16**). The calibrated settling rate (15.69 m/yr) compares with a range of 14.2-30.5 m/yr in previous model updates. Most of the variance in settling rate reflects an error in the outflow total nitrogen load time series used in the previous calibration to 2001-2005 data (EcoLogic et al, 2006). That error resulted in a high settling rate (30.5 m/yr) as compared with 14.2 to 15.5 m/yr for the other calibration periods. Performance of the total nitrogen model is limited by the shift in load speciation from reduced to oxidized forms associated with nitrification of the Metro discharge over the past decade. In addition, decreases in nitrogen removal by phytoplankton are expected as productivity becomes increasing limited by phosphorus levels. This factor may explain the positive nitrogen residual in 2007, the year with the lowest lake P concentration. While the model tracks outflow N concentrations (**Figure 8-16**), a simple first-order model that ignores nitrogen speciation and coupling with phosphorus does not appear to be sufficient. The nitrogen model is included here only for comparison with phosphorus and is not particularly relevant to evaluating management scenarios, since total nitrogen concentrations are not a factor with respect to compliance with water quality standards.

Aside from SRP depletion (**Figure 8-15**), another pattern consistent with the increased importance of phosphorus limitation is the convergence of observed and predicted chlorophyll-a concentrations in recent years (1999-2007, **Figure 8-16**), since the predicted values are based upon the Jones-Bachman regression model derived from other phosphorus-limited lakes. The model generally over-predicts observed chlorophyll-a concentrations in earlier years (1991-1998), when TP and SRP concentrations were higher and less likely to have limited algal growth (**Figure 8-7**). Similar convergence of the observed and predicted lake responses in later years is evident for other trophic indicators (transparency, bloom frequency, organic N, TP – SRP, and HOD rate).

Coefficients of determination (R^2) for the 10-year interval are relatively high for nutrient concentrations (0.57 to 0.84) as compared with chlorophyll-a and related trophic state indicators (0 – 0.59). This reflects the fact that year-to-year variations in chlorophyll-a have been relatively low relative to the inherent error distributions in recent years as growth has become increasing limited by phosphorus. Error coefficients of variation (CV’s) are generally below typical values for empirical models of this type. **Table 8-16** compares results with error CV’s associated with the original BATHTUB calibration based upon data from 40 reservoirs (Walker, 1985). The error CV’s reflect the combined influences of sampling variations (uncertainty in loads and measured lake variables) and model error. Further analysis could be performed to separate these sources of error. Without separation, the current model over-estimates the uncertainty associated with model forecasts.

8.7.5 Model Applications

The Excel workbook (*OLEEM.xls*) for applying the model has been revised to reflect the updated calibration. The workbook facilitates application of the model to user-defined loading scenarios (**Tables 8-16** and **8-17**). Predictions are driven by lake outflow volume, inflow total phosphorus load, and inflow total nitrogen load, each referenced to a specified hydrologic period of record. Model updates and documentation are posted at http://www.wwwalker.net/onondaga.

The AMP hypotheses include numerical criteria for measuring lake-restoration progress, expressed in terms of summer-mean Total P (< 20 ppb, NYSDEC guidance value), frequency of chlorophyll-a values exceeding 15 ppb (< 15%), and frequency of Secchi depths < 1.2 meters (0%). Yearly simulations provide a basis for predicting the percent of years conforming to these and other eutrophication-related criteria for specific management actions. Accordingly, the workbook has been enhanced to simulate yearly time series, as well as a specified average loading regime. This enables characterization of both year-to-year variability and uncertainty in model projections, features which are useful in a TMDL context (Walker, 2001; 2003).

The predicted response of each trophic state indicator to variations in phosphorus load and concentrations is shown in **Figure 8-13**, as derived from the *OLEEM.xls*. The 80% prediction intervals (10th, 50th, 90th percentiles) for an average hydrologic year are shown for each variable. Response curves are shown relative to mean loads and phosphorus concentrations in 1998-2007 and 2006-2007. The latter period represents the status-quo with the Metro discharge concentration at 0.12 ppm, although non-point loads in 2006-2007 were above the 1998-2007 average because of high precipitation (**Figure 8-3**).

The model has been applied to forecast lake responses to various management scenarios involving combinations of Metro effluent P levels and non-point source load controls. Results are based upon simulations of water-years 1998-2007. As discussed above (**Section 8.5**), this period reflects a wide range of annual precipitation and reasonably stable non-point loads when adjusted for variations in precipitation. Forecasts for scenarios stored in the model workbook are summarized below:

		Inflow Conc (ppb)			Lake Conc (ppb)		Freq. Algal Bloom (%)			Freq Secchi (%)	
Scenario	**TP Load (mt/yr)**	**Metro**	**NonPoint**	**Nonpoint Reduc. %**	**P**	**Chl-a**	**>15 ppb**	**>30 ppb**	**Secchi (m)**	**<1.2 m**	**<1.5 m**
Base 1998-2007	56.4	306	67	0%	44	21	66%	15%	1.7	12%	37%
Metro = 120	39.5	120	67	0%	31	12	25%	2%	2.0	4%	19%
Metro = 120, NPS = 50	33.1	120	50	25%	26	9	11%	0%	2.1	3%	15%
Metro = 120, NPS = 40	29.2	120	40	40%	23	8	6%	0%	2.1	2%	12%
Metro = 120, NPS = 30	25.4	120	30	55%	20	6	2%	0%	2.2	2%	10%
Metro = 20	30.3	20	67	0%	24	8	7%	0%	2.1	2%	13%
Metro = 20, NPS = 50	24.1	20	50	25%	19	6	1%	0%	2.2	2%	10%
Metro Diverted	26.3	120	67	0%	24	8	7%	0%	2.1	2%	13%
Metro Div, NPS = 50	19.9	120	50	25%	18	5	1%	0%	2.2	1%	9%

The first scenario uses measured yearly inflows and loads for each source averaged over the 1998-2007 baseline period. The remaining scenarios use the same hydrologic base period with hypothetical values for Metro and non-point source phosphorus concentrations. Except for the diversion scenarios, Metro bypass flows and loads are assumed to be unchanged relative to 1998-2007 baseline conditions. The load from this source (2.2 mt/yr) accounted for 4% of the total baseline load and 5.6% of the total load with Metro operating at 0.12 ppm. Addressing bypass loads is an additional control measure not considered in the scenarios but potentially evaluated with the model. It is possible that these loads will be reduced as a consequence of CSO controls.

The projections differ only slightly from those generated by previous model calibrations (EcoLogic et al, 2001 and 2005). Chlorophyll-a and Secchi exceedance frequencies are reduced substantially with Metro operating at 0.12 ppm. Lake P concentrations approach the 20 ppb criterion for scenarios involving control of Metro load (either by diversion or by achieving the 2012 effluent P level of 20 ppb) and ~20% reduction in non-point load.

Forecasts for scenarios without further reductions in non-point load relative to the 1998-2007 baseline may be conservative; i.e. over-estimate lake TP concentrations and exceedance frequencies. A decreasing trend (-5.9 ± 2.5 %/yr) in the combined load from urban watersheds is apparent over the 1998-2007 period when adjusted for rainfall variations (**Tables 8-10 and 8-11**). A decreasing trend in flow-weighted mean concentration for the total non-point inflow may also exist, but is not strong enough to be statistically significant (-1.5 ± 1.6 %/yr, p = 0.37, **Figure 8-11**) and is potentially masked by inherent variability in the data. The apparent decreasing trend in flow and load from TRIB-5A (**Table 8-10, Figure 8-20**) is also ignored in simulations of future scenarios; this source accounted for only 0.6% of the load over the 1998-2007 period (**Table 8-7**).

As discussed above, the model assumes that the Lake responds equally to point and nonpoint loads. **Figure 8-17** shows that phosphorus residuals are independent of the fraction of total annual load attributed to Metro (treated + bypass) over a range of 0.25 to 0.75. Since the last four scenarios listed above involve extrapolation of the model below that range, they are subject to greater uncertainty. If non-point loads actually have less impact than Metro loads due to density currents and/or bio-availability differences, simulation results for those scenarios would also be conservative. The model workbook includes an additional algorithm for testing the sensitivity of the forecasts to alternative assumptions regarding the bio-availability of the phosphorus loads from each tributary.

Simulation of long-term hydrologic records could be performed using yearly non-point loads predicted from regressions calibrated to the historical data Tracking of future measured non-point loads and lake conditions relative to the prediction intervals of the models developed from 1998-2007 data (**Figures 8-9** and **8-16**) would provide a basis for evaluating future trends and responses to additional non-point controls and other management measures while adjusting for year-to-year variations related to precipitation. Similar tracking methodologies have been developed for Everglades watersheds and wetlands (Walker, 2000).

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8.9 TABLES

Table 8-1 Chloride Balance for 2003-2007

Variable: Chloride — Average for Years: 2003 thru 2007

							Percent of Total Inflow			Drain.		Export
	Flow	Load	Std Error	Conc	RSE	Sampl	Flow	Load	Error	Area	Runoff	mt/
Term	10^6 m3	mt	mt	ppm	%	per yr	%	%	%	km2	cm	km2
Metro Effluent	93.26	37889	1960	406	5%	44	17%	18%	30%			
Metro Bypass	1.89	785	136	416	17%	4	0%	0%	0%			
East Flume	0.76	388	16	509	4%	27	0%	0%	0%			
Trib 5A	1.34	508	11	378	2%	27	0%	0%	0%			
Harbor Brook	12.65	3375	216	267	6%	29	2%	2%	0%	31.4	40.3	107.6
Ley Creek	42.50	14579	1410	343	10%	29	8%	7%	15%	66.1	64.3	220.6
Ninemile Creek	172.94	51853	812	300	2%	30	31%	25%	5%	298.1	58.0	173.9
Onondaga Creek	191.70	85315	2089	445	2%	28	34%	42%	34%	285.1	67.2	299.2
Nonpoint Gauged	419.79	155122	2657	370	2%	117	75%	76%	54%	680.7	61.7	227.9
Nonpoint Ungauged	28.59	10566	1430	370	14%		5%	5%	16%	46.4	61.7	227.9
NonPoint Total	448.38	165687	3017	370	2%	117	80%	81%	70%	727.0	61.7	227.9
Industrial	2.11	896	20	425	2%	55	0%	0%	0%			
Municipal	95.15	38675	1965	406	5%	47	17%	19%	30%			
Total External	545.64	205258	3600	376	2%	219	98%	100%	100%	727.0	75.0	282.3
Precipitation	12.46	12	1	1	9%		2%	0%	0%	11.7	106.5	1.1
Total Inflow	558.10	205270	3600	368	2%	219	100%	100%	100%	738.7	75.5	277.9
Evaporation	8.86						2%			11.7	75.7	
Outflow	549.24	212668	2543	387	1%		98%	104%	50%	738.7	74.3	287.9
Retention	0.00	-7398	4408		60%		0%	-3.6%				
Alternative Estimates of Lake Outflow												
Outlet 12 Feet	549.24	212668	2543	387	1%	27	98%	104%	50%	738.7	74.3	287.9
Outlet 2 Feet	549.24	193864	4328	353	2%	27	98%	94%	144%	738.7	74.3	262.4
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	11.33	2599	88	230	3%	29	2%	1%		27.0	42.0	96.4
Downstream - Hiawatha	12.65	3375	216	267	6%	29	2%	2%		31.4	40.3	107.6
Local Inflow	1.33	776	233	584	30%		0%	0%		4.4	30.2	176.0
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	149.66	16393	292	110	2%	41	27%	8%		229.4	65.2	71.5
Downstream - Kirkpatrick	191.70	85315	2089	445	2%	28	34%	42%		285.1	67.2	299.2
Local Inflow	42.04	68922	2109	1640	3%		8%	34%		55.7	75.4	1236.7
Nonpoint Source Summary - Gauged Watersheds							Percent of Total Gauged Watershed					
Total Watershed	419.79	155122	2657	370	2%		100%	100%		680.7	61.7	227.9
Upper/Rural Watersheds	333.93	70845	868	212	1%		80%	46%		554.5	60.2	127.8

Table 8-2 Total Phosphorus Balance for 2003-2007

Variable: Total Phosphorus   Average for Years: 2003 thru 2007

							Percent of Total Inflow			Drain.		Export
	Flow	Load	Std Error	Conc	RSE	Sampl	Flow	Load	Error	Area	Runoff	kg /
Term	10^6 m3	kg	kg	ppb	%	per yr	%	%	%	km2	cm	km2
Metro Effluent	93.26	26266	333	282	1%	361	17%	45%	3%			
Metro Bypass	1.89	2088	74	1106	4%	42	0%	4%	0%			
East Flume	0.76	118	8	155	7%	27	0%	0%	0%			
Trib 5A	1.34	145	5	108	4%	28	0%	0%	0%			
Harbor Brook	12.65	1111	149	88	13%	29	2%	2%	1%	31.4	40.3	35.4
Ley Creek	42.50	3573	375	84	10%	29	8%	6%	4%	66.1	64.3	54.1
Ninemile Creek	172.94	9173	669	53	7%	30	31%	16%	12%	298.1	58.0	30.8
Onondaga Creek	191.70	13236	1724	69	13%	28	34%	23%	79%	285.1	67.2	46.4
Nonpoint Gauged	419.79	27094	1893	65	7%	117	75%	47%	95%	680.7	61.7	39.8
Nonpoint Ungauged	28.59	1845	280	65	15%		5%	3%	2%	46.4	61.7	39.8
NonPoint Total	448.38	28940	1913	65	7%	117	80%	50%	97%	727.0	61.7	39.8
Industrial	2.11	263	9	125	4%	55	0%	0%	0%			
Municipal	95.15	28355	341	298	1%	403	17%	49%	3%			
Total External	545.64	57557	1944	105	3%	575	98%	99%	100%	727.0	75.0	79.2
Precipitation	12.46	374	34	30	9%		2%	1%	0%	11.7	106.5	31.9
Total Inflow	558.10	57931	1944	104	3%	575	100%	100%	100%	738.7	75.5	78.4
Evaporation	8.86						2%			11.7	75.7	
Outflow	549.24	37264	1080	68	3%		98%	64%	31%	738.7	74.3	50.4
Retention	0.00	20667	2224		11%		0%	36%				
Alternative Estimates of Lake Outflow												
Outlet 12 Feet	549.24	37264	1080	68	3%	27	98%	64%	31%	738.7	74.3	50.4
Outlet 2 Feet	549.24	36098	1141	66	3%	27	98%	62%	34%	738.7	74.3	48.9
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	11.33	481	150	43	31%	29	2%	1%		27.0	42.0	17.9
Downstream - Hiawatha	12.65	1111	149	88	13%	29	2%	2%		31.4	40.3	35.4
Local Inflow	1.33	630	212	474	34%		0%	1%		4.4	30.2	143.0
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	149.66	10155	1762	68	17%	41	27%	18%		229.4	65.2	44.3
Downstream - Kirkpatrick	191.70	13236	1724	69	13%	28	34%	23%		285.1	67.2	46.4
Local Inflow	42.04	3081	2465	73	80%		8%	5%		55.7	75.4	55.3
Nonpoint Source Summary - Gauged Watersheds							Percent of Total Gauged Watershed					
Total Watershed	419.79	27094	1893	65	7%		100%	100%		680.7	61.7	39.8

Table 8-3 Soluble Reactive Phosphorus Balance for 2003-2007

Variable: Soluble Reactive P   Average for Years: 2003 thru 2007

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sampl per yr	Percent of Total Inflow Flow %	Percent of Total Inflow Load %	Error %	Drain. Area km2	Runoff cm	Export kg / km2
Metro Effluent	93.26	8033	784	86	10%	30	17%	62%	84%			
Metro Bypass	1.89	443	179	235	40%	4	0%	3%	4%			
East Flume	0.76	45	5	60	10%	27	0%	0%	0%			
Trib 5A	1.34	45	3	33	6%	27	0%	0%	0%			
Harbor Brook	12.65	408	43	32	11%	29	2%	3%	0%	31.4	40.3	13.0
Ley Creek	42.50	571	36	13	6%	29	8%	4%	0%	66.1	64.3	8.6
Ninemile Creek	172.94	1478	180	9	12%	30	31%	11%	4%	298.1	58.0	5.0
Onondaga Creek	191.70	1550	215	8	14%	28	34%	12%	6%	285.1	67.2	5.4
Nonpoint Gauged	419.79	4007	287	10	7%	117	75%	31%	11%	680.7	61.7	5.9
Nonpoint Ungauged	28.59	273	42	10	15%		5%	2%	0%	46.4	61.7	5.9
NonPoint Total	448.38	4280	290	10	7%	117	80%	33%	11%	727.0	61.7	5.9
Industrial	2.11	90	5	43	6%	55	0%	1%	0%			
Municipal	95.15	8476	805	89	9%	33	17%	65%	88%			
Total External	545.64	12847	855	24	7%	205	98%	99%	100%	727.0	75.0	17.7
Precipitation	12.46	187	17	15	9%		2%	1%	0%	11.7	106.5	16.0
Total Inflow	558.10	13033	855	23	7%	205	100%	100%	100%	738.7	75.5	17.6
Evaporation	8.86						2%			11.7	75.7	
Outflow	549.24	19271	1864	35	10%		98%	148%	475%	738.7	74.3	26.1
Retention	0.00	-6237	2051		33%		0%	-48%				
Alternative Estimates of Lake Outflow												
Outlet 12 Feet	549.24	19271	1864	35	10%	27	98%	148%	475%	738.7	74.3	26.1
Outlet 2 Feet	549.24	17722	1204	32	7%	27	98%	136%	198%	738.7	74.3	24.0
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	11.33	123	18	11	15%	29	2%	1%		27.0	42.0	4.6
Downstream - Hiawatha	12.65	408	43	32	11%	29	2%	3%		31.4	40.3	13.0
Local Inflow	1.33	285	47	214	16%		0%	2%		4.4	30.2	64.6
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	149.66	784	111	5	14%	32	27%	6%		229.4	65.2	3.4
Downstream - Kirkpatrick	191.70	1550	215	8	14%	28	34%	12%		285.1	67.2	5.4
Local Inflow	42.04	766	242	18	32%		8%	6%		55.7	75.4	13.7
Nonpoint Source Summary - Gauged Watersheds							Percent of Total Gauged Watershed					
Total Watershed	419.79	4007	287	10	7%		100%	100%		680.7	61.7	5.9

Table 8-4 Total Nitrogen Balance for 2003-2007

Variable: Total Nitrogen Average for Years: 2003 thru 2007

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sampl per yr	Percent of Total Inflow Flow %	Load %	Error %	Drain. Area km2	Runoff cm	Export kg/ km2
Metro Effluent	93.26	1145344	29278	12281	3%	100	17%	60%	83%			
Metro Bypass	1.89	21446	856	11354	4%	4	0%	1%	0%			
East Flume	0.76	4576	123	6002	3%	27	0%	0%	0%			
Trib 5A	1.34	2036	124	1514	6%	27	0%	0%	0%			
Harbor Brook	12.65	27231	903	2152	3%	27	2%	1%	0%	31.4	40.3	868
Ley Creek	42.50	54871	2476	1291	5%	27	8%	3%	1%	66.1	64.3	830
Ninemile Creek	172.94	290722	7813	1681	3%	27	31%	15%	6%	298.1	58.0	975
Onondaga Creek	191.70	296228	7782	1545	3%	27	34%	15%	6%	285.1	67.2	1039
Nonpoint Gauged	419.79	669053	11338	1594	2%	109	75%	35%	12%	680.7	61.7	983
Nonpoint Ungauged	28.59	45571	6181	1594	14%		5%	2%	4%	46.4	61.7	983
NonPoint Total	448.38	714624	12913	1594	2%	109	80%	37%	16%	727.0	61.7	983
Industrial	2.11	6612	175	3138	3%	54	0%	0%	0%			
Municipal	95.15	1166790	29291	12262	3%	104	17%	61%	83%			
Total External	545.64	1888026	32011	3460	2%	267	98%	99%	100%	727.0	75.0	2597
Precipitation	12.46	23665	2123	1900	9%		2%	1%	0%	11.7	106.5	2023
Total Inflow	558.10	1911691	32082	3425	2%	267	100%	100%	100%	738.7	75.5	2588
Evaporation	8.86						2%			11.7	75.7	
Outflow	549.24	1428717	29221	2601	2%		98%	75%	83%	738.7	74.3	1934
Retention	0.00	482974	43395		9%		0%	25%				
Alternative Estimates of Lake Outflow												
Outlet 12 Feet	549.24	1428717	29221	2601	2%	26	98%	75%	83%	738.7	74.3	1934
Outlet 2 Feet	549.24	1334439	29254	2430	2%	26	98%	70%	83%	738.7	74.3	1806
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	11.33	24142	1343	2132	6%	27	2%	1%		27.0	42.0	896
Downstream - Hiawatha	12.65	27231	903	2152	3%	27	2%	1%		31.4	40.3	868
Local Inflow	1.33	3089	1618	2325	52%		0%	0%		4.4	30.2	701
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	149.66	246055	26049	1644	11%	34	27%	13%		229.4	65.2	1073
Downstream - Kirkpatrick	191.70	296228	7782	1545	3%	27	34%	15%		285.1	67.2	1039
Local Inflow	42.04	50173	27187	1194	54%		8%	3%		55.7	75.4	900
Nonpoint Source Summary - Gauged Watersheds							Percent of Total Gauged Watershed					
Total Watershed	419.79	669053	11338	1594	2%		100%	100%		680.7	61.7	983

Table 8-5 Ammonia Nitrogen Balance for 2003-2007

Variable: Ammonia Nitrogen Average for Years: 2003 thru 2007

							Percent of Total Inflow			Drain.		Export
	Flow	Load	Std Error	Conc	RSE	Sampl	Flow	Load	Error	Area	Runoff	kg/
Term	10^6 m3	kg	kg	ppb	%	per yr	%	%	%	km2	cm	km2
Metro Effluent	93.26	147553	2952	1582	2%	361	17%	64%	40%			
Metro Bypass	1.89	10058	593	5325	6%	42	0%	4%	2%			
East Flume	0.76	356	19	467	5%	27	0%	0%	0%			
Trib 5A	1.34	214	9	159	4%	27	0%	0%	0%			
Harbor Brook	12.65	1033	97	82	9%	28	2%	0%	0%	31.4	40.3	32.9
Ley Creek	42.50	12367	817	291	7%	27	8%	5%	3%	66.1	64.3	187.1
Ninemile Creek	172.94	39121	3247	226	8%	27	31%	17%	49%	298.1	58.0	131.2
Onondaga Creek	191.70	15006	917	78	6%	28	34%	6%	4%	285.1	67.2	52.6
Nonpoint Gauged	419.79	67528	3473	161	5%	109	75%	29%	56%	680.7	61.7	99.2
Nonpoint Ungauged	28.59	4599	665	161	14%		5%	2%	2%	46.4	61.7	99.2
NonPoint Total	448.38	72127	3536	161	5%	109	80%	31%	58%	727.0	61.7	99.2
Industrial	2.11	571	21	271	4%	55	0%	0%	0%			
Municipal	95.15	157611	3011	1656	2%	403	17%	68%	42%			
Total External	545.64	230309	4644	422	2%	567	98%	99%	100%	727.0	75.0	316.8
Precipitation	12.46	1246	112	100	9%		2%	1%	0%	11.7	106.5	106.5
Total Inflow	558.10	231554	4646	415	2%	567	100%	100%	100%	738.7	75.5	313.4
Evaporation	8.86						2%			11.7	75.7	
Outflow	549.24	204982	8839	373	4%		98%	89%	362%	738.7	74.3	277.5
Retention	0.00	26572	9985		38%		0%	11%				
Alternative Estimates of Lake Outflow												
Outlet 12 Feet	549.24	204982	8839	373	4%	27	98%	89%	362%	738.7	74.3	277.5
Outlet 2 Feet	549.24	186838	9113	340	5%	27	98%	81%	385%	738.7	74.3	252.9
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	11.33	587	42	52	7%	28	2%	0%		27.0	42.0	21.8
Downstream - Hiawatha	12.65	1033	97	82	9%	28	2%	0%		31.4	40.3	32.9
Local Inflow	1.33	446	106	336	24%		0%	0%		4.4	30.2	101.3
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	149.66	8100	403	54	5%	40	27%	3%		229.4	65.2	35.3
Downstream - Kirkpatrick	191.70	15006	917	78	6%	28	34%	6%		285.1	67.2	52.6
Local Inflow	42.04	6906	1002	164	15%		8%	3%		55.7	75.4	123.9
Nonpoint Source Summary - Gauged Watersheds							Percent of Total Gauged Watershed					
Total Watershed	419.79	67528	3473	161	5%		100%	100%		680.7	61.7	99.2

Table 8-6 Total Phosphorus Balance for 2006-2007

Variable: Total Phosphorus   Average for Years: 2006 thru 2007

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sampl per yr	Percent of Total Inflow: Flow %	Percent of Total Inflow: Load %	Error %	Drain. Area km2	Runoff cm	Export kg / km2
Metro Effluent	87.90	10659	242	121	2%	361	16%	25%	1%			
Metro Bypass	1.17	1483	74	1263	5%	48	0%	4%	0%			
East Flume	0.65	102	12	158	12%	27	0%	0%	0%			
Trib 5A	0.64	64	3	99	5%	27	0%	0%	0%			
Harbor Brook	13.47	1375	275	102	20%	28	2%	3%	1%	31.4	42.9	43.8
Ley Creek	41.55	3170	515	76	16%	27	8%	8%	2%	66.1	62.9	48.0
Ninemile Creek	172.98	9173	1202	53	13%	36	31%	22%	13%	298.1	58.0	30.8
Onondaga Creek	193.36	13721	3006	71	22%	27	35%	33%	81%	285.1	67.8	48.1
Nonpoint Gauged	421.36	27439	3289	65	12%	117	76%	65%	98%	680.7	61.9	40.3
Nonpoint Ungauged	28.70	1869	457	65	24%		5%	4%	2%	46.4	61.9	40.3
NonPoint Total	450.06	29308	3321	65	11%	117	81%	70%	99%	727.0	61.9	40.3
Industrial	1.29	166	13	129	8%	54	0%	0%	0%			
Municipal	89.08	12142	253	136	2%	409	16%	29%	1%			
Total External	540.42	41616	3330	77	8%	580	98%	99%	100%	727.0	74.3	57.2
Precipitation	13.20	396	56	30	14%		2%	1%	0%	11.7	112.8	33.8
Total Inflow	553.62	42012	3331	76	8%	580	100%	100%	100%	738.7	74.9	56.9
Evaporation	8.86						2%			11.7	75.7	
Outflow	544.76	22862	1036	42	5%		98%	54%	10%	738.7	73.7	30.9
Retention	0.00	19150	3488		18%		0%	46%				
Alternative Estimates of Lake Outflow												
Outlet 12 Feet	544.76	22862	1036	42	5%	26	98%	54%	10%	738.7	73.7	30.9
Outlet 2 Feet	544.76	23983	1200	44	5%	26	98%	57%	13%	738.7	73.7	32.5
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	11.40	478	206	42	43%	28	2%	1%		27.0	42.3	17.7
Downstream - Hiawatha	13.47	1375	275	102	20%	28	2%	3%		31.4	42.9	43.8
Local Inflow	2.07	897	344	433	38%		0%	2%		4.4	47.0	203.5
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	149.77	10397	2549	69	25%	53	27%	25%		229.4	65.3	45.3
Downstream - Kirkpatrick	193.36	13721	3006	71	22%	27	35%	33%		285.1	67.8	48.1
Local Inflow	43.59	3324	3941	76	119%		8%	8%		55.7	78.2	59.7
Nonpoint Source Summary - Gauged Watersheds							Percent of Total Gauged Watershed					
Total Watershed	421.36	27439	3289	65	12%		100%	100%		680.7	61.9	40.3
Upper/Rural Watersheds	334.15	20048	2825	60	14%		79%	73%		554.5	60.3	36.2
Lower/Urban Watersheds	87.21	7391	3989	85	54%		21%	27%		126.2	69.1	58.6
Net Urban	11.13	2827		254			3%	10%		126.2	8.8	22.4

Upper Watersheds: Ninemile + Onondaga(Dorwin) + Harbor(Velasko) - Primarily Rural / Agric Land Uses
Lower Watersheds: Lower Watershed = Ley + Onondaga(Kirkpatrick-Dorwin) + Harbor (Hiawatha - Velasko) - Primarily Urban Land Uses
Net Urban: Net Contribution of Lower Watersheds above Rural Background Loads

Lake Overflow Rate 46.56 m/yr   Calib. Settling Rate 39.0 m/yr   RSE % = Relative Std. Error of Load & Inflow Conc. Estimates
Lake Residence Time 0.23 years   Calib. Retention Coef 46%   Error % = Percent of Variance in Total Inflow Load Estimate

Table 8-7 Total Phosphorus Balance for 1998-2007

Variable: Total Phosphorus Average for Years: 1998 thru 2007

							Percent of Total Inflow			Drain.		Export
	Flow	Load	Std Error	Conc	RSE	Sampl	Flow	Load	Error	Area	Runoff	kg /
Term	10^6 m3	kg	kg	ppb	%	per yr	%	%	%	km2	cm	km2
Metro Effluent	91.31	27477	224	301	1%	363	18%	48%	4%			
Metro Bypass	2.04	2279	53	1118	2%	46	0%	4%	0%			
East Flume	0.57	93	4	163	5%	28	0%	0%	0%			
Trib 5A	2.08	258	6	124	3%	28	0%	0%	0%			
Harbor Brook	10.56	922	89	87	10%	31	2%	2%	1%	31.4	33.7	29.4
Ley Creek	38.54	3567	278	93	8%	31	8%	6%	6%	66.1	58.3	54.0
Ninemile Creek	148.53	8317	390	56	5%	30	30%	15%	11%	298.1	49.8	27.9
Onondaga Creek	167.10	11864	1004	71	8%	32	34%	21%	76%	285.1	58.6	41.6
Nonpoint Gauged	364.73	24671	1116	68	5%	123	73%	43%	94%	680.7	53.6	36.2
Nonpoint Ungauged	24.84	1680	178	68	11%		5%	3%	2%	46.4	53.6	36.2
NonPoint Total	389.57	26351	1130	68	4%	123	78%	46%	96%	727.0	53.6	36.2
Industrial	2.66	352	8	132	2%	55	1%	1%	0%			
Municipal	93.35	29756	230	319	1%	409	19%	52%	4%			
Total External	485.57	56459	1154	116	2%	587	98%	99%	100%	727.0	66.8	77.7
Precipitation	11.55	347	22	30	6%		2%	1%	0%	11.7	98.7	29.6
Total Inflow	497.12	56805	1154	114	2%	587	100%	100%	100%	738.7	67.3	76.9
Evaporation	8.86						2%			11.7	75.7	
Outflow	488.27	35944	747	74	2%		98%	63%	42%	738.7	66.1	48.7
Retention	0.00	20862	1375		7%		0%	37%				
Alternative Estimates of Lake Outflow												
Outlet 12 Feet	488.27	35944	747	74	2%	26	98%	63%	42%	738.7	66.1	48.7
Outlet 2 Feet	488.27	33873	758	69	2%	26	98%	60%	43%	738.7	66.1	45.9
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	9.68	418	97	43	23%	31	2%	1%		27.0	35.9	15.5
Downstream - Hiawatha	10.56	922	89	87	10%	31	2%	2%		31.4	33.7	29.4
Local Inflow	0.88	505	132	570	26%		0%	1%		4.4	20.1	114.5
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	129.49	8419	920	65	11%	38	26%	15%		229.4	56.4	36.7
Downstream - Kirkpatrick	167.10	11864	1004	71	8%	32	34%	21%		285.1	58.6	41.6
Local Inflow	37.61	3445	1362	92	40%		8%	6%		55.7	67.5	61.8
Nonpoint Source Summary - Gauged Watersheds							Percent of Total Gauged Watershed					
Total Watershed	364.73	24671	1116	68	5%		100%	100%		680.7	53.6	36.2
Upper/Rural Watersheds	287.69	17154	1004	60	6%		79%	70%		554.5	51.9	30.9
Lower/Urban Watersheds	77.03	7516	1397	98	19%		21%	30%		126.2	61.0	59.5
Net Urban	11.53	3611		313			3%	15%		126.2	9.1	28.6

Upper Watersheds: Ninemile + Onondaga(Dorwin) + Harbor(Velasko) - Primarily Rural / Agric Land Uses
Lower Watersheds: Lower Watershed = Ley + Onondaga(Kirkpatrick-Dorwin) + Harbor (Hiawatha - Velasko) - Primarily Urban Land Uses
Net Urban: Net Contribution of Lower Watersheds above Rural Background Loads

Lake Overflow Rate 41.73 m/yr Calib. Settling Rate 24.2 m/yr RSE % = Relative Std. Error of Load & Inflow Conc. Estimates
Lake Residence Time 0.26 years Calib. Retention Coef 37% Error % = Percent of Variance in Total Inflow Load Estimate

Table 8-8 Summary of NonPoint Source Loads, 1998-2007

	Flow	Total Phosphorus	Total Dissolved P	Soluble Reactive P	Total Nitrogen	Total Kjeldahl N	Ammonia Nitrogen	Nitrate Nitrogen	5-Day BOD	Total Org Carbon	Filtered Total Org C	Chloride	Sodium
Annual Loads	hm3	kg	kg	kg	kg	kg	kg	kg	mt	mt	mt	mt	mt
Ley	39	3567	1167	568	53037	34782	12867	17406	109	264	242	12827	7586
Ninemile	149	8317	3135	1147	251349	97559	39456	150481	321	491	407	51595	16980
Harbor - Upper	10	418	200	91	20460	3915	622	16417	22	21	19	2198	1195
Harbor - Lower	1	505	174	197	1968	1889	540	37	5	6	6	588	341
Harbor - Total	11	922	375	288	22429	5804	1162	16454	27	27	24	2786	1536
Onondaga - Upper	129	8419	1751	642	202897	58531	8310	132214	269	368	337	14969	9218
Onondaga - Lower	38	3445	1197	643	53113	24474	7998	37122	128	96	81	59873	37164
Onondaga - Total	167	11864	2948	1286	256011	83006	16308	169337	397	464	417	74841	46382
Total Nonpoint Gauged	365	24671	7625	3289	582825	221150	69792	353677	854	1246	1091	142049	72484
Rural Watersheds	288	17154	5086	1881	474707	160005	48388	299112	612	880	762	68762	27393
Urban Watersheds	77	7516	2539	1409	108118	61145	21404	54565	242	366	329	73287	45091
Net Urban	12	3611	1381	981	39	24715	10387	-13536	103	165	155	57632	38854
Unit Area Loads	cm	kg /km2	kg /km2	kg /km2	kg/km2	kg/km2	kg/km2	kg /km2	mt/km2	mt/km2	mt/km2	mt/km2	mt/km2
Ley	58	54	18	9	802	526	195	263	1.7	4.0	3.7	194	115
Ninemile	50	28	11	4	843	327	132	505	1.1	1.6	1.4	173	57
Harbor - Upper	36	16	7	3	759	145	23	609	0.8	0.8	0.7	82	44
Harbor - Lower	20	115	40	45	447	429	122	8	1.2	1.3	1.3	134	77
Harbor - Total	34	29	12	9	715	185	37	525	0.9	0.9	0.8	89	49
Onondaga - Upper	56	37	8	3	884	255	36	576	1.2	1.6	1.5	65	40
Onondaga - Lower	67	62	21	12	953	439	144	666	2.3	1.7	1.4	1074	667
Onondaga - Total	59	42	10	5	898	291	57	594	1.4	1.6	1.5	262	163
Total Nonpoint Gauged	54	36	11	5	856	325	103	520	1.3	1.8	1.6	209	106
Rural Watersheds	52	31	9	3	856	289	87	539	1.1	1.6	1.4	124	49
Urban Watersheds	61	60	20	11	856	484	170	432	1.9	2.9	2.6	581	357
Net Urban	9	29	11	8	0	196	82	-107	0.8	1.3	1.2	457	308
Percent of Total Gauged NonPoint Load													
Ley	11%	14%	15%	17%	9%	16%	18%	5%	13%	21%	22%	9%	10%
Ninemile	41%	34%	41%	35%	43%	44%	57%	43%	38%	39%	37%	36%	23%
Harbor - Upper	3%	2%	3%	3%	4%	2%	1%	5%	3%	2%	2%	2%	2%
Harbor - Lower	0%	2%	2%	6%	0%	1%	1%	0%	1%	0%	1%	0%	0%
Harbor - Total	3%	4%	5%	9%	4%	3%	2%	5%	3%	2%	2%	2%	2%
Onondaga - Upper	36%	34%	23%	20%	35%	26%	12%	37%	31%	30%	31%	11%	13%
Onondaga - Lower	10%	14%	16%	20%	9%	11%	11%	10%	15%	8%	7%	42%	51%
Onondaga - Total	46%	48%	39%	39%	44%	38%	23%	48%	46%	37%	38%	53%	64%
Total Nonpoint Gauged	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Rural Watersheds	79%	70%	67%	57%	81%	72%	69%	85%	72%	71%	70%	48%	38%
Urban Watersheds	21%	30%	33%	43%	19%	28%	31%	15%	28%	29%	30%	52%	62%
Net Urban	3%	15%	18%	30%	0%	11%	15%	-4%	12%	13%	14%	41%	54%
FWM Concentrations		ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppm	ppm	ppm	ppm
Ley	-	93	30	15	1376	902	334	452	2.8	6.8	6.3	333	197
Ninemile	-	56	21	8	1692	657	266	1013	2.2	3.3	2.7	347	114
Harbor - Upper	-	43	21	9	2114	405	64	1696	2.3	2.2	1.9	227	124
Harbor - Lower	-	570	197	223	2226	2136	610	41	5.9	6.6	6.4	665	385
Harbor - Total	-	87	35	27	2124	549	110	1558	2.6	2.6	2.3	264	145
Onondaga - Upper	-	65	14	5	1567	452	64	1021	2.1	2.8	2.6	116	71
Onondaga - Lower	-	92	32	17	1412	651	213	987	3.4	2.6	2.1	1592	988
Onondaga - Total	-	71	18	8	1532	497	98	1013	2.4	2.8	2.5	448	278
Total Nonpoint Gauged	-	68	21	9	1598	606	191	970	2.3	3.4	3.0	389	199
Rural Watersheds	-	60	18	7	1650	556	168	1040	2.1	3.1	2.6	239	95
Urban Watersheds	-	98	33	18	1404	794	278	708	3.1	4.7	4.3	951	585
Net Urban	-	313	120	85	3	2143	901	-1176	8.9	14.3	13.4	4997	3369

Table 8-9 Trends in Total Phosphorus for Each Mass Balance Term, 1990-2007

	Flow						Load								Concentration					
	Mean	Rainfall	Trend % / yr		p Levels		Mean	Rainfall	Trend (kg/yr)		Trend % / yr		p Levels		Mean	Rainfall	Trend % / yr		p Levels	
Source	hm3/yr	Correl	A	B	A	B	kg/yr	Correl	Mean	Std Error	A	B	A	B	ppb	Correl	A	B	A	B
Metro	91.9	0.42			0.55	0.50	38983	-0.03	-3394	628	-9	-9	0.00	0.00	424	-0.09	-9	-8	0.00	0.00
Bypass	3.3	0.28			0.26	0.25	5349	0.26	-462	190	-9	-9	0.03	0.03	1633	0.03	-4	-4	0.00	0.00
E Flume	0.9	0.63			0.43	0.29	143	0.63	-7	4		-5	0.17	0.07	164	-0.35			0.13	0.13
Trib5A	2.6	-0.31	-8	-8	0.00	0.00	213	-0.22		6			0.77	0.79	83	0.05	7	7	0.00	0.00
Harbor/Velasko	9.2	0.82		1	0.17	0.02	493	0.72	-14	8		-3	0.26	0.09	54	0.40	-4	-4	0.02	0.01
Harbor/Lower	1.1	0.46			0.82	0.77	341	0.17	43	8	13	13	0.00	0.00	325	-0.25	14	14	0.03	0.03
Harbor/Hiawatha	10.2	0.84		1	0.30	0.08	828	0.67	27	13		3	0.13	0.05	81	0.33			0.15	0.15
Onondaga/Dorwin	125.6	0.83		1	0.30	0.09	10277	0.78		174			0.50	0.25	82	0.60	-3	-3	0.09	0.03
Onondaga/Lower	36.6	0.88		1	0.29	0.04	5722	0.40	-448	128	-8	-8	0.01	0.00	156	0.16	-9	-9	0.00	0.00
Onond./Kirkpatrick	162.2	0.86		1	0.29	0.05	15999	0.72	-617	219		-4	0.11	0.01	99	0.42	-5	-5	0.00	0.00
Ley/Park	39.3	0.86			0.93	0.76	4616	0.55	-203	61	-4	-4	0.02	0.00	117	0.16	-4	-4	0.00	0.00
Ninemile/Rt48	148.5	0.88			0.78	0.68	9222	0.82		92			0.40	0.11	62	0.40	-2	-2	0.06	0.04
NonPoint Gauged	360.3	0.89			0.56	0.27	30665	0.76	-947	350		-3	0.15	0.02	85	0.40	-4	-4	0.01	0.00
Total Gauged	458.9	0.89			0.69	0.49	75353	0.40	-4750	723	-6	-6	0.00	0.00	164	-0.01	-7	-7	0.00	0.00
Total NonPoint	384.8	0.89			0.56	0.27	32753	0.76	-1012	373		-3	0.15	0.02	85	0.40	-4	-4	0.01	0.00
Total Industrial	3.4	0.02	-7	-7	0.00	0.00	356	0.21		8			0.22	0.22	104	0.26	4	4	0.01	0.01
Total Municipal	95.1	0.62		-1	0.11	0.04	44332	0.02	-4023	724	-9	-9	0.00	0.00	466	-0.05	-9	-9	0.00	0.00
Total Inflow	495.0	0.89			0.68	0.48	77790	0.41	-4808	732	-6	-6	0.00	0.00	157	0.00	-6	-6	0.00	0.00
NP_Rural	283.3	0.87			0.53	0.27	19992	0.82		245			0.44	0.15	71	0.57	-2	-3	0.05	0.02
NP_Urban	77.0	0.92			0.70	0.45	10679	0.52	-593	156	-5	-6	0.01	0.00	139	0.18	-6	-6	0.00	0.00
Outlet2	486.1	0.89			0.68	0.47	43440	0.41	-2050	504	-5	-5	0.00	0.00	89	-0.06	-5	-5	0.00	0.00
Outlet12	486.1	0.89			0.68	0.47	48570	0.27	-2802	623	-6	-6	0.00	0.00	100	-0.16	-6	-6	0.00	0.00

Methods: A = without adjustment for annual precipitation, B = with adjustment for precipitation using equations listed in Figure 9.

Shaded cells indicate trend slopes significantly different from zero at $p < 0.10$ for two-tailed and $p < 0.05$ for one-tailed hypothesis.

Table 8-10 Trends in Total Phosphorus for Each Mass Balance Term, 1998-2007

	Flow						Load								Concentration					
	Mean	Rainfall	Trend Slopes		p Levels		Mean	Rainfall	Trend kg /y		Trend Slopes		p Levels		Mean	Rainfall	Trend Slopes		p Levels	
Source	hm3/yr	Correl	A	C	A	B	kg	Correl	Mean	SE	A	C	A	C	ppb	Correl	A	C	A	C
Metro	91.3	0.30			0.78	0.57	27477	-0.42		2256	-11		0.05	0.15	301	-0.47	-11		0.04	0.14
Bypass	2.0	-0.36			0.34	0.80	2279	-0.29		154			0.38	0.72	1118	0.26			0.76	0.72
E Flume	0.6	0.67	13		0.01	0.13	93	0.60		6	9		0.06	0.43	163	-0.41	-4		0.05	0.12
Trib5A	2.1	-0.67	-17	-17	0.00	0.03	258	-0.72	-40	20	-19	-16	0.00	0.08	124	-0.59			0.27	0.70
Harbor/Velasko	9.7	0.79	6	4	0.00	0.08	418	0.36		25			0.69	0.56	43	-0.13			0.29	0.24
Harbor/Lower	0.9	0.69	28		0.04	0.47	505	0.38	84	22	11	17	0.01	0.01	570	-0.60			0.21	0.87
Harbor/Hiawatha	10.6	0.81	7	5	0.00	0.05	922	0.59	74	29	7	8	0.00	0.04	87	-0.17			0.85	0.41
Onondaga/Dorwin	129.5	0.81	5		0.01	0.41	8419	0.59		434	8		0.04	0.29	65	0.16			0.32	0.34
Onondaga/Lower	37.6	0.97	4		0.01	0.48	3445	-0.07		234			0.26	0.14	92	-0.41	-10		0.05	0.13
Onond./Kirkpatrick	167.1	0.86	5		0.01	0.39	11864	0.62		328	3		0.10	0.71	71	-0.41			0.28	0.80
Ley/Park	38.5	0.76	4		0.04	0.67	3567	0.24		111			0.69	0.13	93	-0.46	-4	-6	0.00	0.01
Ninemile/Rt48	148.5	0.81	5		0.03	0.68	8317	0.71		183			0.13	0.83	56	-0.67	-3		0.03	0.34
NonPoint Gauged	364.7	0.84	5		0.01	0.50	24671	0.75		454	3		0.08	0.99	68	-0.64	-2		0.04	0.37
Total Gauged	460.7	0.83	4		0.02	0.59	54779	-0.15		2288			0.23	0.19	119	-0.61	-7	-7	0.01	0.09
Total NonPoint	389.6	0.84	5		0.01	0.50	26351	0.75		485	3		0.08	0.99	68	-0.64	-2		0.04	0.37
Total Industrial	2.7	-0.58	-10	-10	0.01	0.07	352	-0.60		20	-10		0.02	0.16	132	-0.26			0.75	0.72
Total Municipal	93.3	0.26			0.87	0.56	29756	-0.42		2336	-10		0.06	0.17	319	-0.48	-10		0.04	0.15
Total Inflow	497.1	0.83	4		0.02	0.58	56805	-0.13		2298			0.26	0.19	114	-0.62	-7	-7	0.01	0.08
NP_Rural	287.7	0.82	5		0.02	0.53	17154	0.70		521	5		0.03	0.44	60	-0.28			0.79	0.61
NP_Urban	77.0	0.92	4		0.01	0.44	7516	0.03	-444	190		-6	0.26	0.05	98	-0.56	-6	-7	0.01	0.07
Outlet2	488.3	0.83	4		0.02	0.59	33873	-0.01		1683			0.63	0.49	69	-0.53	-6		0.06	0.31
Outlet12	488.3	0.83	4		0.02	0.59	35944	-0.18		1902			0.30	0.34	74	-0.61	-8		0.02	0.19

Methods: A = without adjustment for annual precipitation, B = with adjustment for precipitation using equations listed in Figure 9

Shaded cells indicate trend slopes significantly different from zero at $p < 0.10$ for two-tailed and $p < 0.05$ for one-tailed hypothesis.

Table 8-11 Trends in Load, 1998-2007

Load Trends (% / yr) 1998 to 2007 Precip Trend = 3.0 +/- 0.9 cm/yr

Term	FLOW	TP	TN	TKN	NH3N	NO2N	NO3N	TOC	TOC_F	TIC	SIO2	ALK	CA	CL	NA
Metro		-11		-23	-32	-23	11	-5	-5				3	4	
Bypass			-8	-8	-9										
E Flume	13	9	11			10	14	11	11	13	10	13	14	15	16
Trib5A	-17	-19	-24	-17	-17	-20	-27	-15	-15	-15	-15	-14	-17	-19	-20
Harbor/Velasko	6		6	5	-4	4	6	7	6	6	5	7	5	6	8
Harbor/Lower	28	11					56			14	13	13	31	12	10
Harbor/Hiawatha	7	7	7	4	-5		8	7	7	7	7	7	6	7	8
Onondaga/Dorwin	5	8	7	7		11	5			6	7	6	7	3	4
Onondaga/Lower	4					-6	7		11	5	5	5	6	6	6
Onond./Kirkpatrick	5	3	5	4		8	5			6	6	6	7	6	6
Ley/Park	4					-3		4	4	4	4	4	4	6	7
Ninemile/Rt48	5						6		6	6	6	6	2		
NonPoint Gauged	5	3	4			4	5	6	6	6	6	6	4	3	5
Total Gauged	4			-13	-23	-13	9			5	5	5	4	3	4
Total NonPoint	5	3	4			4	5	6	6	6	6	6	4	3	5
Total Industrial	-10	-10	-6	-7	-8	6	-7	-7	-8	-8	-7	-7	-10	-9	-6
Total Municipal		-10		-22	-30	-23	11	-5	-5				3	4	
Total Inflow	4			-13	-22	-12	9			5	5	5	4	3	4
NP_Rural	5	5	6			6	5	6	6	6	6	6	3		
NP_Urban	4					-4	6	6	6	5	4	5	6	6	6
Outlet2	4			-8	-16	-4	10			5	11	5	5	4	5
Outlet12	4			-10	-19	-6	9			5	12	5	4	2	3

Load Trends (% / yr), Adjusted for Variations in Rainfall

Term	FLOW	TP	TN	TKN	NH3N	NO2N	NO3N	TOC	TOC_F	TIC	SIO2	ALK	CA	CL	NA
Metro				-24	-35	-27		-5	-6						
Bypass															
E Flume															14
Trib5A	-17	-16	-24	-17	-17	-21	-26	-17	-16	-15	-15	-15	-17	-19	-20
Harbor/Velasko	4		4		-6									7	8
Harbor/Lower		17												12	
Harbor/Hiawatha	5	8	6				6					5	4	8	9
Onondaga/Dorwin						10									
Onondaga/Lower													4	7	7
Onond./Kirkpatrick													3	6	6
Ley/Park						-5								8	8
Ninemile/Rt48					-6										
NonPoint Gauged					-5									3	5
Total Gauged				-15	-24	-14								3	4
Total NonPoint					-5									3	5
Total Industrial	-10		-9	-10	-12		-10	-10	-10				-11		
Total Municipal				-23	-32	-27		-5	-6						
Total Inflow				-14	-23	-13								3	4
NP_Rural					-6										
NP_Urban		-6									2		4	7	7
Outlet2				-11	-18	-6					12				
Outlet12				-13	-19	-8					14				

Trend magnitudes shown for results with p < .10 for two-tailed hypothesis, p<05 for one-tailed hypothesis.
Shaded cells, trend analysis potentially impacted by variations in detection limits.

Table 8-12 Trends in Flow-Weighted-Mean Concentration, 1998-2007

Concentration Trends (%/Yr) Precip Trend = 3.0 +/- 0.9 cm/yr

Term	TP	TN	TKN	NH3N	NO2N	NO3N	TOC	TOC_F	TIC	SIO2	ALK	CA	CL	NA
Metro	-11	-3	-24	-32	-24	11	-5	-5				3	4	
Bypass		-4	-4	-5							2			
E Flume	-4	-2	-9	-14				-3		-4				2
Trib5A		-7				-10			2	2	3			-3
Harbor/Velasko				-9							1			
Harbor/Lower			-29	-34	-35	28	-21	-18						
Harbor/Hiawatha				-12	-5									
Onondaga/Dorwin				-9					1		1	1	-2	-2
Onondaga/Lower	-10		-6		-10				1			2		
Onond./Kirkpatrick				-8					1		1	1		
Ley/Park	-4	-3	-4	-6	-7							1		3
Ninemile/Rt48	-3		-3	-7	-4				1		1	-3	-6	-4
NonPoint Gauged	-2		-2	-7					1		1	-1		
Total Gauged	-7	-4	-17	-27	-17			-3			1			
Total NonPoint	-2		-2	-7					1		1	-1		
Total Industrial			2		16				2	2	2			4
Total Municipal	-10	-3	-23	-30	-23	11	-5	-5				3	3	
Total Inflow	-7	-4	-17	-26	-16			-3			1			
NP_Rural				-7					1		1	-2	-5	-3
NP_Urban	-6		-5	-6	-8				1		1	2		
Outlet2	-6	-2	-12	-20	-8	6			1	7	1	1		
Outlet12	-8	-3	-14	-23	-10	5			1	8	1		-2	

Concentration Trends, Adjusted for Variations in Rainfall (%/Yr)

Term	TP	TN	TKN	NH3N	NO2N	NO3N	TOC	TOC_F	TIC	SIO2	ALK	CA	CL	NA
Metro		-4	-23	-34	-26		-4	-5				2	5	5
Bypass		-4	-4	-5										
E Flume		-4	-11	-19				-4		-6				3
Trib5A		-7				-9			1		2			-3
Harbor/Velasko				-10									3	4
Harbor/Lower						37								
Harbor/Hiawatha				-8					-1				3	4
Onondaga/Dorwin				-9										
Onondaga/Lower												4	6	6
Onond./Kirkpatrick				-5								2	4	
Ley/Park	-6	-4	-6	-4	-6							1	7	7
Ninemile/Rt48				-7									-3	
NonPoint Gauged				-6										
Total Gauged	-7	-3	-16	-25	-15								2	3
Total NonPoint				-6										
Total Industrial					13				1		1			
Total Municipal		-4	-22	-31	-26		-5	-5				2	5	5
Total Inflow	-7	-3	-15	-24	-14								2	3
NP_Rural				-7									-2	
NP_Urban	-7		-4									3	6	6
Outlet2		-2	-12	-19	-7					11		1		2
Outlet12		-3	-14	-20	-9					13				

Trend magnitudes shown for results with p < .10 for two-tailed hypothesis, p<05 for one-tailed hypothesis.
Shaded cells, trend analysis potentially impacted by variations in detection limits.

Table 8-13 Trends in Load, Mass Units, 1998-2007

Load Trends (mass / yr) , Adjusted for Variations in Rainfall — Precip Trend = 3.0 +/- 0.9 cm/yr

Term	FLOW	TP	TN	TKN	NH3N	NO2N	NO3N	TOC	TOC_F	TIC	SIO2	ALK	CA	CL	NA
Units	hm3	kg	kg	kg	kg	kg	kg	mt	mt	mt	mt	mt	mt	mt	mt
Metro				-125166	-120025	-6660		-45	-43						
Bypass															
E Flume															31
Trib5A	-0.35	-40	-860	-184	-58	-15	-649	-1	-1	-12	-2	-46	-47	-159	-81
Harbor/Velasko	0.37		914		-40									144	98
Harbor/Lower		84												69	
Harbor/Hiawatha	0.52	74	1342				1058					114	92	210	137
Onondaga/Dorwin						299									
Onondaga/Lower													315	4086	2443
Onond./Kirkpatrick													618	4384	2618
Ley/Park						-44								1020	634
Ninemile/Rt48					-2191										
NonPoint Gauged					-3205									4499	3293
Total Gauged				-113219	-101904	-4701								5904	4115
Total NonPoint					-3423									4805	3517
Total Industrial	-0.27		-654	-183	-82		-485	-1	-1				-38		
Total Municipal				-124351	-114449	-6628		-49	-47						
Total Inflow				-112654	-101400	-4581								6211	4340
NP_Rural					-2808										
NP_Urban		-444									9		432	5213	3140
Outlet2				-57743	-51999	-1555					179				
Outlet12				-74649	-63372	-2287					203				

Trend magnitudes shown for results with p < .10 for two-tailed hypothesis, p<05 for one-tailed hypothesis.

Shaded cells, trend analysis potentially impacted by variations in detection limits.

Table 8-14 Yearly Data Used for Model Calibration & Testing

Phosphorus Balance

Water Year	Net Inflow hm3	Metro+ Bypass kg	Total Load kg	Outflow Load kg	Inflow P P Conc ppb	Outflow P Conc ppb	HLR m/yr	Res Time Yrs	Settling Rate m/yr	Lake P Conc ppb	SE ppb
1991	545	53056	97121	55123	178	101	46.5	0.23	35.5	61.5	4.8
1992	483	67573	108270	49880	224	103	41.3	0.26	48.4	63.6	11.6
1993	572	65756	168104	102535	294	179	48.9	0.22	31.3	125.2	15.7
1994	484	56071	81212	66203	168	137	41.3	0.26	9.4	98.2	31.8
1995	298	45061	62085	49542	209	166	25.4	0.43	6.4	70.8	8.4
1996	488	48734	98479	65066	202	133	41.7	0.26	21.4	69.1	6.1
1997	450	38423	79475	52948	176	118	38.5	0.28	19.3	56.9	6.0
1998	475	38388	69667	39197	147	82	40.6	0.27	31.6	54.7	4.7
1999	315	31559	54752	33412	174	106	26.9	0.41	17.2	56.0	5.3
2000	485	29953	58512	37741	121	78	41.5	0.26	22.8	43.5	3.4
2001	412	21357	47493	31423	115	76	35.3	0.31	18.0	38.9	7.4
2002	422	22059	45608	29530	108	70	36.1	0.30	19.7	41.5	3.3
2003	486	36510	62473	40235	129	83	41.6	0.26	23.0	66.6	1.5
2004	593	49786	87229	55931	147	94	50.7	0.21	28.4	59.0	4.1
2005	513	26301	53056	42727	103	83	43.8	0.25	10.6	35.6	1.3
2006	558	12037	46376	30244	83	54	47.7	0.23	25.4	40.7	5.1
2007	571	11239	39527	24318	69	43	48.8	0.22	30.5	25.1	2.1
2003-2007	544	27174	57732	38691	106	71	46.5	0.23	22.9	45.4	7.6

Nitrogen Balance

Water Year	Net Inflow hm3	Metro+ Bypass kg	Total Load kg	Outflow Load kg	Inflow P P Conc ppb	Outflow N Conc ppb	HLR m/yr	Res Time Yrs	Settling Rate m/yr	Lake N Conc ppb	SE ppb
1991	545	1755992	2560250	1962682	4701	3604	46.5	0.23	14.2	4364	168
1992	483	1672009	2418004	1880217	5002	3889	41.3	0.26	11.8	4418	305
1993	572	1387500	2724153	2046168	4759	3575	48.9	0.22	16.2	3701	128
1994	484	1766085	2462262	1947854	5090	4027	41.3	0.26	10.9	4153	274
1995	298	1837802	2209321	1357467	7421	4559	25.4	0.43	16.0	5157	302
1996	488	1847815	2676295	1973197	5489	4047	41.7	0.26	14.8	3873	182
1997	450	1636220	2304162	1603544	5116	3560	38.5	0.28	16.8	3661	180
1998	475	1691731	2340156	1658378	4925	3490	40.6	0.27	16.7	3573	204
1999	315	1252391	1663682	1041103	5287	3309	26.9	0.41	16.1	3378	172
2000	485	1133824	1823711	1448012	3759	2985	41.5	0.26	10.8	2396	78
2001	412	1051118	1638335	1214090	3972	2944	35.3	0.31	12.3	2863	123
2002	422	929115	1478285	1070365	3500	2534	36.1	0.30	13.8	1951	182
2003	486	1112245	1883052	1285293	3873	2644	41.6	0.26	19.3	2549	110
2004	593	1242461	2127565	1568221	3587	2644	50.7	0.21	18.1	2403	128
2005	513	1229985	1935767	1459464	3774	2845	43.8	0.25	14.3	2584	116
2006	558	1074588	1790093	1373718	3207	2461	47.7	0.23	14.5	2477	124
2007	571	1054030	1769335	1397105	3101	2449	48.8	0.22	13.0	2951	49
2003-2007	544	1142662	1901163	1416760	3494	2603	46.5	0.23	15.9	2593	95

Chlorophyll-a Photic Zone or 0-3 m averages

Water Year	Sample Dates	Mean ppb	Std Dev ppb	SE ppb	CV -	Freq > 15 -	Freq > 20 -	Freq > 30 -	Freq > 40 -	Freq > 60 -
1991	20	30.0	25.2	5.6	0.84	60%	50%	45%	30%	10%
1992	18	16.3	10.6	2.5	0.65	56%	28%	17%	0%	0%
1993	9	18.8	19.3	6.4	1.03	33%	33%	33%	11%	0%
1994	9	33.3	42.5	14.2	1.28	44%	44%	44%	44%	22%
1995	9	7.9	4.7	1.6	0.59	0%	0%	0%	0%	0%
1996	8	34.0	28.4	10.0	0.83	75%	75%	63%	13%	13%
1997	9	13.5	13.2	4.4	0.98	44%	11%	11%	11%	0%
1998	12	19.4	10.1	2.9	0.52	50%	33%	17%	0%	0%
1999	19	26.4	18.0	4.1	0.68	74%	58%	42%	21%	5%
2000	17	21.9	16.6	4.0	0.76	59%	53%	24%	12%	0%
2001	17	27.3	25.7	6.2	0.94	47%	41%	35%	29%	18%
2002	18	25.8	15.1	3.6	0.59	72%	61%	28%	22%	0%
2003	17	37.2	28.9	7.0	0.78	76%	71%	53%	29%	18%
2004	18	25.5	13.2	3.1	0.52	67%	61%	39%	22%	0%
2005	17	12.8	4.1	1.0	0.32	35%	0%	0%	0%	0%
2006	17	17.4	5.9	1.4	0.34	53%	41%	0%	0%	0%
2007	17	9.6	5.7	1.4	0.59	6%	6%	0%	0%	0%
2003-2007	17	21	12	4.6	0.51	47%	36%	18%	10%	4%

Secchi Depth

Water	Sample	Mean	Std Dev	SE	CV	Freq < 1.2	Freq < 1.5	HOD (mg/m²-day)		
Year	Dates	m	m	m	-	-	-	< 6 m	< 9 m	< 12 m
1991	7	1.44	1.02	0.39	0.71	57%	71%	1602	1484	1333
1992	9	1.99	1.33	0.44	0.67	0%	22%	1966	1795	1521
1993	9	2.31	1.24	0.41	0.53	11%	22%			
1994	9	2.13	1.01	0.34	0.48	33%	33%			
1995	8	1.99	0.58	0.20	0.29	0%	13%	1393	1364	1270
1996	8	1.56	0.95	0.33	0.61	38%	75%	1477	1354	1191
1997	9	2.97	2.09	0.70	0.70	0%	11%	1095	970	873
1998	9	1.82	0.60	0.20	0.33	22%	33%	927	922	899
1999	18	1.72	1.14	0.27	0.66	28%	44%	1699	1455	1196
2000	17	2.08	0.82	0.20	0.40	6%	24%	1041	988	888
2001	17	2.38	1.29	0.31	0.54	18%	41%	1146	1073	909
2002	16	1.96	0.72	0.18	0.37	0%	25%	1085	988	876
2003	17	1.35	0.49	0.12	0.36	35%	65%	968	946	860
2004	18	1.72	0.33	0.08	0.19	6%	17%	1160	1186	1073
2005	17	1.81	0.45	0.11	0.25	0%	24%	900	794	644
2006	17	1.71	0.34	0.08	0.20	12%	18%	1114	1145	1051
2007	17	2.14	0.75	0.18	0.35	6%	18%	984	866	723
2003-2007	17	1.75	0.47	0.08	0.27	12%	28%	1025	987	870

Nutrient Species

	Total Org. Carbon		Organic N		Inorganic N		TP - SRP		SRP	
Water	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Year	ppm	ppm	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb
1991	6.4	0.47	1034	167	3330	140	58	4.8	3.1	0.1
1992	5.7	0.18	1303	126	3115	213	51	11.0	12.3	4.7
1993	5.3	0.21	941	80	2760	169	96	8.7	29.2	8.7
1994	9.3	4.52	1055	248	3098	137	80	32.3	18.3	6.0
1995	4.8	0.38	1015	154	4142	183	51	5.2	19.9	8.4
1996	6.0	0.34	1018	131	2855	177	62	5.1	7.2	1.9
1997	4.6	0.10	917	61	2745	155	48	3.5	9.0	3.4
1998	4.7	0.12	671	98	2901	200	51	4.4	4.2	0.9
1999	4.7	0.17	915	124	2463	190	50	5.4	5.5	1.7
2000	4.5	0.09	658	25	1739	70	39	3.9	4.6	1.1
2001	4.3	0.15	766	68	2098	177	36	7.4	3.0	0.0
2002	4.4	0.10	751	38	1200	201	39	3.3	3.0	0.0
2003	5.1	0.28	873	72	1676	95	62	1.4	4.5	0.8
2004	5.9	0.26	682	22	1721	140	48	3.3	10.8	3.8
2005	4.5	0.14	608	19	1976	114	33	1.3	3.1	0.1
2006	3.9	0.06	626	27	1852	122	38	5.1	3.0	0.0
2007	3.7	0.07	536	21	2414	32	22	2.1	3.0	0.0
2003-2007	4.6	0.40	692	57	1848	133	40	6.8	4.3	1.5

SE = Standard Error of Mean
Lake Summary Statistics from for South Station, 0-3 m for Grabs or Epil Composites, June-September

Table 8-15 Model Equations & Coefficients

Predicted Trophic Response Variables:

	Po =	Water Year Flow-Wtd-Mean Outflow Total P (ppb)
*	P =	Mean Total P (ppb)
	No =	Water Year Flow-Wtd-Mean Outflow Total N (ppb)
*	N =	Mean Total N (ppb)
*	B =	Mean Chlorophyll-a (ppb)
*	S =	Mean Secchi Depth (m)
	HOD =	Hypolimnetic Oxygen Depletion Rate (mg/m^2-day)
*	TON =	Total Organic Nitrogen (ppb)
*	TP-SRP	Total Phosphorus - Soluble Reactive P (ppb)

* June-August, 0-3 meters, Lake South Station

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 2003-2007

Period	2003-2007	1998-2007	1991-2007
Residual CV	0.12	0.11	0.17
R^2	0.85	0.80	0.78

Lake Surface Total P:

Reference: Walker (1978), Sas (1989)

$P = F_P P_O$

F_P = 0.59 Calibrated to 2004-2007

Period	2003-2007	1998-2007	1991-2007
Residual CV	0.20	0.14	0.18
R^2	0.71	0.74	0.81

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 = 15.9 m/yr

Calibrated to 2003-2007

Period	2003-2007	1998-2007	1991-2007
Residual CV	0.04	0.05	0.05
R^2	0.50	0.84	0.94

Lake Summer Total N:

$N = F_N$ No

F_N = 1.00 Calibrated to 2003-2007

Period	2003-2007	1998-2007	1991-2007
Residual CV	0.15	0.13	0.13
R^2	0.00	0.57	0.77

Lake Photic Zone Chlorophyll-a:

Reference: Jones & Bachman (1976)

$B = 0.081 P^{1.46}$

not recalibrated

Period	2003-2007	1998-2007
Residual CV	0.33	0.32
R^2	0.63	0.00

Algal Bloom Frequencies:

Reference: BATHTUB Walker (1984; 2004)

F_X = 1 - Normal [(ln(X) - ln(B) - 0.5 S_B^2) / S_B]

Normal: Cumulative Normal Frequency Distribution

X = Bloom Criterion (15, 20, 30 or 40 ppb)

F_X = Frequency of Chl-a > X

S_B = Standard Deviation of ln (Chl-a)

$S_B = [\ln (1 + C_B^2)]^{1/2}$

C_B = Within-Year Temporal CV = SD / Mean

C_B = 0.508 Calibrated to 2003-2007

Lake Secchi Depth:

Reference: BATHTUB, Walker (1985; 2004)

$S = 1 / (a + b B)$

a = 0.4014 1/m

b = 0.0091 m^2/mg

Calibrated to 2003-2007

Period	2003-2007	1998-2007
Residual CV	0.14	0.17
R^2	0.24	0.00

Secchi Interval Frequencies:

Reference: Walker (1984)

F_Y = Normal [(ln(Y) - ln(S) - 0.5 S_S^2) / S_S]

Normal: Cumulative Normal Frequency Distribution

F_Y = Frequency of Secchi < Y

Y = Secchi Criterion (1.2 or 1.5 m)

S_S = Standard Deviation of ln (Secchi)

$S_S = [\ln (1 + C_S^2)]^{1/2}$

C_S = Within-Year Temporal CV = 0.27

Calibrated to 2003-2007

Lake Summer Total P - SRP:

Reference: BATHTUB, Walker (1985; 2004)

TP - SRP = -4.1 + 1.78 B + 23.7a

Not recalibrated

Period	2003-2007	1998-2007
Residual CV	0.23	0.17
R^2	0.62	0.59

Lake Summer Organic Nitrogen:

Reference: BATHTUB, Walker (1985; 2004)

TON = K (157 + 22.8 B + 75.3 a)

K = 2003-2007 Calibration = 1.1

	2003-2007	1998-2007
Residual CV	0.19	0.20
R^2	0.00	0.00

Hypolimnetic Oxygen Depletion Rate:

Reference: BATHTUB, Walker (1985; 2004)

$HOD = 240 B^{0.45}$

not recalibrated

Period	2003-2007	1998-2007
Residual CV	0.22	0.19
R^2	0.00	0.00

Table 8-16 Model Inputs & Outputs

Lake Features		
Lake Area	km2	11.7
Mean Hypol Depth	m	7.02
Stratified Period	days	183
Spring DO Conc	ppm	12

Coefficients Calibrated to 2003-2007 Data		
P Settling Rate	m/yr	22.900
Summer UML / Outflow P	-	0.59
Total N Setting Rate	m/yr	15.900
Summer UML / Outflow N		0.996
Chla/P Slope	-	1.4600
Chla/P Intercept	-	0.081
Non-Algal Turbidity	1/m	0.401
Secchi/Chla Slope	m2/mg	0.009
Organic N Calib Factor		1.100
Chla Temporal CV	-	0.508
Secchi Temporal CV	-	0.269

Error Coefficients of Variation for Yearly Simulations, 1998-2007		BATHTUB Calib*
Outflow P Error CV	0.105	0.364
Summer Epil P Error CV	0.139	0.272
Outflow N CV	0.051	0.230
Summer Epil N CV	0.128	0.219
Chl-a Error CV	0.318	0.350
Secchi Error CV	0.172	0.281
HOD Error CV	0.194	0.205
Organic N Error CV	0.200	0.253
TP-OP Error CV	0.173	0.350

Predicted Values			Confidence Intervals for Long-Term Means				Year-to-Year Variations		Observed Mean 1998 - 2007	
			50%	10%	90%		10%	90%		
Output Variable		Units	Mean	Low	High	Std Error	Low	High	Mean	Std Error
Outflow P Conc		ppb	75	72	79	2.5	47	102	76	5.8
Lake P Conc		ppb	44	41	47	1.9	40	86	46	4.0
Mean Chl-a		ppb	20.5	17.6	23.9	2.1	10	32	22	2.5
Algal Bloom Frequencies										
	>	15	66%	54%	77%		16%	91%	54%	7%
	>	20	43%	31%	55%		5%	77%	43%	7%
	>	30	15%	9%	24%		1%	45%	24%	6%
	>	40	5%	3%	9%		0%	23%	14%	4%
	>	60	1%	0%	2%		0%	6%	4%	2%
Mean Secchi Depth		m	1.7	1.6	1.8	0.1	1.4	2.0	1.9	0.09
Secchi Interval Frequencies										
	<	1.2	12%	19%	7%		3%	28%	13%	4%
	<	1.5	37%	49%	26%		16%	60%	31%	5%
	<	2.0	77%	86%	67%		54%	91%	64%	5%
Oxygen Depletion Rate		mg/m^2-day	1087	990	1195	66.7	773	1352	1036	60
Oxygen Depletion Rate		mg/m3-day	155	141	170	9.5	110	193	148	9
Days Hypol. DO < .5 ppm		days	0	0	11		79	123	50	
Days Hypol. DO < 2 ppm		days	0	15	33		92	131	68	
Days Hypol. DO < 5 ppm		days	49	66	78		119	147	102	
Organic N		ppb	721	654	794	45.6	466	1002	708	37
Total P - SRP		ppb	42	39	46	2.3	24	62	42	4

* Error coefficients for BATHTUB original calibration dataset based upon data from 40 reservoirs (Walker, 1985)
shown for comparison with values for Onondaga Lake
Error CV's are for yearly predictions (lower for long-term means).

Table 8-17 Model Interface for Evaluating Management Scenarios

Onondaga Lake Empirical Eutrophication Model — Version: April 27, 2009

Select Scenario:

- Base 1998-2007
- Metro =120
- Metro=120, NPS=50
- Metro=120, NPS=40
- Metro=120, NPS=30
- Metro=20
- Metro =120, NPS=50
- Metro Diverted
- Metro Div, NPS=50
- Metro =120, Model 2
- Metro =120, NPS=40, Model 2

Scenario Index | Detailed Output | Yearly Simulation | Save Scenario | P Load Response | Documen-tation | Delete Scenario | Lake P Response | Sheet Index

User input cells are red

Press 'Ctrl-I' to return here from other worksheets

Define Historical Baseline Period: 1998 2007

Scenario Name: Metro =120

	Scenario: Metro =120			Historical Baseline: 1998 - 2007			Percent Reduction		
	Flow cfs	TP ppb	TP Load kg/yr	Flow cfs	TP ppb	TP Load kg/yr	Flow cfs	TP ppb	TP Load kg/yr
Metro Effluent	102.1	120	10,957	102.1	306	27,919	0%	61%	61%
Metro Bypass	2.2	1118	2,228	2.2	1118	2,228	0%	0%	0%
East Flume	0.6	165	93	0.6	165	93	0%	0%	0%
Trib 5A	2.4	122	261	2.4	122	261	0%	0%	0%
Harbor Brook	11.6	86	891	11.6	86	891	0%	0%	0%
Ley Creek	42.6	94	3,575	42.6	94	3,575	0%	0%	0%
Ninemile Creek	163.9	55	8,076	163.9	55	8,076	0%	0%	0%
Onondaga Creek	184.4	69	11,449	184.4	69	11,449	0%	0%	0%
Nonpoint Ungauged	27.4	67	1,634	27.4	67	1,634	0%	0%	0%
Precipitation	10.8	30	290	10.8	30	290	0%	0%	0%
Evaporation	9.9			9.9			0%		
NonPoint Total	429.9	67	25,625	429.9	67	25,625	0%	0%	0%
Total Municipal	104.3	141	13,185	104.3	323	30,147	0%	56%	56%
Total Industrial	3.0	131	354	3.0	131	354	0%	0%	0%
Total External	537.3	82	39,164	537.3	117	56,126	0%	30%	30%
Total Inflow	548.1	80	39,454	548.1	115	56,416	0%	30%	30%
Outflow	538.2	53	25,345	538.2	76	36,341			30%
Retention			14,109			20,074			

Output Variable		Predicted	Std Error	Observed	Std Error	Percent Reduction
Outflow TP ppb	ppb	53	1.7	76	5.8	30%
Lake Total P	ppb	31	1.4	46	4.0	33%
Mean Chlorophyll-a	ppb	12.2	1.2	22.3	2.5	45%
Mean Secchi	m	2.0	0.1	1.9	0.1	-4%

Yearly Simulation

Scenario: Metro =120

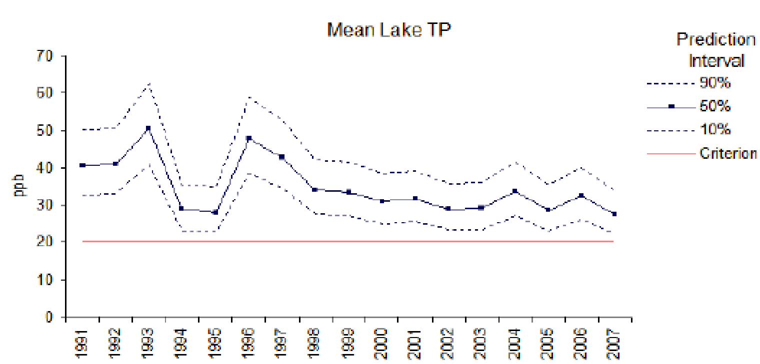
Select Scenario

- Base 1998-2007
- Metro =120
- Metro=120, NPS=50
- Metro=120, NPS=40
- Metro=120, NPS=30
- Metro=20
- Metro =120, NPS=50
- Metro Diverted
- Metro Div, NPS=50
- Metro =120, Model 2
- Metro =120, NPS=40, Model 2

Plot Variable

- Outflow TP Conc
- Mean Lake TP
- Mean Chlorophyll-a
- Freq Chla > 15 ppb
- Freq Chla > 20 ppb
- Freq Chla > 30 ppb
- Freq Chla > 40 ppb
- Freq Chla > 60 ppb
- Mean Secchi Depth
- Freq Secchi < 1.2 m
- Freq Secchi < 1.5 m
- Freq Secchi < 2.0 m
- Area O2 Depletion Rate
- Vol. O2 Depletion Rate
- Days Hypol. DO < .5 ppm
- Days Hypol. DO < 2 ppm
- Days Hypol. DO < 5 ppm
- Organic Nitrogen
- Total P - SRP

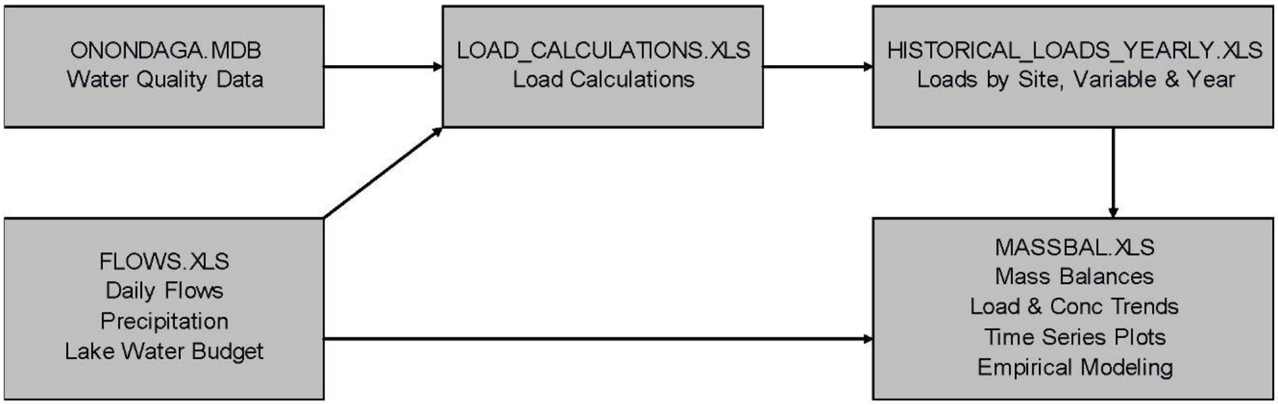
Go To Input Sheet



Criterion = AMP Goal or Guidance Value for Long-Term Mean

8.10 FIGURES

Figure 8-1
Mass Balance Computations Integrated with AMP Long-Term Database



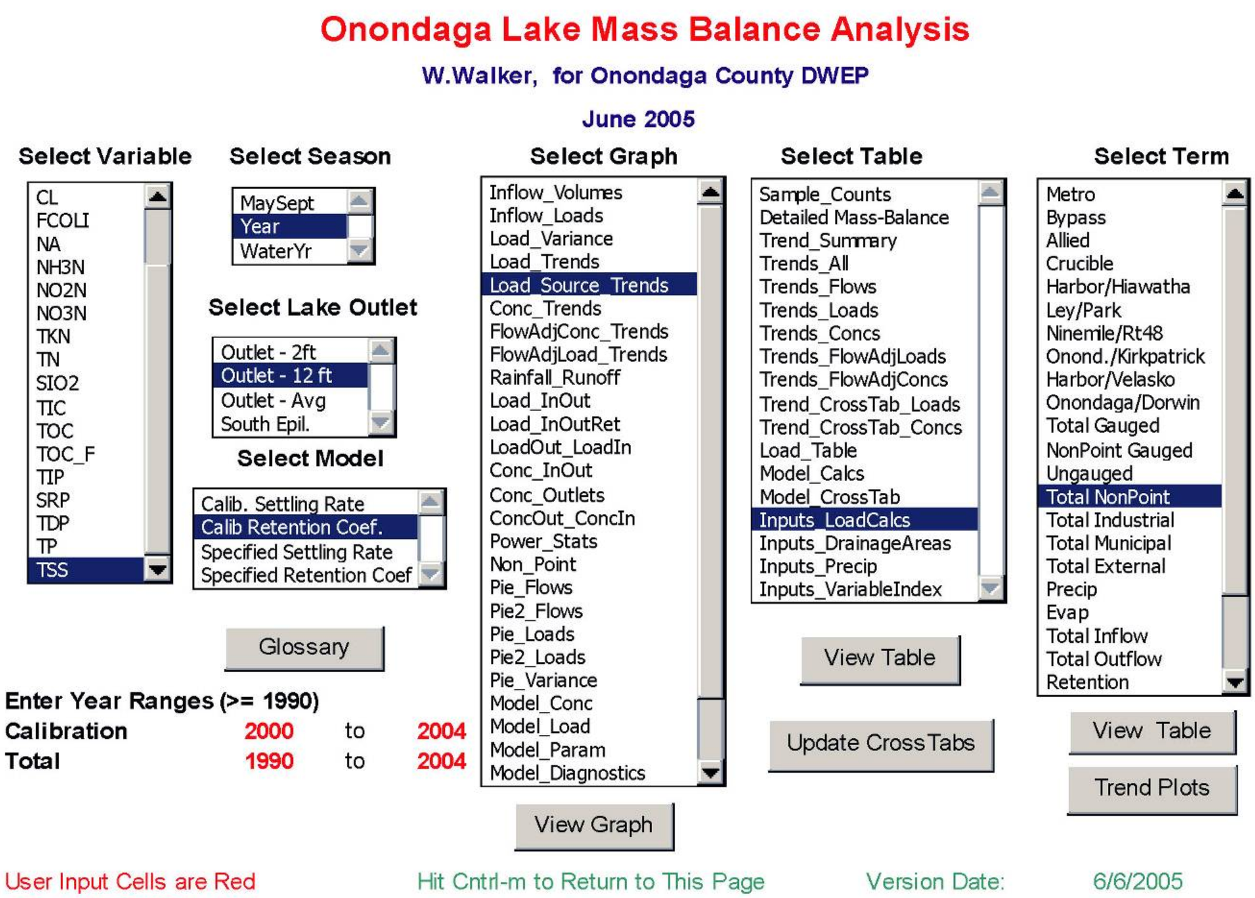
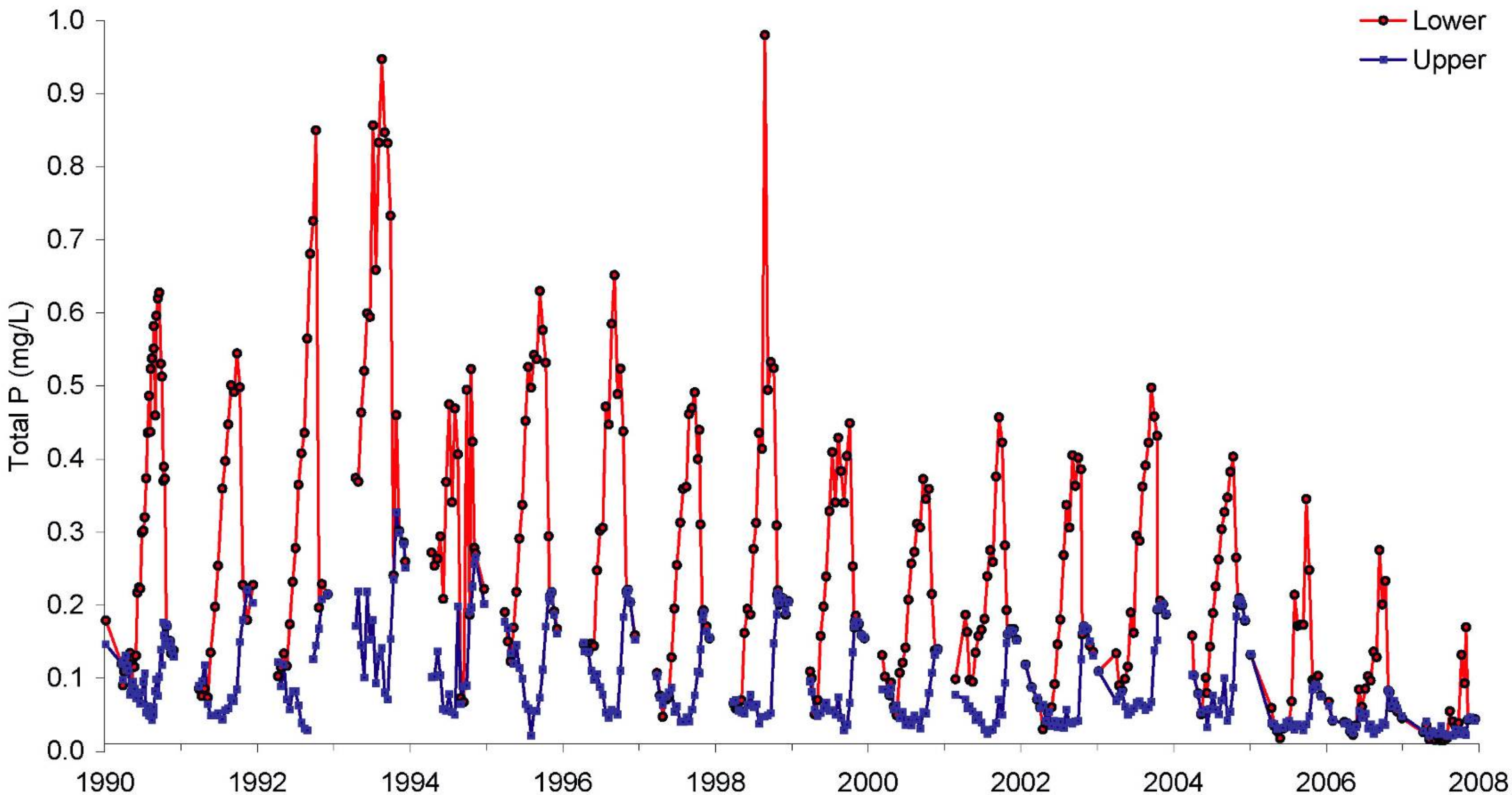
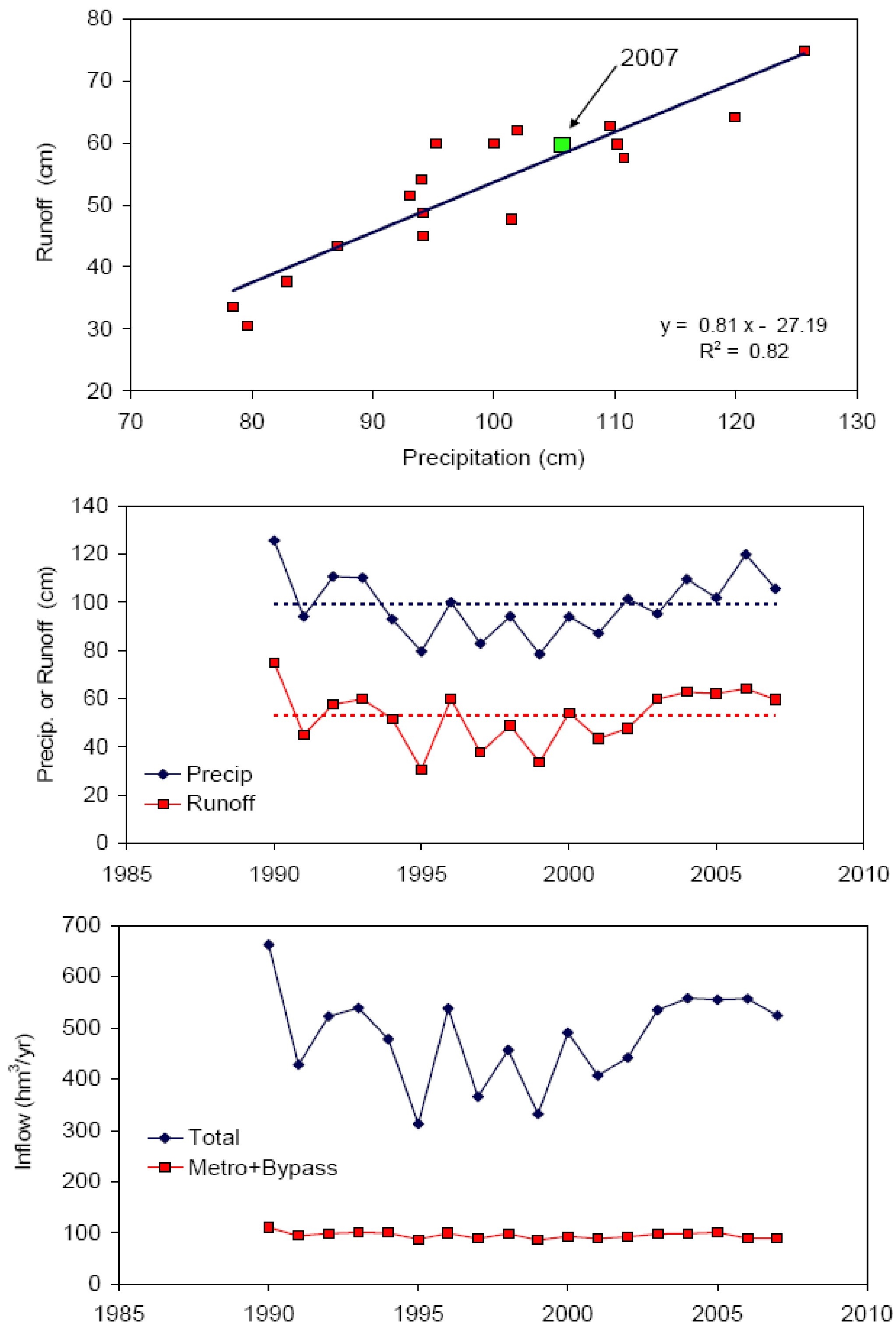


Figure 8-2
Long-Term Trends in Lake Phosphorus Concentration



Lower 9 - 18 meters, South Deep station
Upper 0 - 3 meters

Figure 8-3
Precipitation, Runoff, & Lake Inflow Volumes



X Axis: Calendar Year

Figure 8-4
Long-Term Variations in Total Inflow & Outflow Concentrations

Squares = Inflow, Circles = Outflow   Error Bars = +/- 1 Standard Error   X-Axis = Calendar Year

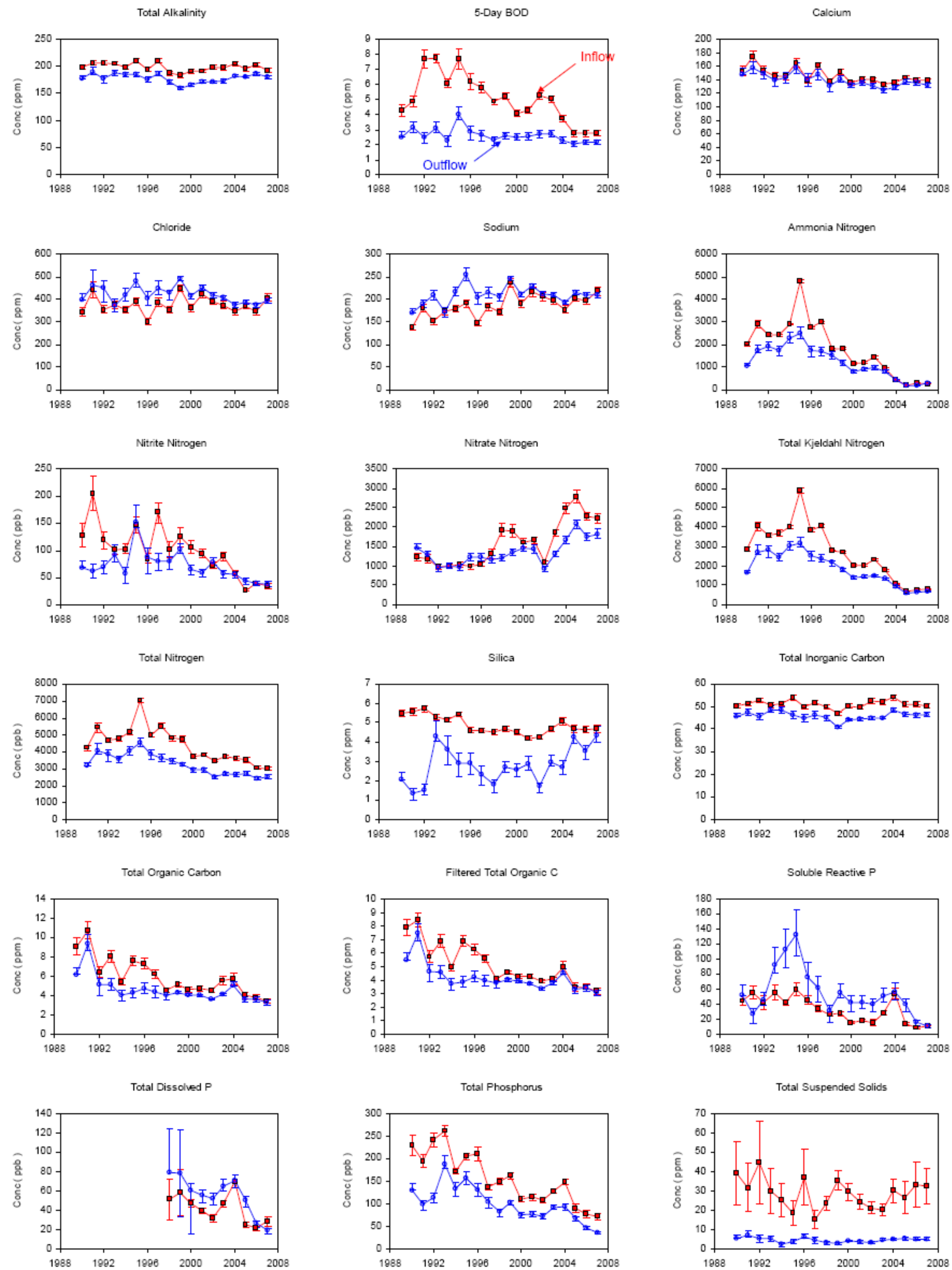


Figure 8-5
Long-Term Variations in Total Inflow & Outflow Loads

Squares = Inflow, Circles = Outflow   Error Bars = +/- 1 Standard Error   X-Axis = Calendar Year

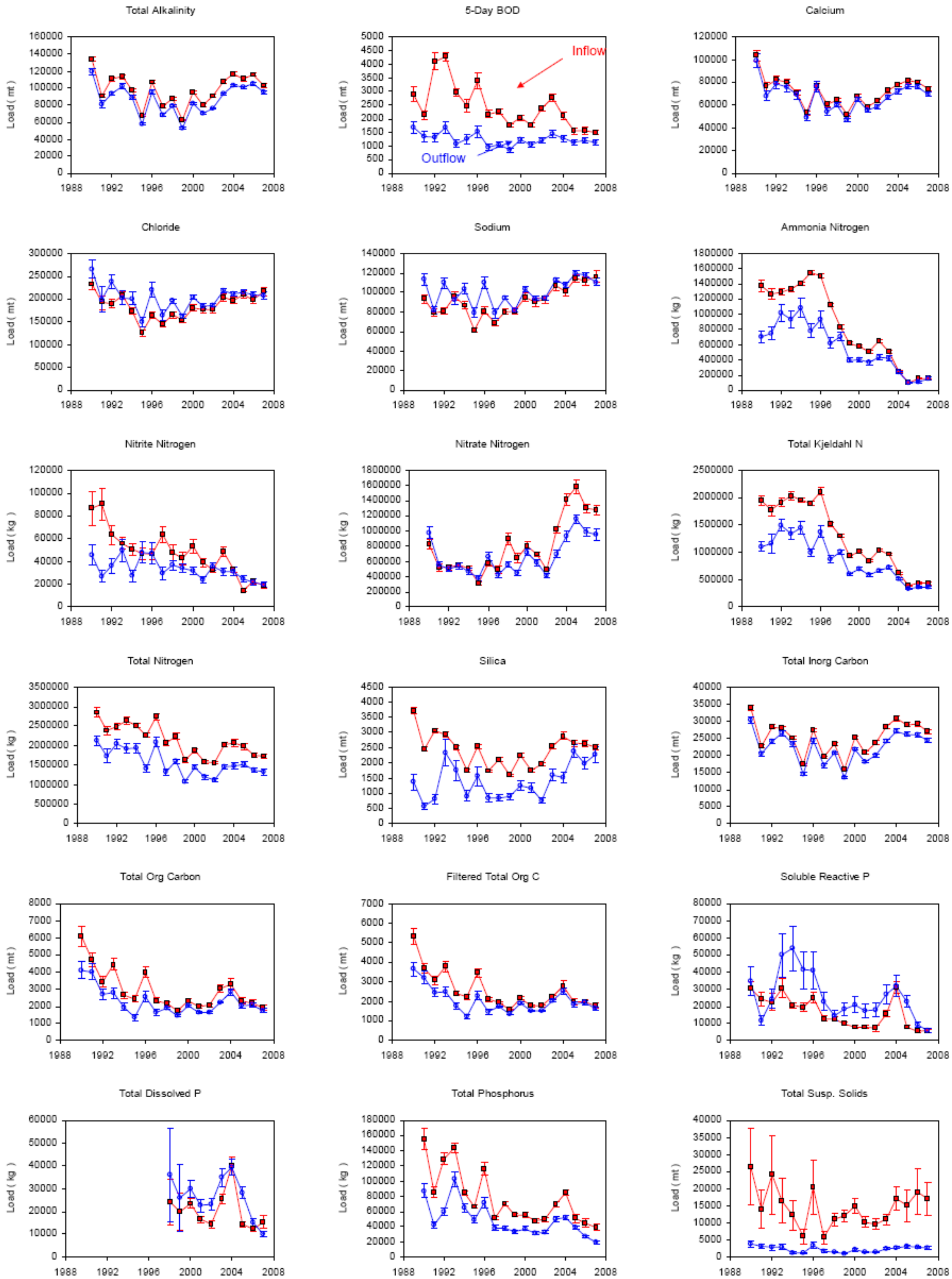


Figure 8-6
Long-Term Variations in NonPoint & Metro Loads

Squares = NonPoint Sources, Circles = Metro + Bypass   Error Bars = +/- 1 Standard Error   X-Axis = Calendar Year

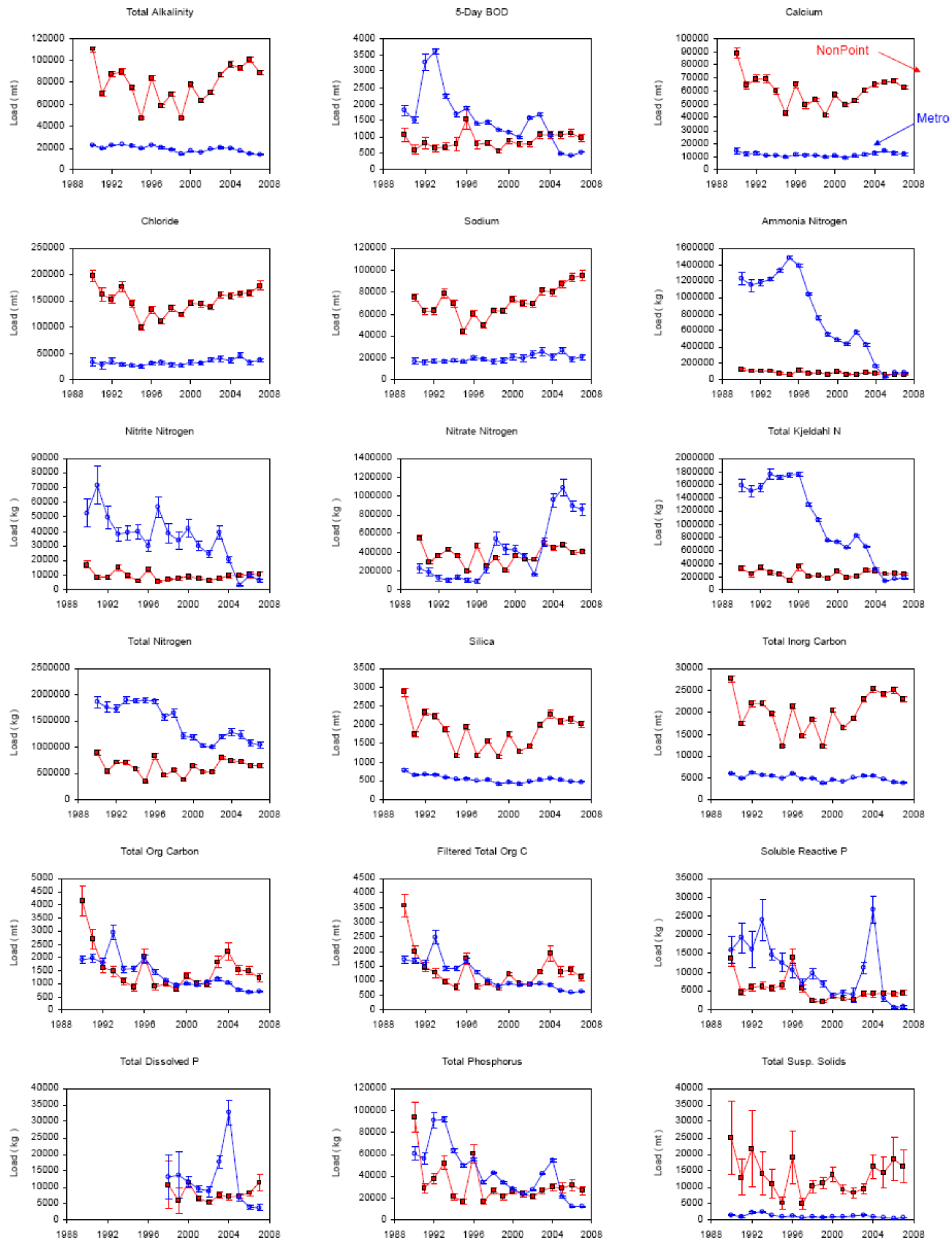
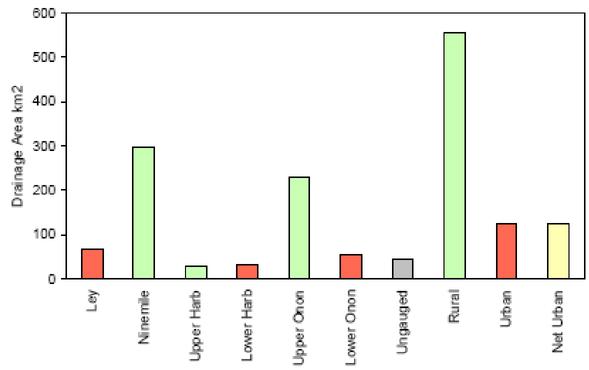


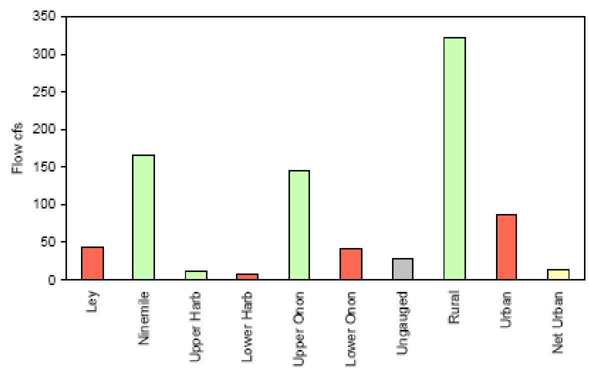
Figure 8-7 Spatial Variations in NonPoint Phosphorus Loads

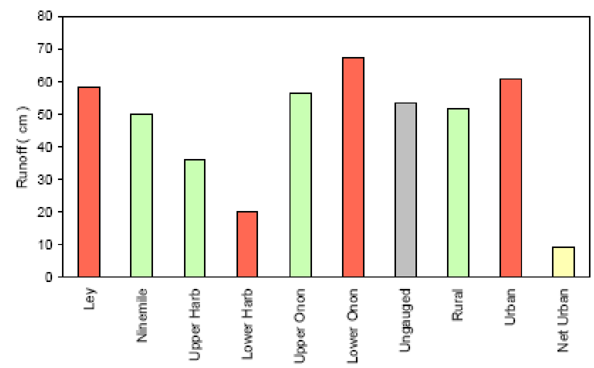
Variable: Total Phosphorus Period: 1998 - 2007

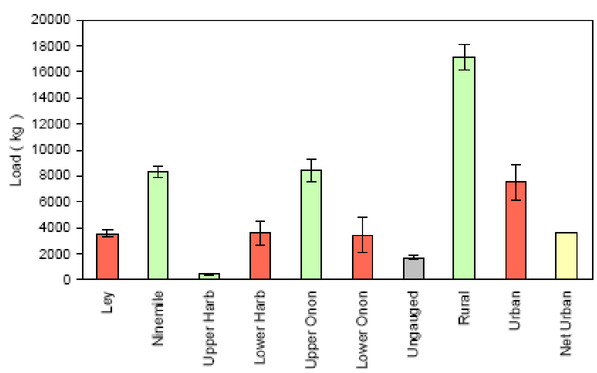
Total Values | Unit Area Values

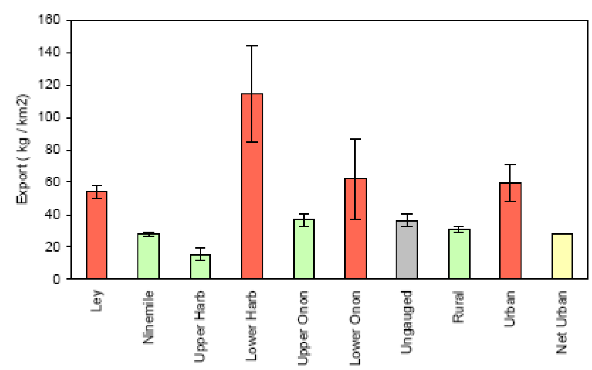


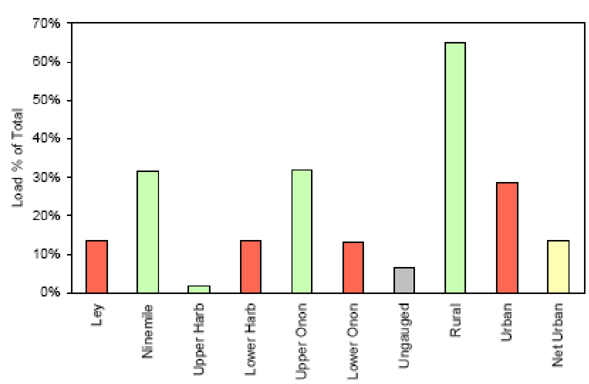
Label	Description
Ley	Above Park
Ninemile	Above Lakeland
Upper Harb	Above Velasko
Lower Harb	Between Velasko & Hiawatha
Upper Onon	Above Dorwin
Lower Onon	Between Dorwin & Kirkpatrick
Ungauged	Ungauged Watershed (Estimated)
Red	Lower Watersheds (~ Urban)
Green	Upper Watersheds (~ Rural)
Yellow	Net From Lower/Urban Areas vs. Rural Background











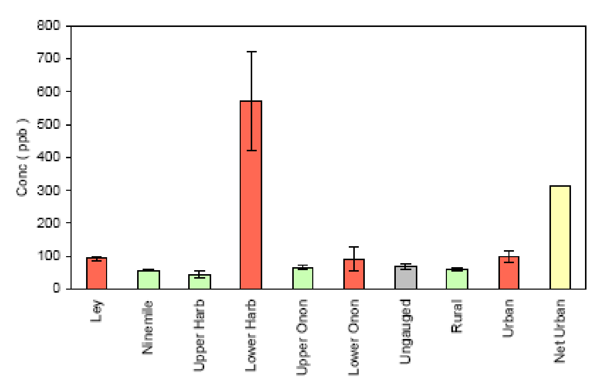
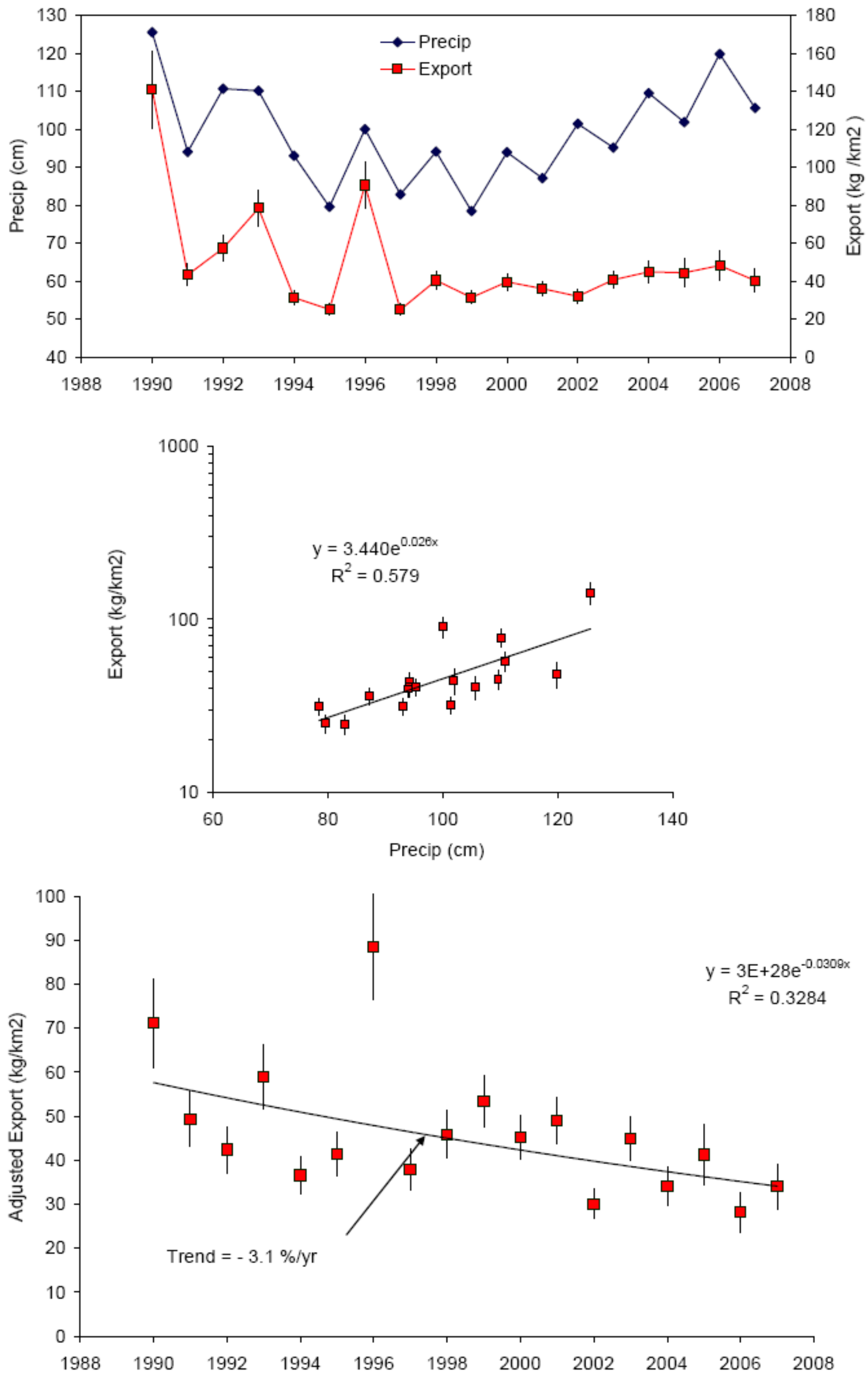


Figure 8-8 Adjustment of NonPoint P Loads for Variations in Rainfall



P_Export = Total Nonpoint Load (kg/yr) / Watershed Area (km2)

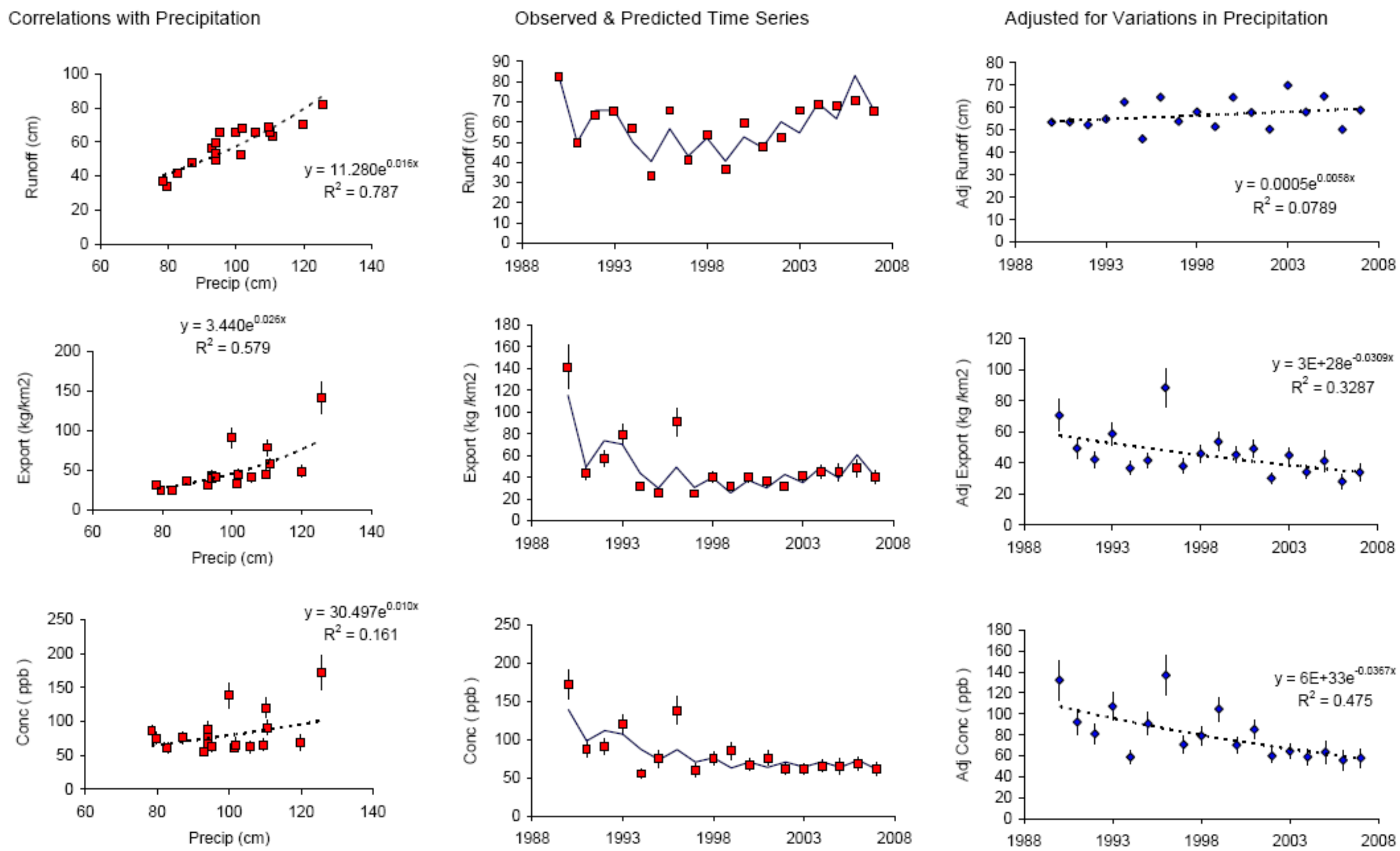
Precip = Hancock Airport Precipitation (cm)

Adjusted_P_Export = P_Export Adjusted for Yearly Variations in Precipitation

Adjusted_P_Export = Measured_P_Export x Exp [.026 x (Mean_Precip - Precip)]

Trend in Adjusted_P_Export (% per year) = -3.1% +/- 1.1% p= 0.016

Figure 8-9 Trends in Nonpoint Runoff, Total P Load, & Concentration, 1990-2007



Dashed Line = Regression vs. Precip
Vertical Bars = +/- 1 Standard Error of Measured Yearly Value

Solid Line = Regression vs. Year and Precip

Dashed Line = Regressionof Adjusted Value vs. Year

Regression Model: Ln (Y) = A0 + A1 Year + A2 Precip — Years: 18

Adjustment to Mean Precip: Ln (Yadjusted) = Ln (Y) + A2 (Mean_Precip - Precip) — Mean_Precip = 99 cm/yr

	Ln Runoff vs. Precip & Year			Ln Export vs. Precip & Year			Ln Conc vs. Precip & Year		
	Coef	SE	p	Coef	SE	p	Coef	SE	p
A0	-9.22861			62.94281			76.77659		
A1 (Yr)	0.00583	0.00515	0.27	-0.03089	0.01140	0.02	-0.03672	0.00997	0.00
A2 (Precip)	0.01623	0.00210	0.00	0.02607	0.00465	0.00	0.00984	0.00407	0.03
R^2	0.80350			0.71735			0.55930		
Std Error	0.11324			0.25089			0.21942		

Summary of Trends (Percent / Year)

	Trend	p
Runoff	0.6%	0.27
Export	-3.1%	0.02
Conc	-3.7%	0.00

Figure 8-10 Trends in Rainfall-Adjusted Phosphorus Loads from Individual Sources, 1990-2007

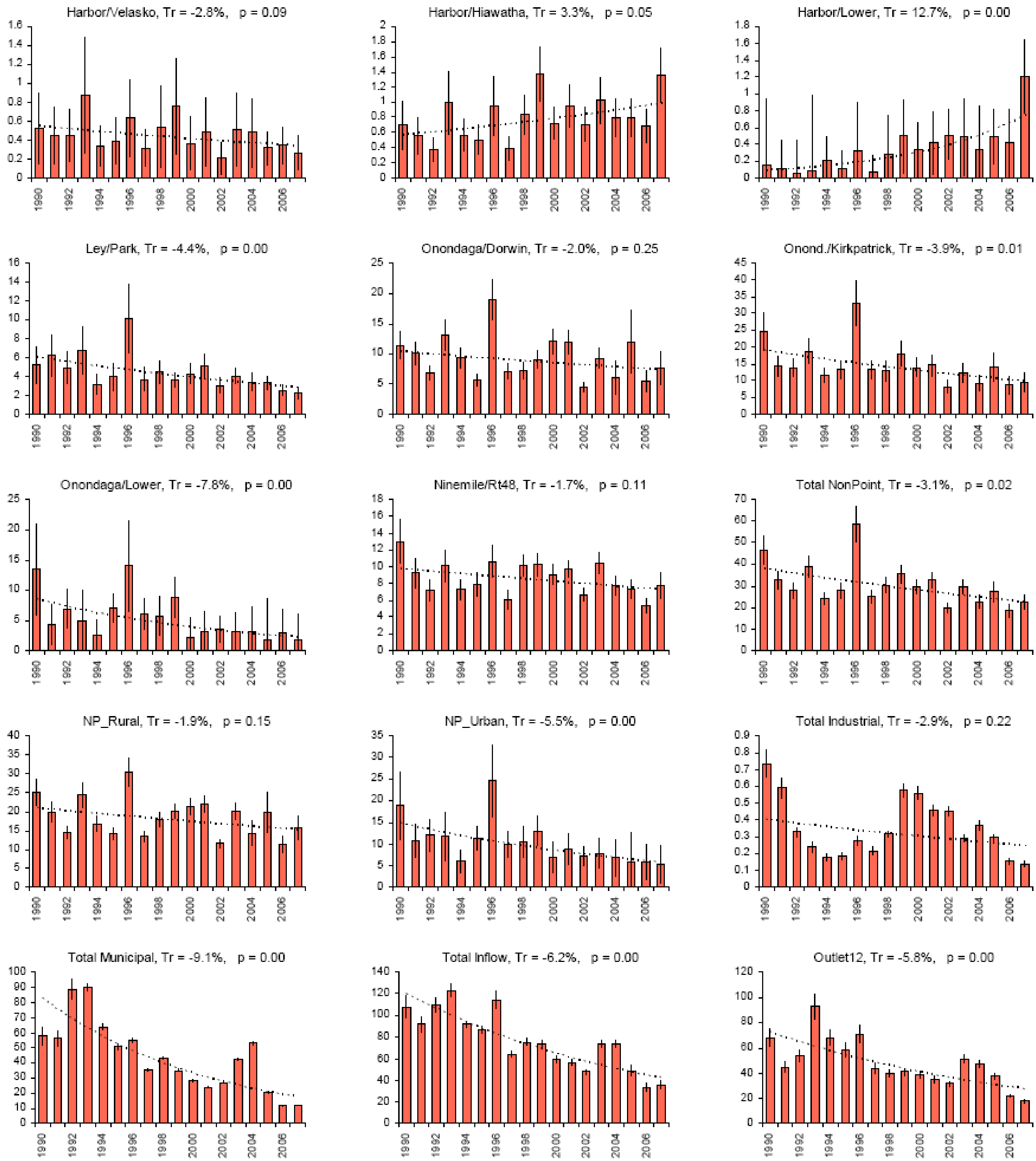
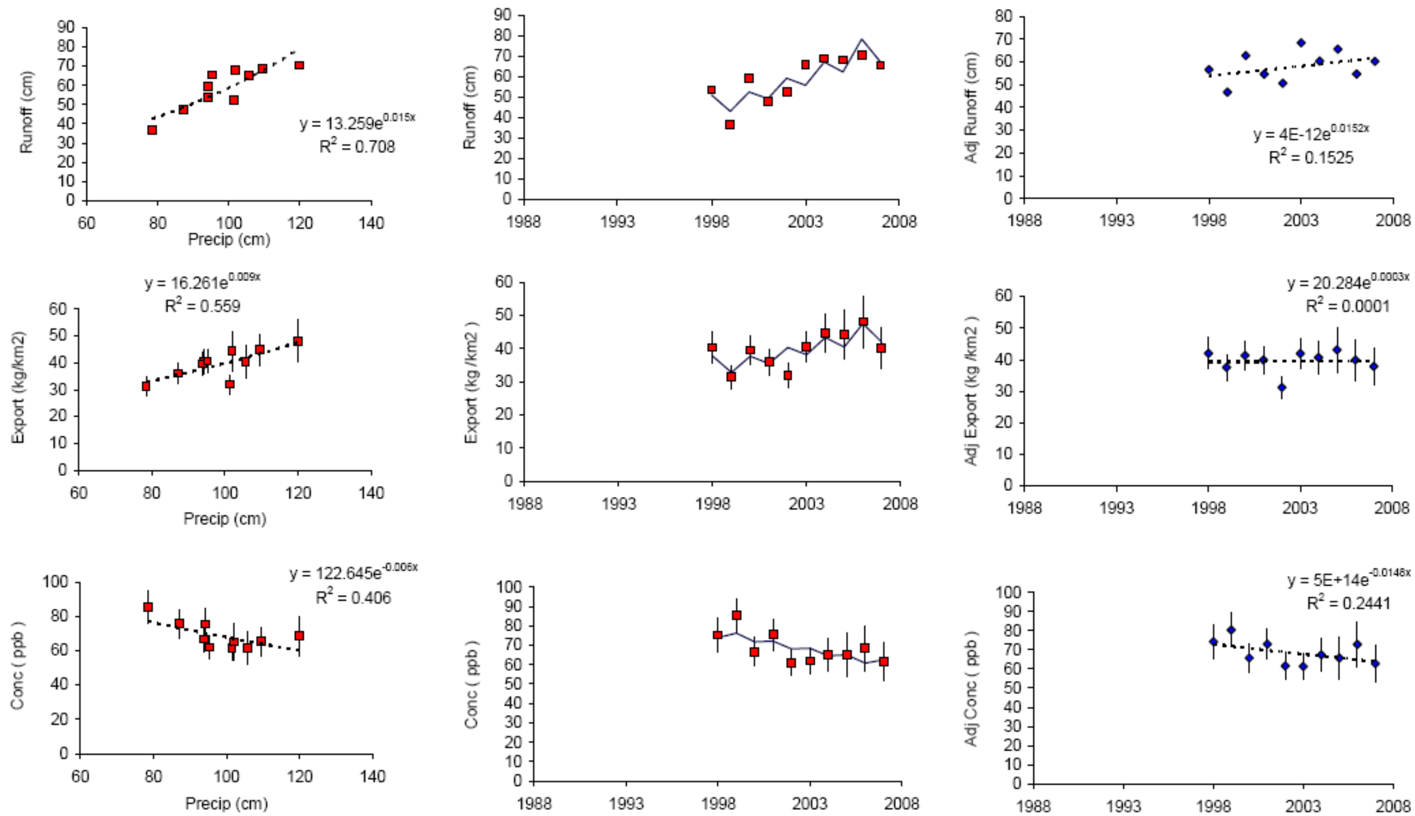


Figure 8-11 Trends in Nonpoint Runoff, Total P Load, and Concentration, 1998-2007

Correlations with Precipitation | Observed & Predicted Time Series | Adjusted for Variations in Precipitation



Dashed Line = Regression vs. Precip
Vertical Bars = +/- 1 Standard Error of Measured Yearly Value

Solid Line = Regression vs. Year and Precip

Dashed Line = Regressionof Adjusted Value vs. Year

Regression Model: Ln (Y) = A0 + A1 Year + A2 Precip Years: 10

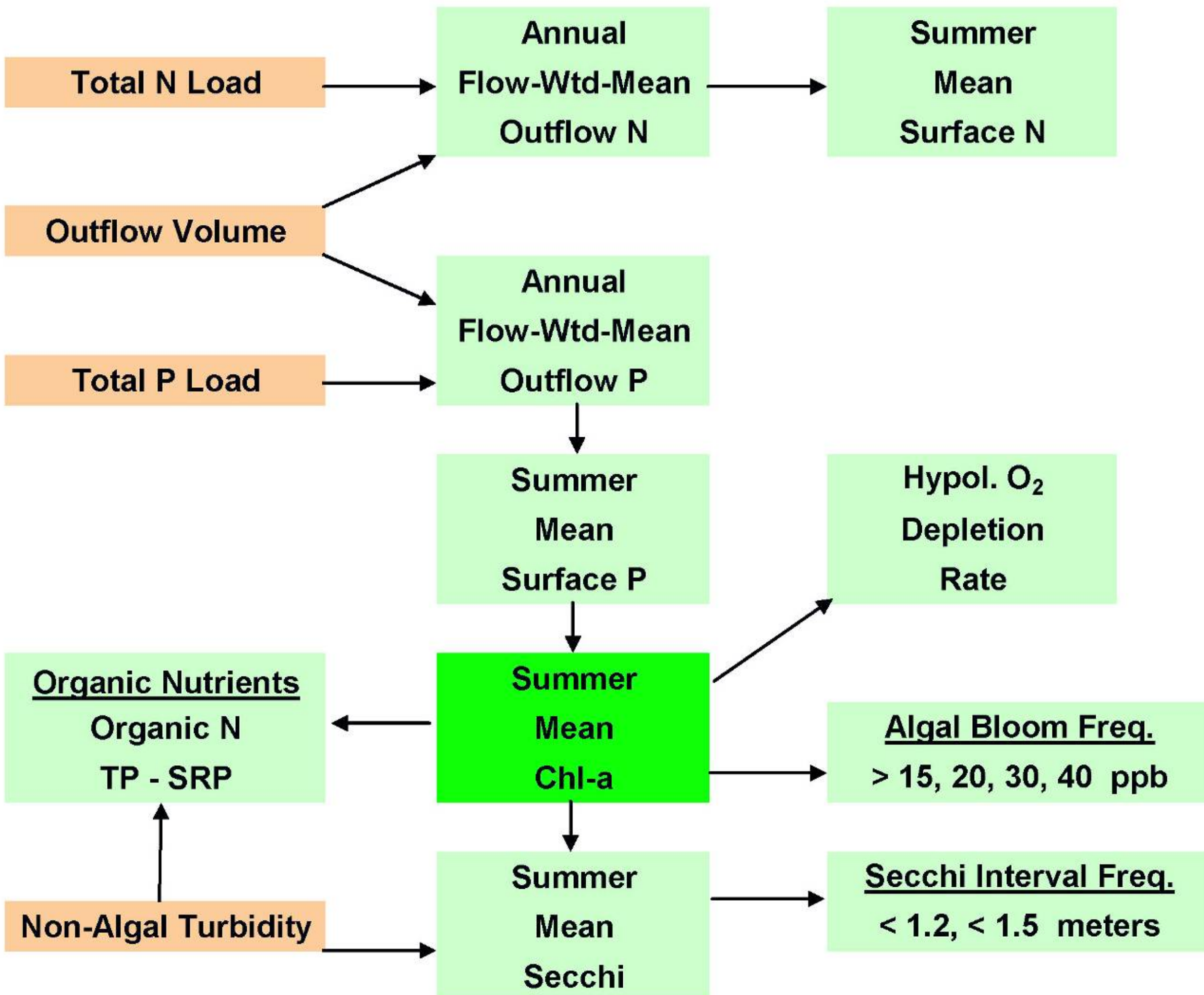
Adjustment to Mean Precip: Ln (Yadjusted) = Ln (Y) + A2 (Mean_Precip - Precip) Mean_Precip = 99 cm/yr

	Ln Runoff vs. Precip & Year			Ln Export vs. Precip & Year			Ln Conc vs. Precip & Year		
	Coef	SE	p	Coef	SE	p	Coef	SE	p
A0	-27.48206			2.13101			34.21824		
A1 (Yr)	0.01516	0.02139	0.50	0.00033	0.01842	0.99	-0.01483	0.01562	0.37
A2 (Precip)	0.01186	0.00553	0.07	0.00890	0.00476	0.10	-0.00296	0.00404	0.49
R^2	0.72751			0.55938			0.47408		
Std Error	0.12274			0.10568			0.08961		

Summary of Trends (Percent / Year)

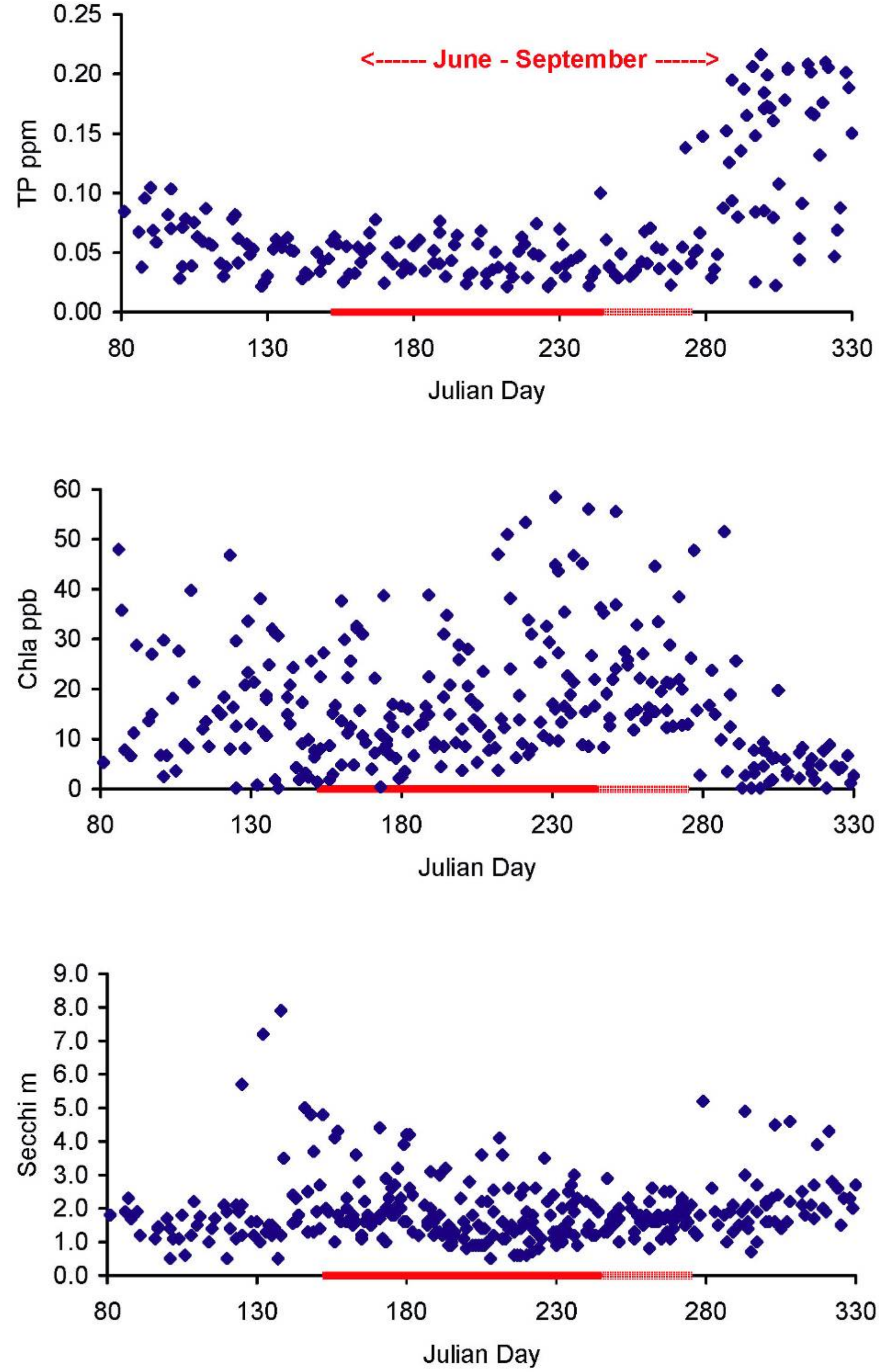
	Trend	p
Runoff	1.5%	0.50
Export	0.0%	0.99
Conc	-1.5%	0.37

Figure 8-12 Onondaga Lake Empirical Eutrophication Model



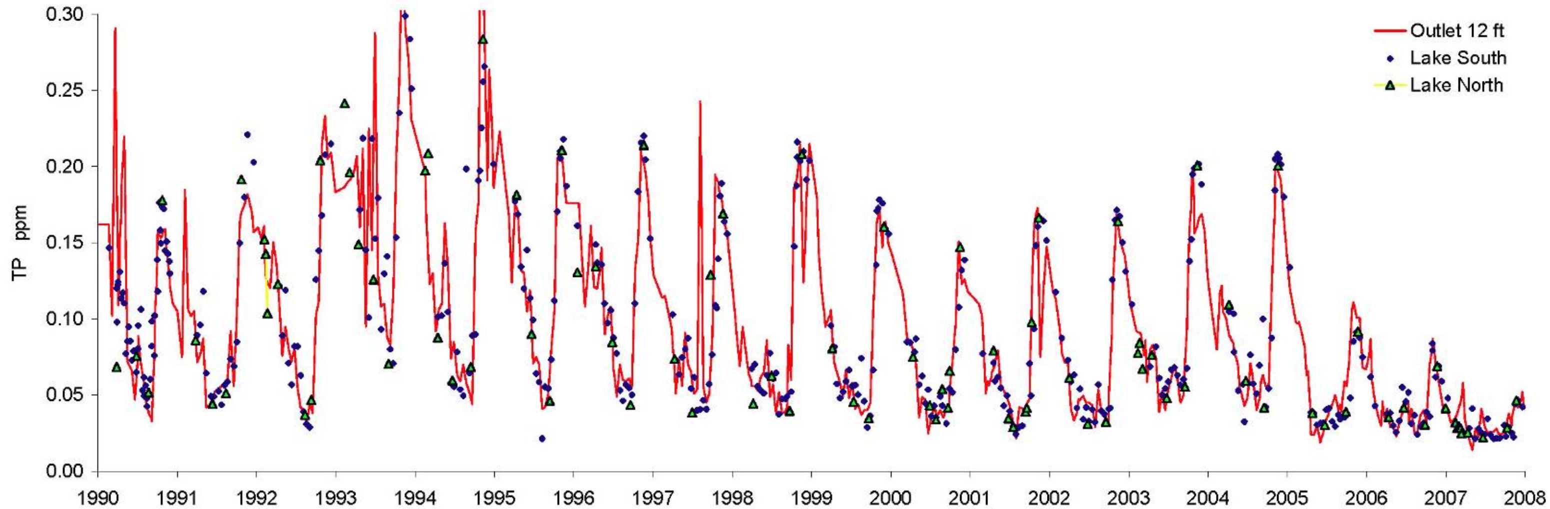
Adapted from BATHTUB (Walker, 2006)

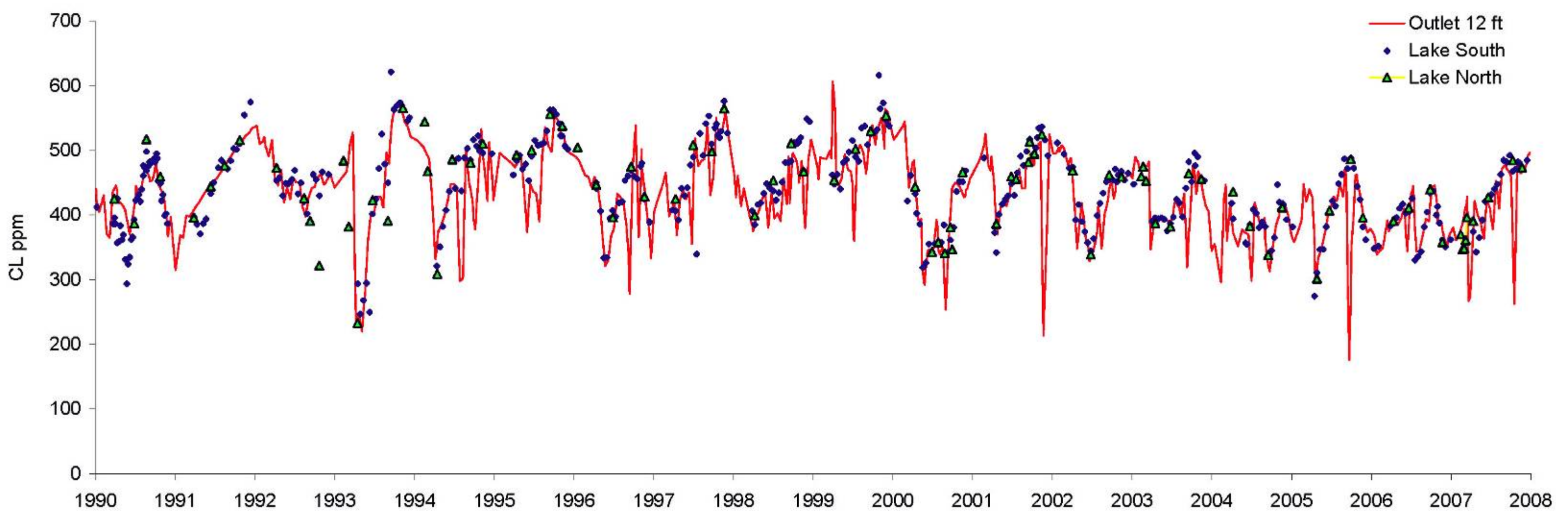
Figure 8-13 Seasonal Variations in Trophic State Indicators



Red bars show June-September averaging period.
Data from Lake South Upper Mixed Layer, 1998 - 2007

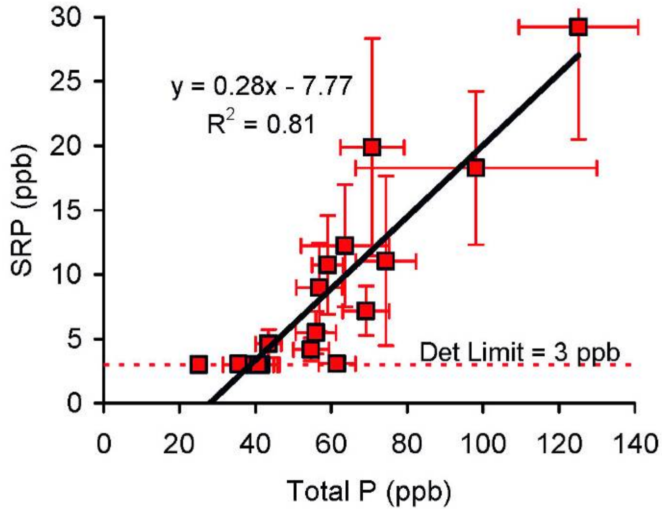
Figure 8-14 Total Phosphorus & Chloride in Lake Upper Mixed Layer & Outlet

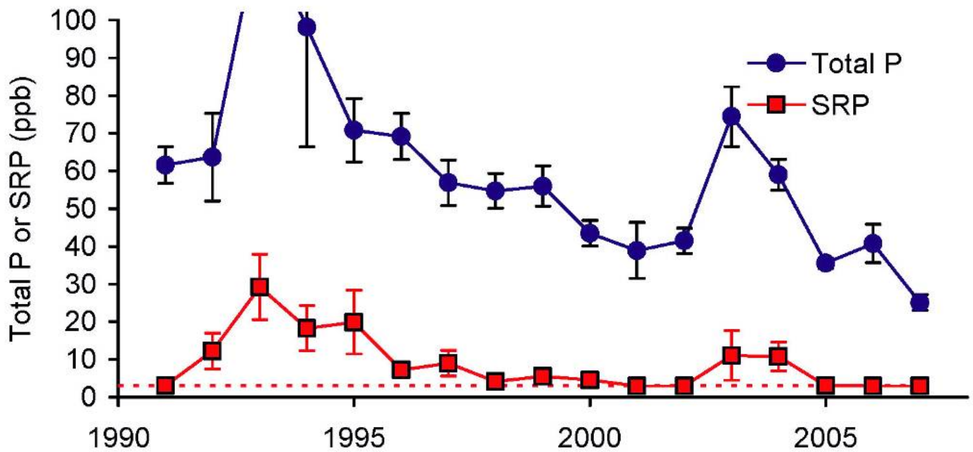




Volume 127.53 hm3 WY 2007

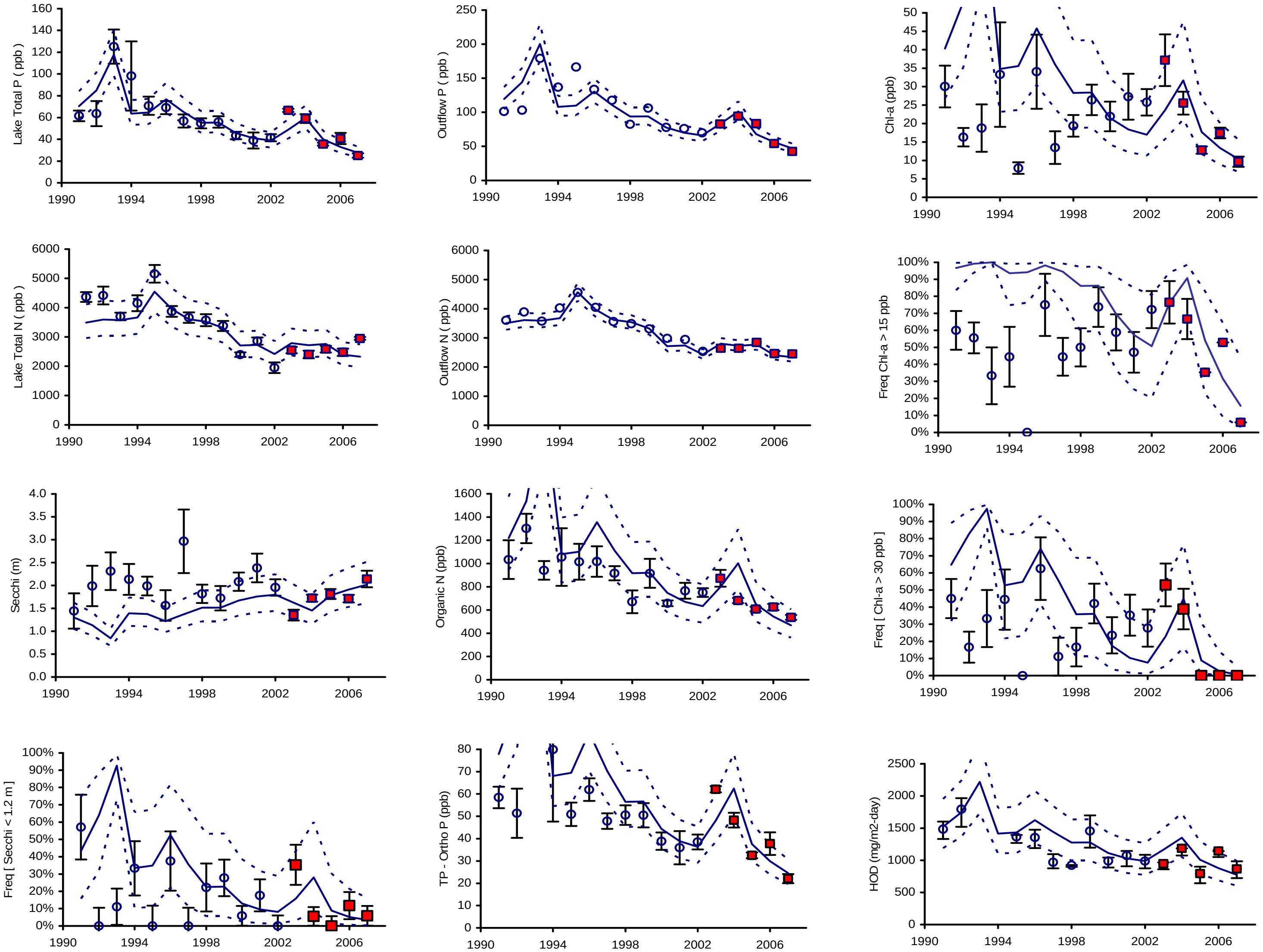
Figure 8-15 Soluble Reactive P vs. Total P Concentrations





June-September Means, 0-3 meters, Lake South Station
Error bars show mean +/- 1 standard error

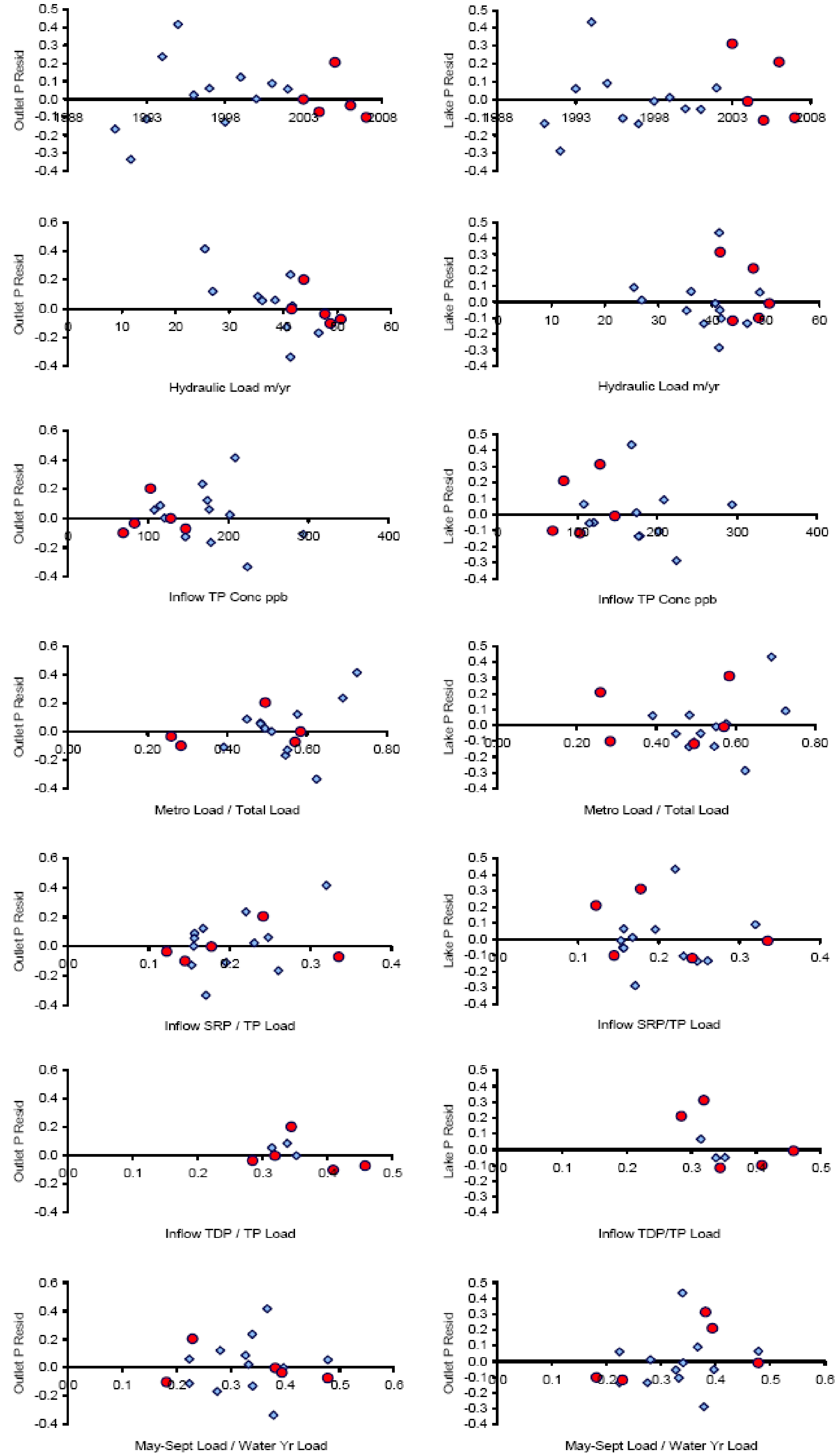
Figure 8-16. Observed and Predicted Time Series



Square Symbols = Calibration Period; Observed Means +/- 1 Std Error

Lines = 80% Prediction Intervals

Figure 8-17 Phosphorus Residuals vs. Various Factors



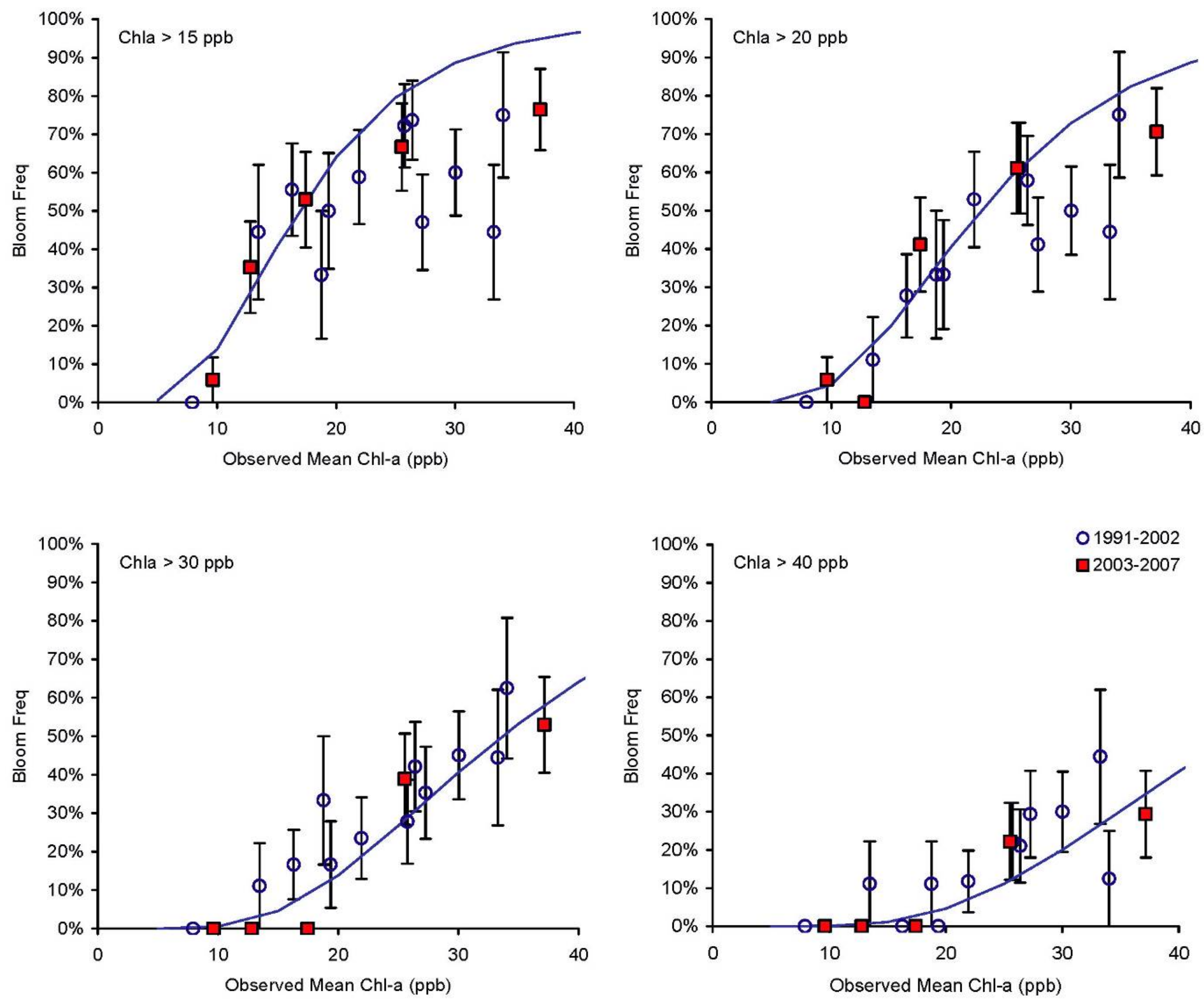
Residual = Observed - Predicted Concentration

Red circles = calibration period (2003 - 2007)

Red symbols = calibration period (2003-2007)

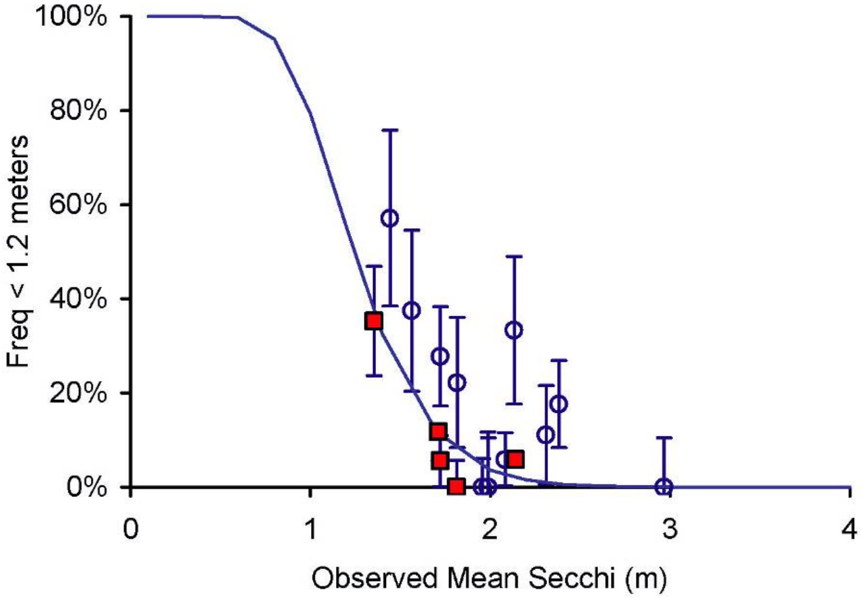
Residual = LN (observed/predicted concentration)

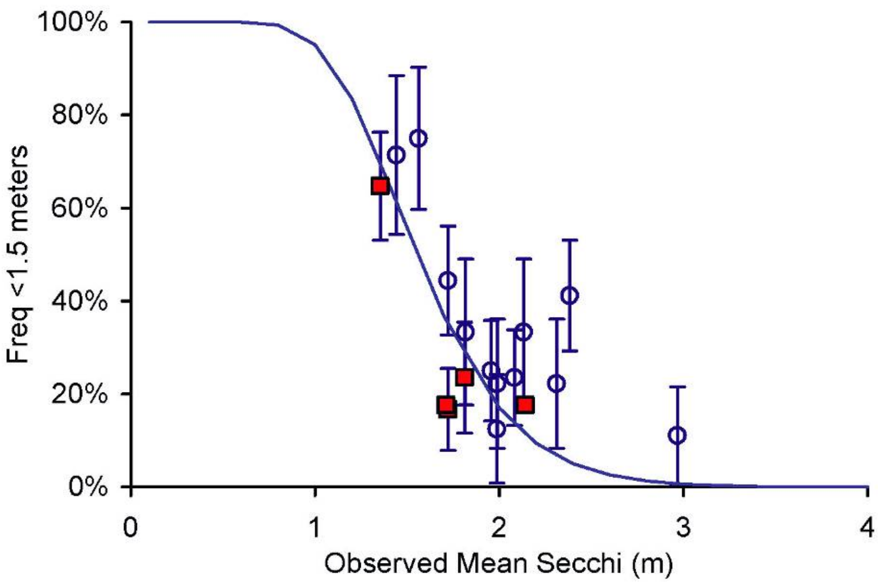
Figure 8-18 Algal Bloom Frequencies vs. Observed Mean Chlorophyll-a



Model: Log-Normal Frequency Distribution, CV = 0.51 Months: 6 thru 9

Figure 8-19 Secchi Interval Frequencies vs. Mean Secchi Depth



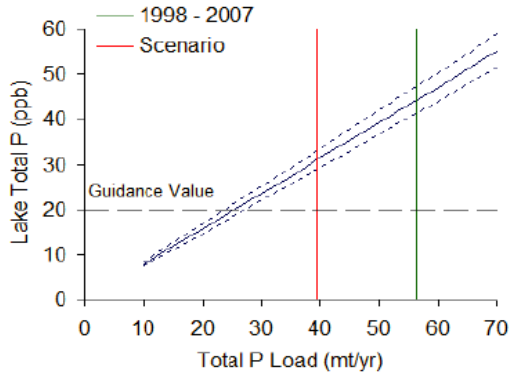


Model: Log-Normal Frequency Distribution, CV = 0.27
Months: 6 thru 9

Figure 8-20 Predicted Lake Responses to Reductions in Phosphorus Load

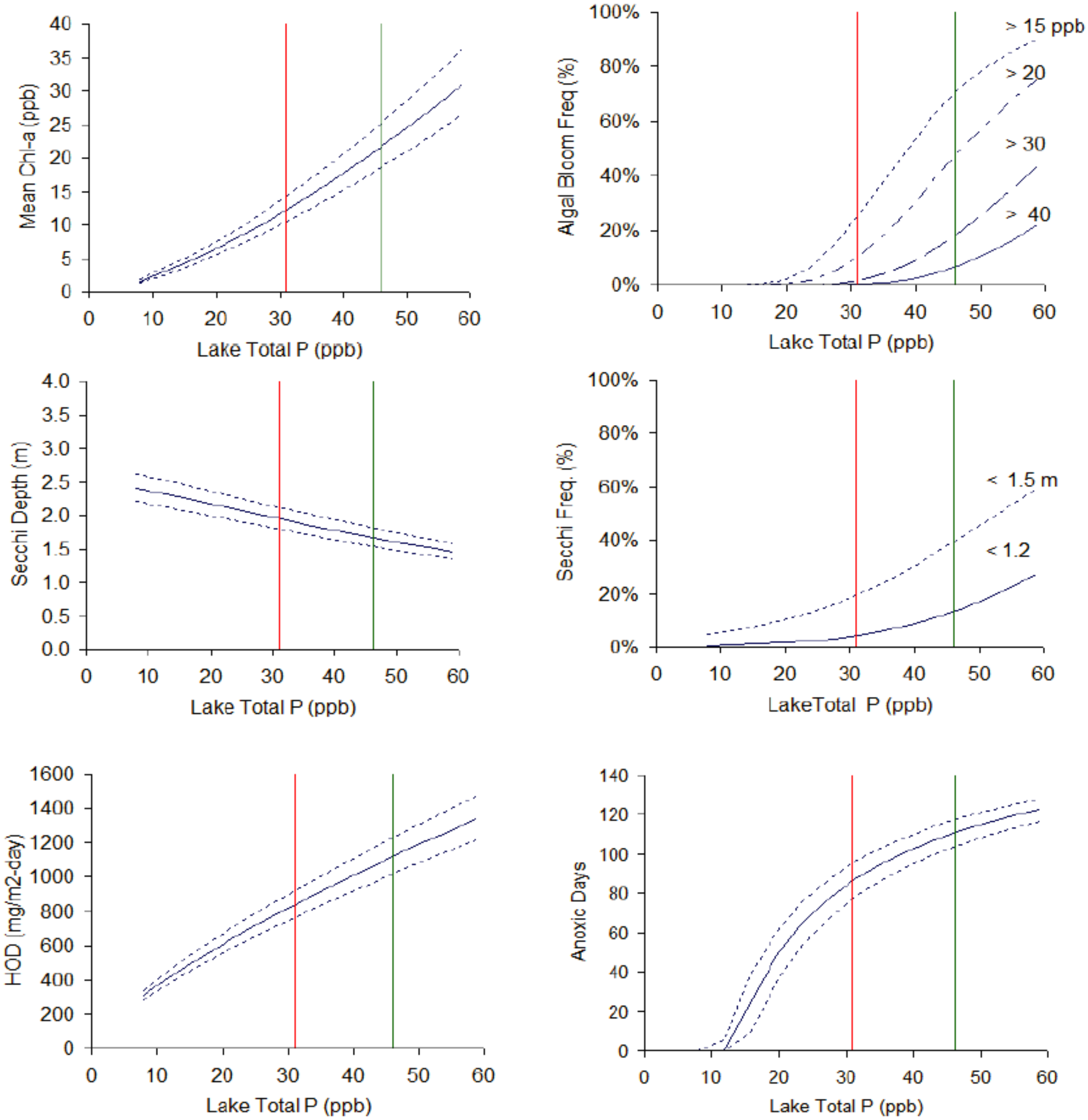
Onondaga Lake Empirical Eutrophication Model
Scenario: Metro =120

Responses to Phosphorus Load & Concentration
Historical Baseline: 1998 - 2007



		Scenario	Baseline
Outflow Volume	cfs	538	538
Total P Load	kg/yr	39.5	56.4
Lake TP	ppb	31	46

Dashed lines show 80% prediction intervals for long-term mean
Vertical Lines = Scenario & Historical Averages



CHAPTER 9: TMDL ALLOCATION FOR PHOSPHORUS

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CHAPTER 9. TMDL ALLOCATION FOR PHOSPHORUS

9.1 REGULATORY BACKGROUND

The Clean Water Act (PL92-500) serves as the legislative foundation for managing water resources in the U.S. As promulgated in 1972, the Clean Water Act addresses both human uses and ecological integrity of surface waters. This dual focus on human-centered as well as ecological metrics is evident in the Act's commitment to protecting public health, ensuring that waters are "fishable and swimmable" and maintaining the "chemical, physical, and biological integrity of the Nation's waters" (§101a). In order to evaluate the extent to which these goals are met, resource management agencies monitor water quality and habitat conditions and compare these measured conditions with ambient water quality standards and criteria. Ambient water quality standards and criteria are numerical or narrative limits on levels of pollutants that result in conditions that support the designated use of a waterbody.

Despite the decades of investment in source controls, municipal and industrial wastewater treatment, storm water management, air pollution controls and other technical and regulatory approaches to reducing point and nonpoint source pollution, water quality problems persist in some areas. The Clean Water Act requires the States to monitor water quality and habitat conditions to identify impaired waters where designated uses are not fully supported. For these impaired waters, States must consider development of a *Total Maximum Daily Load (TMDL)* or other strategy to reduce the input of the specific pollutant(s) restricting waterbody uses, in order to restore and protect such uses. The resulting lists are termed 303(d) lists, named for the section of the Clean Water Act requiring their submittal to the EPA for review and approval.

9.2 NEW YORK STATE SECTION 303(d) LISTS

In 1996, New York began submitting their Section 303(d) list of impaired waters for EPA approval. Lists are updated every two years. Lakes, stream and rivers, estuaries, and coastal waters, or segments thereof exhibiting water quality or habitat conditions that preclude attainment of the designated use are placed in one of several categories. The following description of the reporting categories is posted on the NYSDEC web site *http://www.dec.ny.gov/chemical/31290.html*.

Part 1 Individual Waterbody Segments with Impairments Requiring TMDL Development

These are waters with verified impairments that are expected to be addressed by a segment/pollutant-specific TMDL or other restoration strategy.

Part 2 Multiple Segment/Categorical Waterbody Impairments Requiring TMDL Development

These are groups of waters affected by similar causes/sources where a single TMDL may be able to address multiple waters with the same issue. Part 2 is subdivided into:

- Waters Impaired by Atmospheric Deposition (acid rain)
- Waters Impaired by Fish Consumption Advisories
- Waters Impaired by Shellfishing Restrictions

Part 3 Waterbody Segments for which TMDL Development May Be Deferred

These are waters where scheduling of TMDL development may be deferred pending verification of the suspected impairment, the cause/pollutant related to the impairment, or the effectiveness of other restoration measures in place. Part 3 is subdivided into:

- Waterbody Segments Requiring Verification of Impairment
- Waterbody Segments Requiring Verification of Cause/Pollutants
- Waterbody Segments Being Addressed Through Other Restoration Measures

Part 4 Waterbody Segments Not Proposed for TMDL Development

- Category 4a – TMDL development is not necessary because a TMDL has already been established for the segment/pollutant.
- Category 4b – TMDL is not necessary because other required control measures are expected to result in restoration in a reasonable period of time.
- Category 4c – TMDL is not appropriate because the impairment is the result of pollution, rather than a pollutant that can be allocated/reduced through a TMDL.

For each water body reported in Category 1 of the 303(d) list, the state must define the type of pollutants (e.g., sediment and phosphorus) and the sources considered to be responsible (e.g., agriculture and urban runoff). Next, the state is required to establish a Total Maximum Daily Loads (TMDL) allocation for each pollutant. The TMDL is the total input of the specific pollutant that will bring the water body into compliance with ambient standards associated with designated uses. As a final step, the state must allocate responsibility to specific sources for their pollutant releases. Often, reductions in both point and nonpoint sources of defined pollutants are required. The source allocation is subject to EPA approval.

9.3 LOCAL WATERBODIES ON THE NEW YORK STATE SECTION 303(d) LISTS

Several waterbodies within the Onondaga Lake watershed have been placed on the latest draft of the State's Section 303(d) list. The 2008 list, for which EPA approval is pending, includes Onondaga Lake, segments of the Seneca River, and several tributaries to Onondaga Lake among the several categories of impaired waters. The list is posted on the NYSDEC web site at http://www.dec.ny.gov/docs/water_pdf/303dlistdraft08.pdf.

Only the Seneca River was placed on the *Part 1 – Individual Waterbody Segments with Impairment Requiring TMDL/Other Strategy* section of the proposed 2008 list. The Seneca River is noted as a high priority for TMDL development, with completion scheduled within two years. The segment is listed as impaired due to its low dissolved oxygen concentration. Causes are listed as oxygen demand and agriculture. The segment has been on the State's 303(d) list since 1998.

Both the northern (Class B) and southern (Class C) ends of Onondaga Lake are included in the *Part 2b – Multiple Segment/Categorical Impaired Waterbody Segments (fish consumption)* section of the proposed 2008 list. These segments have been listed since 1998 for sediments contaminated by mercury, PCBs, and dioxin.

A segment of the Seneca River is also included on *Part 3a – Waterbodies for which TMDL Development May be Deferred (Requiring Verification of Impairment).* The river is cited for elevated indicators of potential presence of pathogens, with the cause cited as on-site wastewater treatment systems. This segment of the river has been on the State's list of impaired waters since 1998.

In addition, there is a narrative included in the 2008 draft *Part 3a* that addresses how NYSDEC is planning to evaluate compliance with dissolved oxygen concentrations in lakes that undergo thermal stratification. This discussion may be relevant to analysis of the water quality status of Onondaga Lake. The text is reproduced below.

> "Waters with areas of Dissolved Oxygen less than 5.0 (trout) or 4.0 (non-trout) mg/l.
>
> "Morphology and other natural conditions may contribute to periodic dissolved oxygen depletion in significant numbers of thermally stratified waters. However, deep water conditions are not necessarily representative of the water as a whole and aquatic life and other uses are often fully supported in these waters. NYSDEC evaluates data and conditions in these waters on a case-by-case basis to determine 1) whether impacts result in impairments to aquatic life and/or other uses, and 2) the degree to which natural conditions contribute to the impacts. This evaluation will be made using best professional judgment and will take into account other available physical/chemical data and biological assessments.
>
> "NYSDEC also recognizes that additional research into naturally occurring low dissolved oxygen waters and the resulting impacts is necessary, and because the issue concerns other States such research would best be conducted at the regional or national level. As the triennial water quality standards rule-making effort moves forward, NYSDEC will evaluate the current DO standards for freshwater in light of available research and adopt a criterion that might better reflect the natural occurrence of low DO in deeper waters and its impact on use support. Pending the development of revised standards/criteria for freshwater DO waters exhibiting periodic or deep water DO below the current standard may be assessed as waters with Insufficient Data to make a determination regarding listing (Integrated Reporting Category 3)."

There are several waterbody segments within the Onondaga Lake watershed included in *Part 3c – Waterbodies for which TMDL Development May be Deferred (Pending Implementation / Evaluation of Other Restoration Measures)*. Many segments are newly listed in 2008.

The Lake Outlet, the lake's northern end (Class B), the lake's southern end (Class C), Onondaga Creek and tributaries, Ley Creek and tributaries, Bloody Brook and tributaries, Ninemile Creek, and Geddes Brook are listed for various pollutants, including pathogens phosphorus and ammonia, cyanide, and unknown toxicity. Sources are attributed to combined sewer overflows, urban runoff, and municipal discharges.

Onondaga Lake previously appeared on the list of *Other Impaired Waterbody Segments Not Listed Because Development of a TMDL is Not Necessary* due to impairments from, and development of a TMDL for, ammonia. Subsequently the lake has been found to be meeting water quality standards for ammonia, so Onondaga Lake is considered to have been restored for this pollutant.

9.4 COMPONENTS OF TOTAL MAXIMUM DAILY LOAD (TMDL) ALLOCATION

The term TMDL refers to both the planning process used by the States to estimate the reduction in pollutant inputs needed to meet ambient water quality standards and the resulting numerical allocation among sources. The TMDL allocation is the total pollutant input that will not violate State water quality standards, with an adequate margin of safety. The calculation typically includes a point source component (if applicable) called a wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The margin of safety is included to account for uncertainties in the relationship between pollutant input and resultant water quality.

$$TMDL = WLA + LA + MOS$$

The TMDL allocation process requires monitoring data and a modeling framework relating inputs to resulting concentration. Stream discharge data are required, as are ambient water quality data. Land use data support the estimate of nonpoint source inputs; and flows and loads of any point sources are required as well. Estimates of atmospheric deposition are important in certain receiving waters. For many impaired waters, an estimate of upstream sources or legacy pollution sources (such as contaminated sediments) is necessary. When nonpoint source pollution is an important component of total load, it may be necessary to estimate the effectiveness of various Best Management Practices (BMPs) in order to benchmark a realistic goal for reduction.

A TMDL for phosphorus presents an additional challenge, as there is no numerical standard for phosphorus. New York has a narrative standard for phosphorus (NYCRR Title 6, Chapter X, Part 703.2) as follows:

> "Phosphorus and Nitrogen: None in amounts that will result in growths of algae, weeds, and slime that will impair the waters for their best use."

The narrative standard has been interpreted at NYSDEC through a guidance value for phosphorus applicable to all Class AA, A, and B ponded waters with the exception of Lakes Champlain, Ontario, and Erie. The narrative standard, which is based on user perception of the suitability of water for recreational use, is set at 20 µg/l in the upper waters as a summer average value. NYSDEC published a Phosphorus Fact Sheet describing the underlying analysis (NYSDEC 1993).

9.5 PHASE 1 TMDL FOR PHOSPHORUS IN ONONDAGA LAKE

9.5.1 Background

In August 1997, NYSDEC completed a Phase 1 TMDL for phosphorus in Onondaga Lake. The lake was included as a high priority for TMDL development on the State's 1996 303(d) list. The NYSDEC adopted a phased approach to establishing the lake's phosphorus TMDL, in accordance with EPA guidance for receiving waters exhibiting serious and complex water quality problems (EPA 1991).

Water quality models of Onondaga Lake were developed by Upstate Freshwater Institute (UFI) on behalf of the former Onondaga Lake Management Conference. The phosphorus model of the lake, released in April 1993, was used by NYSDEC to estimate the effectiveness of reductions in point and nonpoint source loadings for the TMDL allocation. The model is a seasonal, two-layer mass balance model calibrated to inflows and lake conditions over the period 1987 – 1990. Inputs and kinetic coefficients used in the mechanistic model were independently measured (Canale et al 1993). CSO loads were incorporated in the measured inputs at the tributary mouths.

9.5.2 Calculations

The Phase 1 phosphorus TMDL for Onondaga Lake uses the UFI model to project the lake's "loading capacity"; that is, how much phosphorus can flow into the lake and still achieve a summer average concentration of 20 µg/l in the upper waters. The selection of 20 µg/l as the target value was consistent with the statewide guidance value for phosphorus in lakes. However, NYSDEC specifically cites its commitment to examine whether this was the appropriate target for Onondaga Lake:

> "The Department is committed to the review and revision, as appropriate, of the phosphorus guidance value for Onondaga Lake. As such, the Department may develop a site-specific guidance value that appropriately protects uses and achieves the narrative water quality standard for phosphorus." (NYSDEC 1997 p. 17)

NYSDEC applied the UFI model to estimate the lake's loading capacity for phosphorus to be 163 pounds per day (ppd) based on average hydrologic conditions. The loading capacity of 163 ppd was then allocated to the point and nonpoint source inputs based on current conditions and professional engineering judgment.

The point source allocation (WLA) for Metro outfall 001 was calculated using a design flow of 84.2 mgd and an effluent concentration of 0.02 mg/l for a total of 14 ppd for outfall 001, in addition to 21 ppd from outfall 002. The summed load from the Metro plant was set at 35 ppd. Setting aside a 10% margin of safety (16.3 ppd), the remaining loading capacity was allocated to watershed sources, both nonpoint sources and CSOs. The watershed allocation was set at 112 ppd. This represented an approximate 50% reduction in tributary loading as measured during the 1987 – 1990 baseline period.

The calculations may be summarized as follows:

TMDL = WLA + LA + MOS

WLA = 14 ppd outfall 001 + 21 ppd outfall 002; total Metro 35 ppd

LA = 112 ppd (nonpoint load from entire watershed, including CSOs)

MOS = 16 ppd (10%)

9.5.3 Implementation Strategy

NYSDEC determined that the phosphorus TMDL for Onondaga Lake would be implemented in three stages. Stage I established a "no net increase" limit for phosphorus in the Metro effluent; the limit was set at 400 ppd as a 12-month rolling average. The CSOs were also referenced in the Stage I WLA. The planned BMPs for directing additional wet weather flow to the Metro plant were considered reasonable surrogates for a "no net increase" from CSOs. Models of the collection system were used to project that the BMPs would comply with the minimum technology-based effluent limits required by the Clean Water Act. These BMPs were estimated to direct 62% of the annual combined sewage volume to Metro for treatment. This translated into a Stage I WLA for CSO loadings to the lake at 37.3 ppd.

The Stage II interim limits for Metro were derived considering the results of the UFI model and the levels of phosphorus removal considered technologically achievable. A reduction of approximately 80%, to a concentration-based limit of 0.12 mg/l was established as the Stage II limit. This limit is interpreted as a 12-month rolling average, and was referenced in the NYSDEC document as representing the limit of technology for a large municipal wastewater treatment plant serving a combined sewer system in a cold climate.

The Stage II CSO limit was based on projections using the presumptive approach for the water quality improvements realized by capture and treatment of combined sewage flows. As estimated using available models, the equivalent CSO discharge after completion of the County's CSO program and capture of at least 85% of the combined sewage volume will result in an equivalent CSO discharge of 14.6 ppd.

The Stage III limit for phosphorus discharged from the Metro plant represents a further 80% reduction to an effluent limit of 0.020 mg/l. The watershed nonpoint source load (LA) is targeted to reach 112 ppd. However, a Phase 2 TMDL will be developed that holds the potential to modify this allocation. Three factors will be considered in the Phase 2 TMDL:

- enhanced water quality models of the lake and watershed,
- monitoring data describing ambient chemical, physical and biological conditions in the lake and watershed,
- review of the necessity of achieving the water quality guidance value and/or the corresponding proposed effluent limit in order to protect the designated uses.

The staged TMDL allocations for Metro, the CSOs and watershed nonpoint sources are summarized in **Table 9-1**.

Table 9-1. Summary of phosphorus allocations in the Phase 1 TMDL (NYSDEC August 27, 1997)

TP Load (pounds per day, ppd)	Stage I	Stage II	Stage III
Metro (WLA) Outfalls 001 + 002 (at design flows)	400 (no net increase)	84.3 (outfall 001) + 21 (outfall 002)	14 (outfall 001) + 21 (outfall 002)
CSO (approximate values)	37	14.6	Included in watershed
Watershed (LA)	177	176.4	112
Margin of Safety (10%)	N/A	N/A	16
Total Load	Approx 600*	296	163

**NYSDEC noted that interannual variability in total P load may be as high as +/- 40%*

9.5.4 Summary of Uncertainties in the Phase 1 Phosphorus TMDL

The NYSDEC document describing the TMDL process, assumptions, and proposed allocation cited various sources of uncertainty. In addition, members of the UFI team that developed the mass-balance model used to support the Phase 1 TMDL subsequently published a critique (Effler et al. 2002), pointing out that their model structure did not accommodate several phenomena that might affect the relationship between phosphorus loading and lake response. The UFI team outlined major limitations of their model for its use in the Phase 1 TMDL as summarized below.

- The two-layer model might not route tributary inflows with higher density (due primarily to salinity) to the correct water depth under all conditions.
- The potential for exchange between the Seneca River and the lake was not accommodated.
- The model fails to account for potential difference in bioavailability of sources.
- Particulate phosphorus from various sources could settle at different rates; this is not incorporated in the model.
- During high flow periods, elevated turbidity in stream samples might have interfered with the analytical measurements of total P, leading to loading estimates that were biased high.

- The seasonal model did not adequately reflect the impacts of the short water residence time.

The authors concluded with a recommendation to enhance the TMDL analysis through an integrated program of monitoring and modeling (Effler et al. 2002). The NYSDEC commitment to enhance the model, and to rely on the Ambient Monitoring Program to provide the detailed chemical, biological, and physical data to support this effort along with the evaluation of the applicability of the current TP guidance value was stated in the Phase 1 TMDL narrative. The next section describes recent progress in developing tools to support a technically-defensible phosphorus TMDL allocation for Onondaga Lake.

9.6 ADVANCES IN SYSTEM TOOLS

Since completion of the Phase 1 TMDL in 1997, there has been significant progress in developing improved tools for characterizing both watershed export and lake dynamics. These initiatives are under the overall direction of the Onondaga Lake Partnership, which has six members: Onondaga County, NYSDEC, City of Syracuse, Army Corps of Engineers, EPA, and the NYS Attorney General. In addition, Dr. William Walker, a member of the Onondaga Lake Technical Advisory Committee, has continued to develop an empirical mass-balance phosphorus model of Onondaga Lake using the AMP database that includes trophic state parameters.

9.6.1 Watershed Model

Research scientists from the US Geological Survey (USGS) developed the Onondaga Lake Basin Model for use in creating and analyzing scenarios to project the consequences of land use changes on the export of water, nutrients, and sediment to Onondaga Lake (Coon and Reddy 2008). The watershed model, developed in cooperation with the Onondaga Lake Partnership, serves as a tool for testing the effectiveness of land use scenarios such as changes in development patterns, implementation of best management practices, and measures such as stormwater retention basins to mitigate peak runoff rates.

The watershed model was developed between 2003 and 2007 using the program Hydrological Simulation Program-FORTRAN (HSPF). Onondaga Lake's watershed was segmented into 107 subbasins for the analysis. Land areas within the subbasins were delineated and mapped according to land use and land cover, hydrologic soil group, and aspect. The model simulated streamflow, water temperature, concentration of dissolved oxygen, and concentrations and loads of sediment, SRP, total phosphorus, nitrate, ammonia, and organic nitrogen. Four tributaries were modeled: Onondaga Creek, Harbor Brook, Ley Creek, and Ninemile Creek. Simulated flows were calibrated to data from nine USGS streamflow-monitoring sites; simulated nutrient concentrations and loads were calibrated to data collected at six of the nine streamflow-monitoring sites. Water quality samples were collected by the County's Department of Water Environment Protection trained field technicians and analyzed in the County's certified laboratory.

Coon and Reddy (2008) present model performance results, comparing simulated streamflow, water temperature, concentrations, and loads using both graphical depictions and statistical analyses. Simulated daily and monthly stream flows were rated “very good” (within 10 % of measured flows) at all monitoring sites except Onondaga Creek at Cardiff, which was rated “fair” (15–25 % difference). Simulations of monthly total phosphorus loads were generally rated “very good” at all monitoring sites.

The researchers include a discussion of factors contributing to uncertainty in the watershed model. Variability in precipitation across the basin was considered a major factor; precipitation for the 285- square mile basin was measured at only three locations and there were significant differences between stations reflecting localized rainfall and runoff events. Also cited were changes in land use between 1991 and 1993, when the land use land cover data were collected, and the monitoring and modeling period from 1997 to 2003. Other uncertainties relate to model structure, scaling effects, whether all processes have been identified and incorporated, and errors in sampling and analysis (Coon and Reddy 2008).

Despite these potential uncertainties, the USGS researchers conclude that the watershed model can be used to simulate the potential impact of changes in land use, water flow, and CSO remediation on the export of water, nitrogen, sediment, and phosphorus in the basin. As described, the model can be used to support the watershed loading (nonpoint source, LA) inputs for the Phase 2 TMDL allocation. Effectiveness of implementing specific BMPs in specific locations can be projected. Moreover, the model can be used to identify locations and land use practices where investment in BMPs would produce the greatest environmental benefit (Coon and Reddy 2008).

9.6.2 Enhanced Onondaga Lake Model

As specified in the Phase 1 TMDL for phosphorus, NYSDEC recognized the need for an enhanced water quality model of Onondaga Lake to support the final decisions regarding level of treatment and location of the discharge from the Metro plant. The Onondaga Lake Partnership through Onondaga County issued a Request for Proposals and selected Quantitative Environmental Analysis LLC (QEA) of Liverpool NY to develop the Onondaga Lake Water Quality Model (OLWQM). Dr. William Walker and EcoLogic LLC are included on the modeling project team.

The OLWQM is a keystone component of an integrated watershed/lake/river modeling framework. A water quality model of the Three Rivers system (TRWQM) was recently developed by QEA and will be coupled to the lake model (QEA 2005). The USGS watershed model, described in section 8.5.1, will be used to estimate changes in external loading of water, nutrients, and sediment to the lake from watershed activities. As outlined in the project work plan (QEA 2006), this integrated framework will provide a predictive tool necessary to facilitate:

- an understanding of the mechanisms underlying observed trends in the water quality of the lake;
- a projection of the benefits of Metro upgrades and CSO abatement measures;

- a more complete assessment of the assimilative capacity of the Seneca River and its ability to accept diverted Metro effluent as well as the impact of such a potential diversion on lake water quality;
- a projection of the benefits of any proposed watershed best management practices (BMPs); and
- development of total maximum daily loads (TMDLs) for phosphorus in the lake and support the development of a TMDL for dissolved oxygen in the Seneca River.

9.6.2.1 OLWQM Development

The development of the OLWQM framework is being conducted in three phases: (1) development of the modeling work plan; (2) development and calibration of the lake model; and (3) lake model validation, integration with the USGS watershed model and the TRWQM, and preliminary model application. This phased approach has permitted the model development team to address and incorporate the results of external peer review which has been evaluating the modeling effort at the end of each phase.

The first phase of the OLWQM development involved the development of a detailed modeling work plan that: 1) identified the relevant management questions the model would address as well as the spatial, temporal, and process resolution the model needed to address those questions; and 2) described the proposed model framework and the approach planned for model development, calibration, and validation. The model work plan was completed in January 2006 (QEA 2006) and a peer review of that document was conducted in June 2006. The written comments on the modeling work plan developed by the peer review panel were submitted to the OLP in July 2006 (OLP 2006). QEA and OCDWEP developed responses to the peer reviewers' comments (OCDWEP 2006).

Phase 2 of the project involved the development and calibration of the OLWQM; many of the changes and recommendations from the Phase 1 peer reviewers were incorporated into these efforts. A report documenting the lake model development and calibration effort (QEA 2007) was subjected to review by a panel of independent external experts in December 2007; the panel subsequently submitted written comments (OLP 2008). QEA and OCDWEP developed responses to the peer reviewers' comments (OCDWEP 2008) and are currently making a number of recommended changes to the model. An interim report documenting these changes to the model calibration will be submitted to the peer review panel in late summer 2008. Phase 3 of the model development process, involving lake and river model validation to water quality monitoring data collected between 2004 and 2007, is currently scheduled to be completed by spring 2009.

9.6.2.2 Summary of the OLWQM Framework and Calibration

The OLWQM consists of a number of submodels representing the major hydrodynamic, water column nutrient cycling, and sediment processes controlling water quality in the lake (**Figure 9-1**). The hydrodynamic modeling framework incorporates two model codes: DYRESM and EFDC. DYRESM, a one-dimensional modeling framework, simulates temperature and vertical mixing, while EFDC simulates water depth, advection, and horizontal mixing using a two-dimensional representation of the lake. The water column submodel describes the major water column processes affecting lake water quality, including nitrification, organic matter decomposition, algal photosynthesis, respiration, and nutrient uptake, and zooplankton and zebra mussel grazing and respiration and particulate settling to the sediment bed. The sediment flux submodel simulates the conversion of particulate organic material to dissolved nutrients and the concurrent consumption of oxidized compounds from the overlying water column.

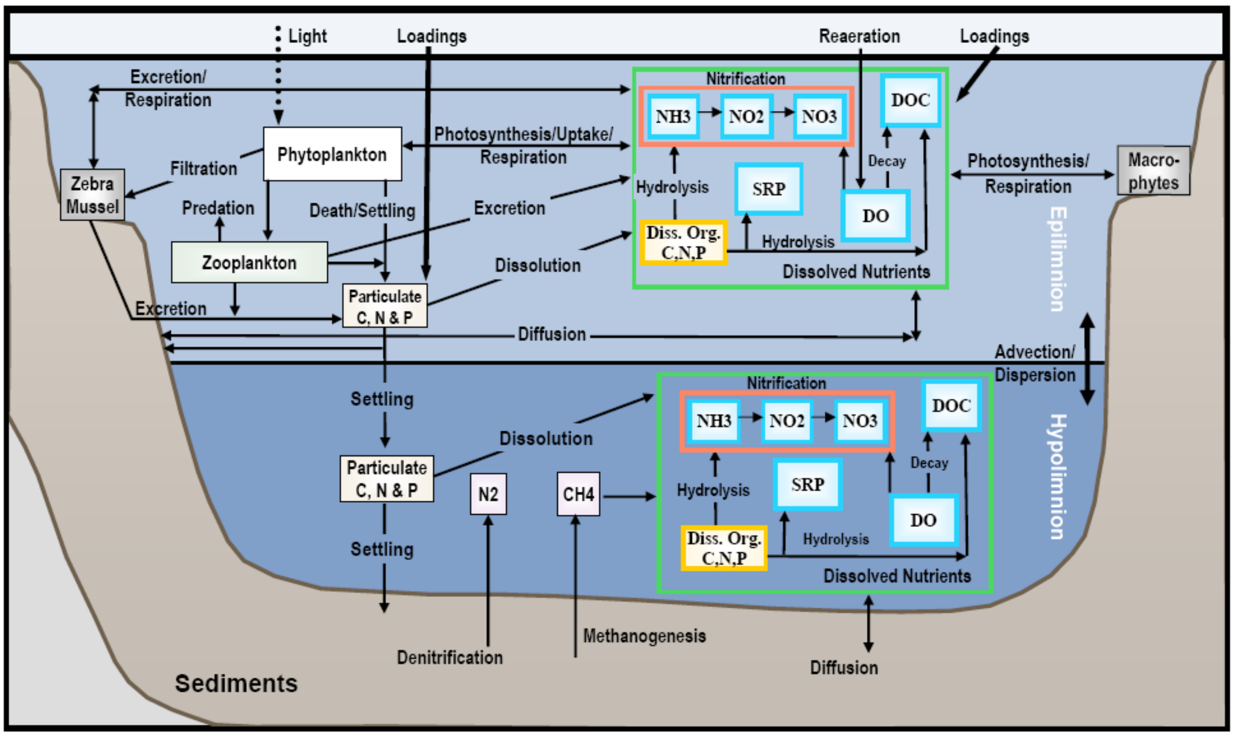

Figure 9-1. Conceptual diagram of major state variables and processes represented within the OLWQM.

The model was initially calibrated to water column monitoring data collected over the period from 2000 to 2003, during which extensive lake water quality and biota data were available from the OCDWEP AMP monitoring programs. Subsequently, the calibration was extended to cover 1994 to 2003. Over this 10-year period, tributary and Metro loadings varied considerably year to year due to changes in precipitation patterns and in Metro ammonia and TP treatment efficiencies. The model successfully simulates the major water quality dynamics observed within the system over both these periods (QEA, 2007). The annual onset and breakdown of thermal stratification was well-simulated by the hydrodynamics models. The model's predictions of the consumption of oxygen and nitrate and the accumulation of SRP and ammonia within the LWL during periods of water column stratification closely matched the data. The model simulated the gross patterns in chlorophyll-a in the UML, although it did not always match the dynamics of the individual phytoplankton and zooplankton groups. The model-based estimates of phosphorus retention within the lake closely tracked those estimated from data alone.

The model was able to simulate compliance-based measures of important water quality standards and guidance values developed for the lake (QEA, 2007). In general, model-based compliance frequencies for dissolved oxygen concentration at turnover, total phosphorus concentration in the UML during the summer growing season, and the UML ammonia concentration were statistically similar to the same metrics developed based on the data.

Following the effort to address the Phase 2 peer reviewer's comments, the OLWQM will be formally linked to the TRWQM and a joint model validation against 2004 – 2007 water quality monitoring data will be performed. During the 2004 – 2007 period, both ammonia and phosphorus loadings from Metro changed significantly as a result of the construction and operation of advanced tertiary treatment systems at the plant. Thus, this next phase of work will provide for a robust test of the model's predictive ability. Following validation, the combined lake-river model will be linked to the Onondaga Lake watershed model developed by the USGS to complete the integrated water quality management tool for the system.

9.6.3 Phosphorus Mass-balance Model

To supplement the OLWQM, the empirical phosphorus mass balance model (PMBM) developed by Dr. William Walker provides an alternative tool for evaluating TMDLs and other phosphorus loading scenarios for Onondaga Lake in a simple spreadsheet format. As described in Chapter 8, the model was initially developed based upon data collected thru 1999 and most recently tested against data collected thru 2007. The PMBM is linked to the Onondaga Lake long-term water quality database and mass balance framework. The latter has been routinely used in the annual AMP reports to track magnitudes and precision of tributary and point-source loads and overall mass balances.

The PMBM links phosphorus and nitrogen balances to empirical models for predicting eutrophication-related water quality variables (chlorophyll-a, transparency, organic nitrogen, oxygen depletion). The equations and calibrations are similar to published models developed from independent lake and reservoir datasets. Equations for predicting frequencies of algal blooms (daily chlorophyll-a concentrations > 15 or 30 ppb) are used in both the PMBM and OLWQM. The PMBM provides a basis for predicting year-to-year variations in summer-average lake concentrations and bloom frequencies in response to reductions in external phosphorus loads potentially resulting from implementation of point-source and non-point-source control measures. The model provides explicit estimates of uncertainty and year-to-year variability derived from simulations of long hydrologic time series.

The most recent model update and preliminary evaluations of lake responses to various load reduction scenarios were presented in Chapter 8 of this report. PMBM input loads and scenario results will be compared with NYDEC previous TMDL calculations and OLWQM simulations. Comparison of the three models will provide a basis for assessing the sensitivity of results to alternative modeling approaches.

9.7 DEFINING AN ENDPOINT: PHOSPHORUS GUIDANCE VALUE

The TMDL for phosphorus in Onondaga Lake requires definition of an acceptable phosphorus input that will meet water quality standards. As described above, the acceptable input will be calculated to meet a selected in-lake target concentration to attain and/or protect designated use, using the enhanced Onondaga Lake Water Quality Model to link load with in-lake concentration. The State is committed to evaluating a site-specific interpretation of the narrative standard for phosphorus that would allow Onondaga Lake to attain and/or protect its designated use.

9.7.1 Ecoregional Criteria

EPA published a guidance document for developing nutrient criteria in lakes entitled *Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs* (U.S. EPA 2000a). This guidance manual reviews the technical literature regarding the effects of nutrients on aquatic productivity and outlines methods for setting ecoregional nutrient criteria. Ecoregional criteria are intended to reflect variability in land use, land cover, geology, aquatic biota, and stakeholder desires. Fourteen aggregate ecoregions were delineated.

The ecoregional nutrient criteria summarize EPA's recommendations to States (and authorized tribes) for use in establishing their water quality standards consistent with section 303(c) of the Clean Water Act. The ambient water quality standards adopted by States must contain scientifically defensible water quality criteria that are protective of designated uses. EPA's ecoregional nutrient criteria are not laws or regulations – they are guidance that may serve as a starting point for the criteria for their water quality standards (U. S. EPA 2000b).

Onondaga Lake is located within Ecoregion VII, delineated as the "Mostly Glaciated Dairy Region including all or parts of the States of: New York, Pennsylvania, Michigan, Wisconsin, Minnesota, Iowa, Ohio, Indiana, Illinois and the authorized Tribes within the Ecoregion" (U.S. EPA 2000b). Sub-ecoregions are delineated within the broad aggregated ecoregions; Onondaga Lake lies within sub-ecoregion 83 (**Figure 9-2**).

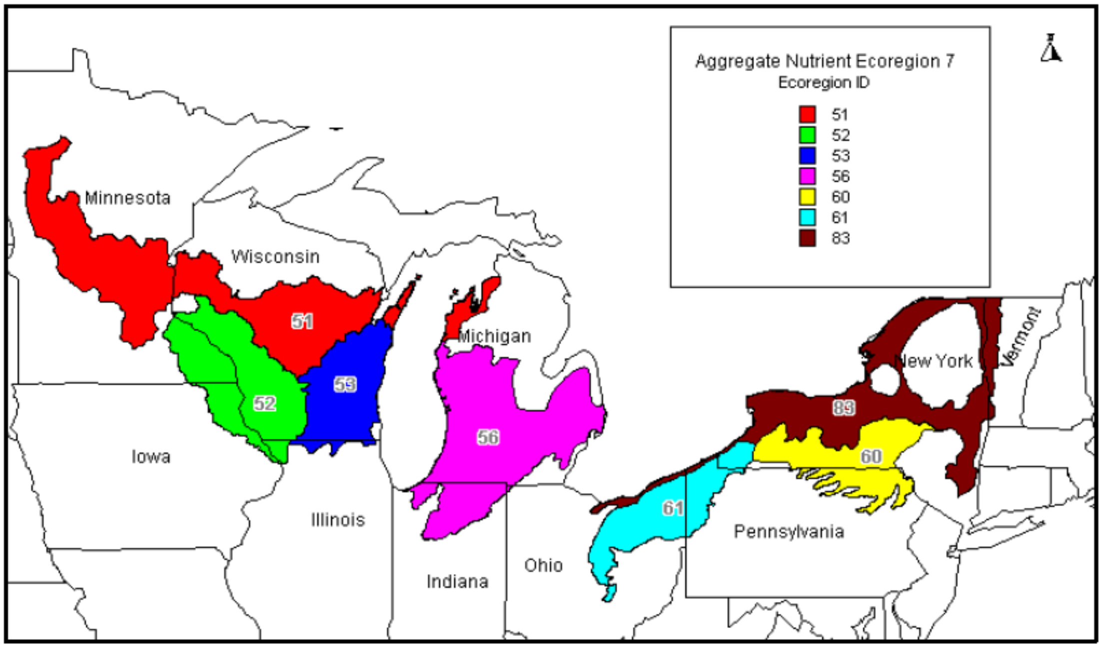

Figure 9-2. Delineation of Ecoregion VII and sub-ecoregions. Source: U.S. EPA 2000b.

EPA proposed two calculation methods for setting ecoregional nutrient criteria; both methods are based on a statistical analysis of the distribution of trophic state indicators of ponded waters: TP, TN, chlorophyll-a, and Secchi disk transparency (or turbidity, depending on data availability). Ecoregional nutrient criteria can be estimated from the lower 25th percentile of the cumulative frequency distribution of the trophic state indicators measured in ponded waters in the defined region. Alternatively, the nutrient criteria can be estimated from the upper 75th percentile of trophic state parameters measured in reference waterbodies in the ecoregion. Reference waterbodies are non-impacted and fully meet designated uses.

Nutrient criteria for lakes and reservoirs in Ecoregion VII and sub-ecoregion 83 are summarized in **Table 9-2**. These values were calculated using the lower 25th percentile of the cumulative frequency distribution of available data for all ponded waters. A total of 1381 lake and reservoirs were included in the aggregated Ecoregion VII; of these, 147 were located in sub-ecoregion 83. More than 41,000 TP records were available in aggregated Ecoregion VII, and more than 4,000 were included in the sub-ecoregion 83.

Table 9-2. Summary of nutrient criteria calculated for Ecoregion VII.

Nutrient Criteria	Aggregate Ecoregion VII Reference Conditions	Sub-Ecoregion 83 Reference Conditions
Total P (µg/l)	14.75	11.25
Total N (µg/l)	0.66	0.42
Chlorophyll-a (µg/l)	2.63	2.84
Secchi disk transparency (m)	3.33	4.75

Under the provisions of the Clean Water Act, if States have not either adopted the regional nutrient criteria developed by EPA, or prepared a plan documenting how they plan to develop nutrient criteria, EPA may promulgate criteria based on the regional criteria. Moreover, once EPA has issued the regional nutrient criteria, States, tribes or other entities may propose site-specific nutrient criteria for specific water bodies where the regional criteria are not appropriate (WERF 2005). As of the date of this report, EPA has not promulgated nutrient criteria for lakes.

The proposed ecoregional nutrient criteria are based on statistical analysis of data from many lakes; they are not based on a mechanistic relationship between nutrients, numeric water quality standards, or attainment of designated use. For water bodies where the correlation between nutrient concentrations and algal abundance is weak, applying the ecoregional criterion may not result in the desired effect (WERF 2005). While they are likely to be a refinement of statewide criteria because effects of geology and land use are factored in, ecoregional criteria do not reflect system-specific factors such as trophic interactions, sediment exchange, water residence time, and stakeholder priorities. Site-specific nutrient criteria are a means to overcome these limitations.

9.7.2 Site-specific Nutrient Criteria

Site-specific nutrient criteria are relevant in cases where ecoregional or statewide criteria are either more stringent or less stringent than necessary to protect the designated use. In the case of Onondaga Lake, NYSDEC is committed to examining the applicability of the statewide phosphorus guidance value as it may be too stringent for this urban lake. The relationship between nutrient criteria, use attainment, and regulatory action is outlined in **Figure 9-3**.

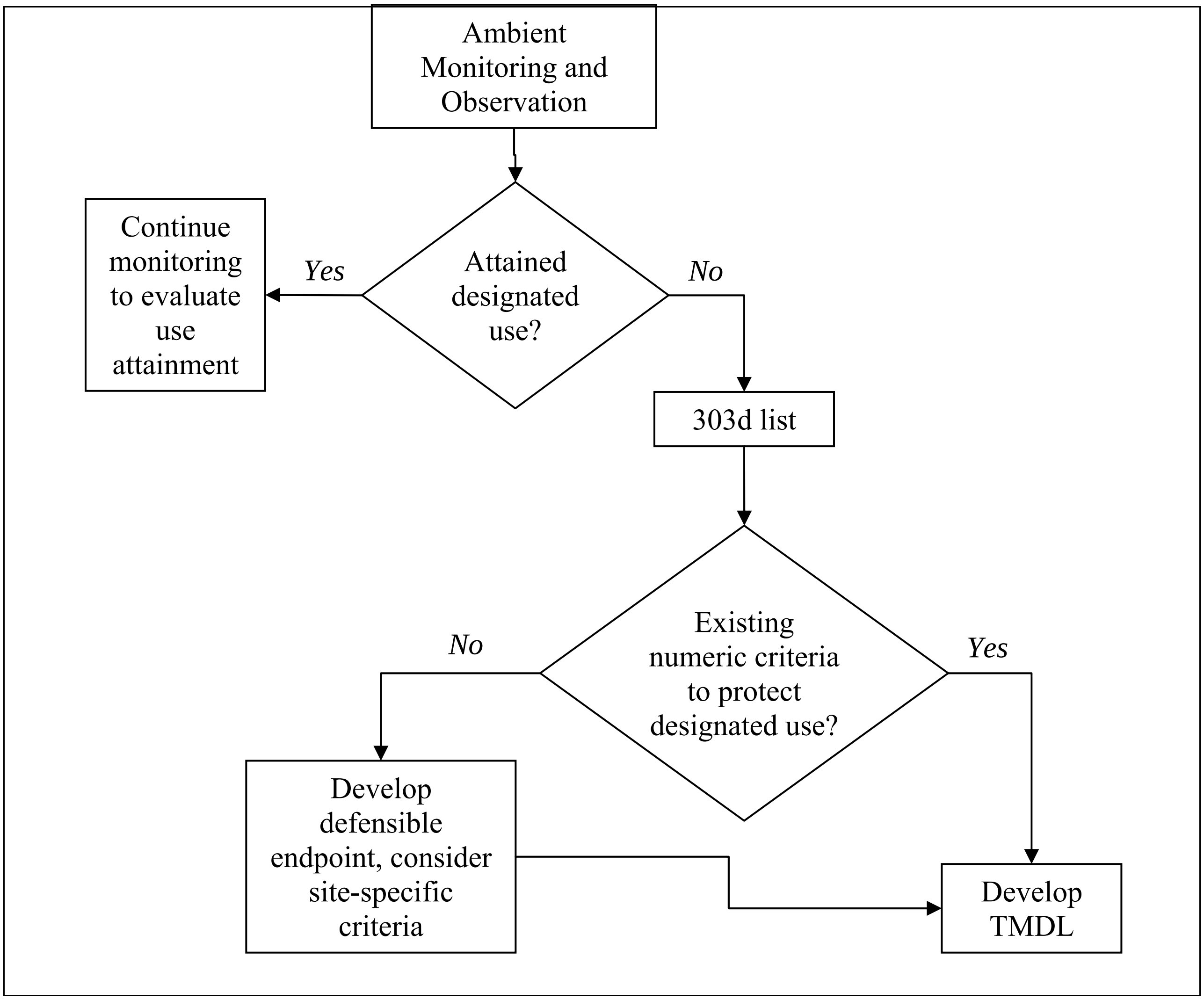

Figure 9-3. Relationship between nutrient criteria, use attainment, and regulatory actions.

NYSDEC has previously approved a site-specific interpretation of the narrative water quality standard for phosphorus under Title 6, Chapter X, Part 703.2 of the NYCRR. A more stringent site-specific phosphorus target was adopted for certain drinking water reservoirs within the New York City watershed. The site-specific guidance value was justified based on the need to protect the public water supply from algal blooms, organic carbon/THM precursors, and taste and odor issues for consumers. A target of 15 µg/l was used in the Phase 2 TMDL allocation for the New York City water supply watershed in the following reservoirs: Kensico, Rondout, Ashokan, West Branch, New Croton, Croton Falls and Cross River.

The New York City Department of Environmental Protection developed the technical justification and data analysis to support the site-specific phosphorus criterion for these reservoirs within the New York City water supply watershed (NYCDEP 1999). The following sequence of data analysis was completed:

- Define algal groups and specific genera that are problematic for water supplies.
- Compile data relating algal abundance thresholds that are associated with complaints of taste and odor.
- Quantify the relationship between total phosphorus and algae, using a least-squares regression analysis of total P and chlorophyll-a
- Perform a cross-tabulation between mean TP and chlorophyll-a concentrations with selected water quality variables that are important to water supplies, including total algal counts above threshold, percent of incidents of cyanobacteria as the dominant algal class, thresholds of color, reported odor complaints, and THM precursor concentrations.
- Evaluate the chlorophyll-a concentration associated with an acceptable risk of exceedance of the criteria (for example, chlorophyll-a concentration of 7 µg/l that cannot be exceeded in more than 25% of all cases).

The resulting site-specific criterion for phosphorus in the NYC water supply reservoirs is consequently directly related to the use to be protected.

9.8 RECOMMENDED FRAMEWORK FOR A PHASE 2 PHOSPHORUS TMDL FOR ONONDAGA LAKE

As stated in the Phase 1 TMDL, NYSDEC is committed to evaluating whether the current state-wide phosphorus guidance value of 20 µg/l is an appropriate target concentration for Onondaga Lake for use in the Phase 2 TMDL. As described below, additional discussion is needed to determine how compliance would be evaluated: each year, or as a long-term average. Development of a TMDL that reflects the unique conditions in Onondaga Lake is feasible because of the extensive database of water quality and biological data, and the ongoing commitment to developing peer-reviewed models linking phosphorus load and in-lake concentration. Moreover, there is an engaged stakeholder community that includes regulatory agencies, members of OLTAC and other scientists, municipal officials, and professional staff from natural resources management agencies at the county, state, and federal levels. The Onondaga Lake Partnership has sponsored community outreach and a visioning project in addition to the lake and watershed modeling efforts.

9.8.1 Confirm the uses to be Protected Based on the Current Water Quality Classification

The Phase 2 TMDL should reflect the current water quality classification of Onondaga Lake, given that the goal of current efforts as reflected in the ACJ is to achieve and/or protect water quality standards that are consistent with current classifications. In developing the Phase 2 TMDL allocation for phosphorus, it is necessary to consider what has been accomplished, what is achievable in a cost-effective manner, and what is sustainable.

The lake’s current recreational uses are primarily focused along the shoreline, where Onondaga County Parks maintains popular recreational trails and sponsors various cultural and educational activities. Non-contact recreation is typical on the lake; boating and fishing are popular. The 2020 Vision Project – Engaging the Community in the Future of Onondaga Lake – compiled elements of a community vision for a rehabilitated ecosystem and reported findings to the OLP (EcoLogic 2007).

As summarized in the following text box, the stakeholder community is looking forward to the time when Onondaga Lake supports community recreational needs and is a source of pride. Discussion among the stakeholders is needed to reach consensus on specific elements and parameters of the desired use. For example, the issue of a cold water or warm water fish community has not been resolved. Does having a lake that's safe for swimming require an official beach? Are there other non-nutrient issues that would interfere with attainment of these uses? If so, are those issues tractable?

Elements of the Community Vision
Reconnect to Onondaga Lake

- What does this mean?
  - Accessibility – *retain public control of and access to the Lake*
  - Activities – *public resource for entertainment, recreation and aesthetic enjoyment*
  - Community commitment to rehabilitation – *widespread understanding that these values are contingent on restoring a healthy lake*
- How would the community measure progress?
  - Continued and improved public access to the lake and its shoreline
  - Growing number of attractive activities occurring at or on the lake
  - Signs of an improving natural environment in a healthy, sustainable ecosystem
- Elements of the public's vision
  - Trails
  - Swimmable water and edible fish
  - Fishing
  - Boating
  - Year-round activities
  - Community education regarding ecosystem rehabilitation

9.8.2 Define Metrics of Ecological Response Related to Desired use

There are a number of potential indicators of progress (metrics) in Onondaga Lake for consideration in the Phase 2 TMDL phosphorus loading allocation. Several metrics of lake ecology are measured and tracked annually in the AMP. As outlined in WERF (2005), metrics may be considered in three overall categories: nutrient variables, primary response variables, and secondary response variables.

The nutrient variables include estimates of external loading and in-lake concentrations of the various fractions of nitrogen and phosphorus. The primary response variables include the trophic state indicator parameters: chlorophyll-*a*, algal bloom frequency, intensity and duration, water clarity, and dissolved oxygen concentrations. Metrics reported annually as part of the AMP, such as volume-days of anoxia and hypoxia, may be considered primary response variables.

Secondary response variables incorporate trophic level information such as the species comprising the algal community, zooplankton abundance, species composition, and community size structure, species composition and abundance of the fish community, and the composition, abundance, and depth distribution of submerged aquatic vegetation. While these secondary food-web parameters may influence public perception and relate to the desired use, they are influenced by factors in addition to nutrient load and concentration.

9.8.3 Explore Relationships Between Phosphorus and Desired Use

The conceptual basis for evaluating attainment of the phosphorus-related narrative water quality standard relies on a quantitative link between the concentration of nutrients (in this case, phosphorus) and attainment of designated use. To the extent that phosphorus limits primary production in a lake, there is a strong correlation between paired measurements of phosphorus and chlorophyll-*a*. This relationship in Onondaga Lake has become stronger in recent years as concentrations in the lake have fallen (**Figure 9-4**). The variability in individual measurements may be attributed to changes in composition of the algal community and luxury uptake of phosphorus by some species. Plotting summer average TP and chlorophyll-a data reduces the variability (**Figure 9-5**).

Perhaps more important to lake users than average algal abundance (as measured by chlorophyll-*a*) is the frequency, magnitude and duration of bloom conditions. On this metric, Onondaga Lake is improving, and there is a strong relationship between the lake's store of phosphorus in the spring and the frequency of algal blooms during the summer recreational period (**Figure 9-6**).

Dr. William Walker's empirical mass-balance framework predicts eutrophication-related water quality conditions (as measured by nutrient concentrations, chlorophyll-a, algal bloom frequency, transparency, and hypolimnetic oxygen depletion) as a function of yearly nutrient loads, inflows, and lake morphometry. The PMBM enables managers to quantify the risk of algal blooms as a function of TP concentration in the lake's upper waters. Conditions measured in 2006 – 2007, with Stage II phosphorus removal at Metro, correspond to a less than 10% risk of nuisance algal blooms. The lake water quality improvements associated with reductions in phosphorus loads over the 1990-2007 period are shown in **Figure 8-16**. In addition, the rate at which the risk of algal blooms diminishes is very low as phosphorus continues to decline (refer to **Figure 8-20**).. This suggests that a cost-benefit analysis of additional reductions in Metro effluent is warranted.

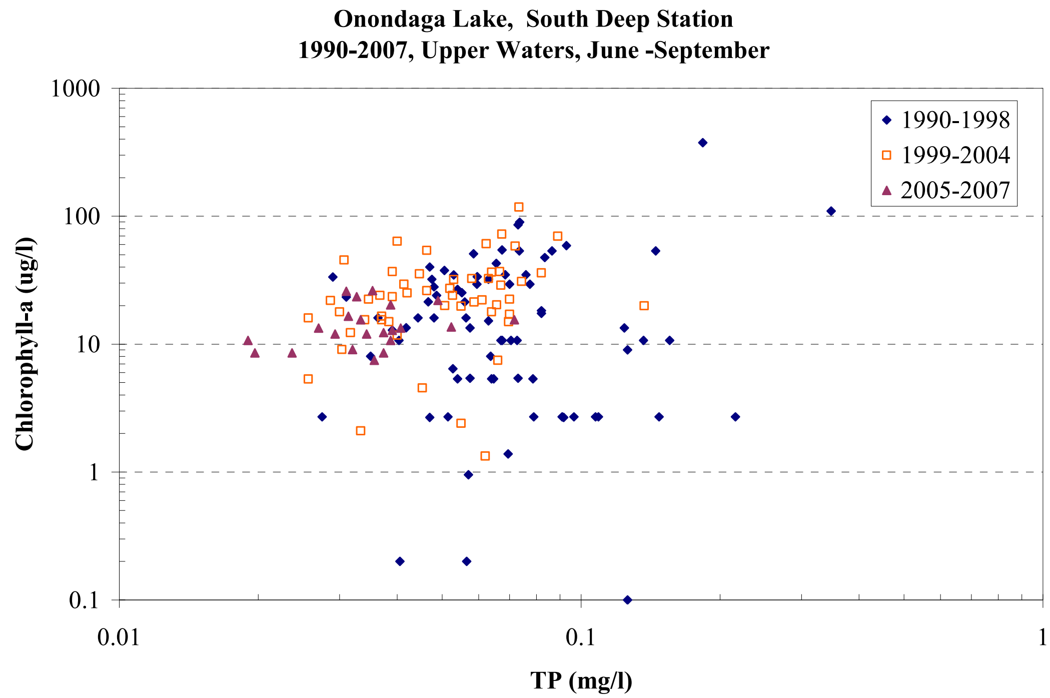

Figure 9-4. Paired measurements of total P and chlorophyll-a, Onondaga Lake.

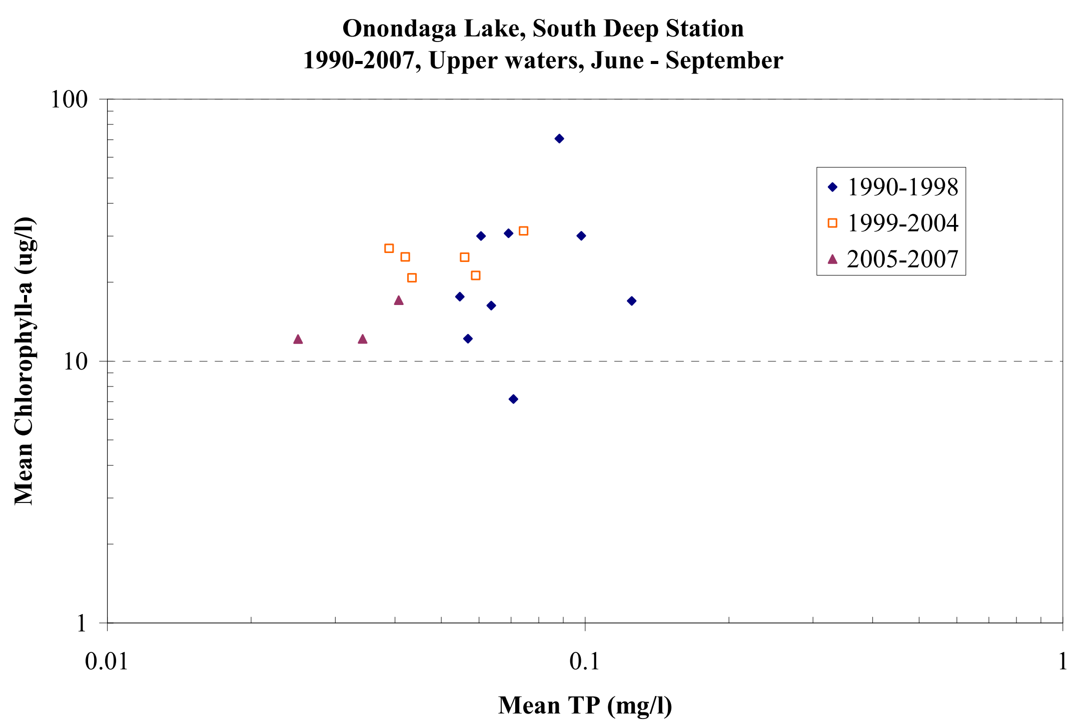

Figure 9-5. Paired measurements of average total P and chlorophyll-a, Onondaga Lake.

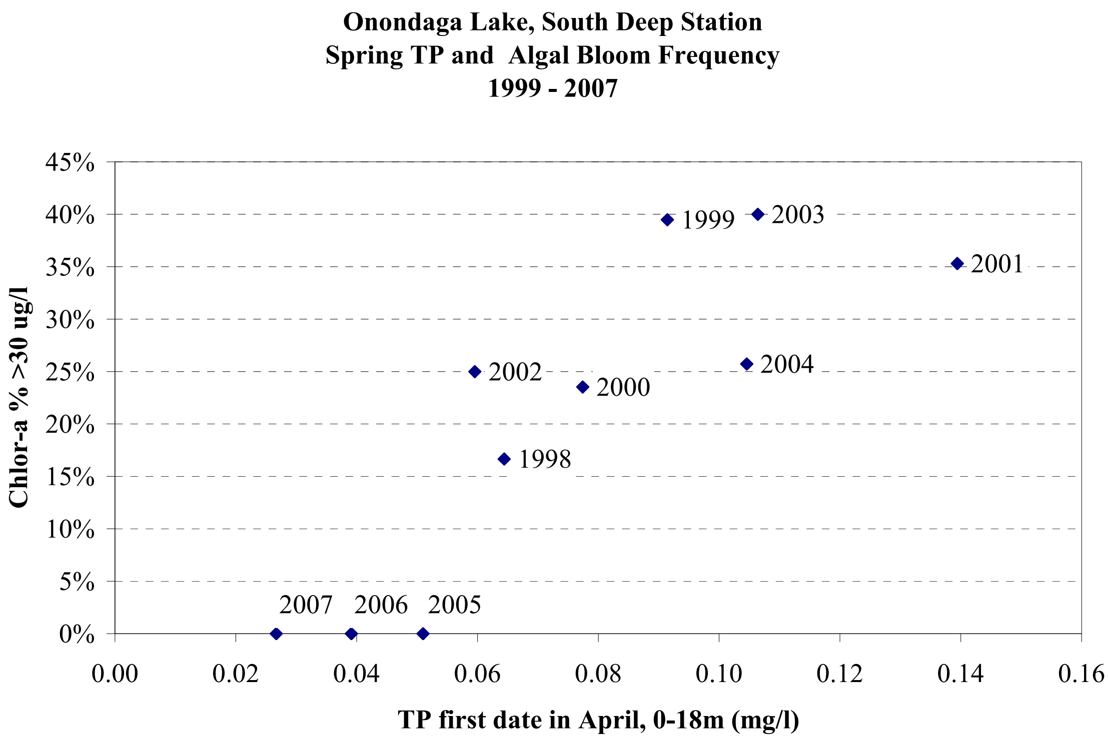

Figure 9-6. Relationship between spring TP and summer algal bloom frequency, 1999 – 2007.

9.8.4 Reach Consensus on how Compliance with Metrics will be Assessed

Because Onondaga Lake receives both point and nonpoint source TP inputs from the large watershed, year-to-year changes in precipitation will influence the load and consequently the in-lake conditions. Since the concern with elevated phosphorus is aesthetics and recreation, not toxicity, a reasonable compliance target may be a summer average TP concentration as measured over a number of years or a decade. It is recommended that water resource managers select a target hydrologic period (typically at least 10 years) that would be representative of long-term average precipitation. The various model of inputs and lake response would be run for each year; managers may base their decisions on the frequency distribution of projected water quality conditions across years. The selected water quality criterion would be compared with the average of the yearly simulated values over the representative hydrologic period. Year-to-year variations in nonpoint loads can be estimated from annual rainfall using simple regression models shown in Chapter 8.

9.8.5 Apply the Enhanced Onondaga Lake Water Quality Model and Phosphorus Mass Balance Model to determine the TMDL

The OLWQM and PMBM can be used to quantify the benefits associated with nutrient reductions from both nonpoint and point sources. Reduction in algal bloom frequency, changes in water clarity, and improved dissolved oxygen levels are projected. This will provide a basis for testing sensitivity of results to modeling approach. This process to define attainment of the narrative water quality standard for Onondaga Lake will reflect the progress made to date, consider the economic benefit and cost relationship, look ahead to factors beyond local control such as climate change, draw on the extensive database resulting from over thirty years of monitoring, and be supported by an integrated watershed/lake/river modeling framework that has undergone a rigorous peer review.

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CHAPTER 10: RECOMMENDATIONS

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CHAPTER 10. RECOMMENDATIONS

Several specific recommendations are offered in the context of the 2007 AMP report findings.

1. **NYSDEC, Onondaga County, and other stakeholders should proceed with the technical analysis and procedural requirements necessary to define a site-specific interpretation of the narrative phosphorus standard for Onondaga Lake.**

   The site-specific interpretation of the narrative phosphorus standard for Onondaga Lake will serve as the target in-lake total phosphorus concentration for the Phase 2 TMDL allocation that NYSDEC will prepare. As described in Chapter 8 of this annual report, the recommended framework for the site-specific interpretation of the narrative phosphorus standard is as follows:

   1. Reach consensus on the uses of the lake to be protected based on the existing water quality classifications.
   2. Define metrics of ecological response related to desired use.
   3. Explore relationships between phosphorus and desired use.
   4. Reach consensus on how compliance with metrics will be assessed.
   5. Apply the enhanced Onondaga Lake Water Quality Model and the Phosphorus Mass Balance Model to determine the total load that will allow compliance with the narrative standard for phosphorus.

2. **It is recommended that Onondaga County continue to disseminate the findings of the AMP to the scientific community, water resources managers, OLP stakeholders, and the interested public.**

   The success of the wastewater treatment plant improvements and progress towards recovery of Onondaga Lake are issues of great interest to many, including state and local officials, environmental scientists, and the community at large. Several points support this recommendation:

   - The AMP is designed and implemented with a commitment to high technical standards and an open process.
   - Carefully designed methodologies, QA/QC protocols, and inter-laboratory comparisons have focused on maintaining standards in laboratory data.
   - The County uses technical reviewers to oversee program design, provide guidance on data analysis and interpretation, and comment on reports.
   - There is a parallel commitment to community outreach through the Onondaga County website http://www.ongov.net/WEP, fact sheets, brochures, and user-friendly versions of the annual report.

- Onondaga County has invested in a large and complex program of water quality and biological monitoring, resulting in an extensive dataset. There is a tremendous potential for further exploration of the data and testing various trophic interaction models.
- Onondaga County has invested in custom databases to manage its extensive water quality and biological data and facilitate their integrated analysis and interpretation.
- The Onondaga Lake water quality model is being developed in an open and collaborative manner, with peer review at each phase. The tool that results will be of value to the stakeholder community.

3. **Future lake water quality improvements will require a commitment to reductions in nonpoint source loading from the watershed. The USGS watershed model accommodates reduced loading from Best Management Practices (BMPs). An effort to monitor and document the effectiveness of BMPs as implemented would improve managers' understanding of the potential benefits of these actions on improved water quality and habitat conditions.**

   There is currently no central repository of nonpoint source reduction projects within the Onondaga Lake watershed. Analysis of the implementation status of such projects might provide insight to observed changes in water quality and habitat conditions in the tributary subwatersheds. Specific project information and any pre- and post-BMP monitoring results are in individual reports in consultant and agency files. This information could also support an analysis of the effectiveness of particular BMPs and help set priorities for additional measures.

4. **A Wetland Fish Index (WFI) is recommended for inclusion in the AMP. This index will serve to integrate data from the entire fish community into a single value. The WFI detects both spatial and temporal patterns, and appears to be correlated with other metrics of habitat quality and biological response in Onondaga Lake.**

5. **Onondaga Lake is a regionally popular bass fishing destination. Local anglers have contacted OCDWEP with concerns regarding the seemingly "thinner" smallmouth bass they have been catching in recent years. The AMP fish community monitoring program has verified that the relative weight of smallmouth bass has decreased substantially since 2003. The cause of the decrease is not entirely understood. Because of the importance of smallmouth bass to the lake's fishery, the County should investigate this issue further, possibly in coordination with researchers from Cornell's Biological Field Station at Shackelton Point.**

6. **The issue of the sources and transport of bacteria within the Onondaga Lake watershed continues to be important to use attainment and policy considerations. The County should continue its efforts to pinpoint and remediate specific sources.**