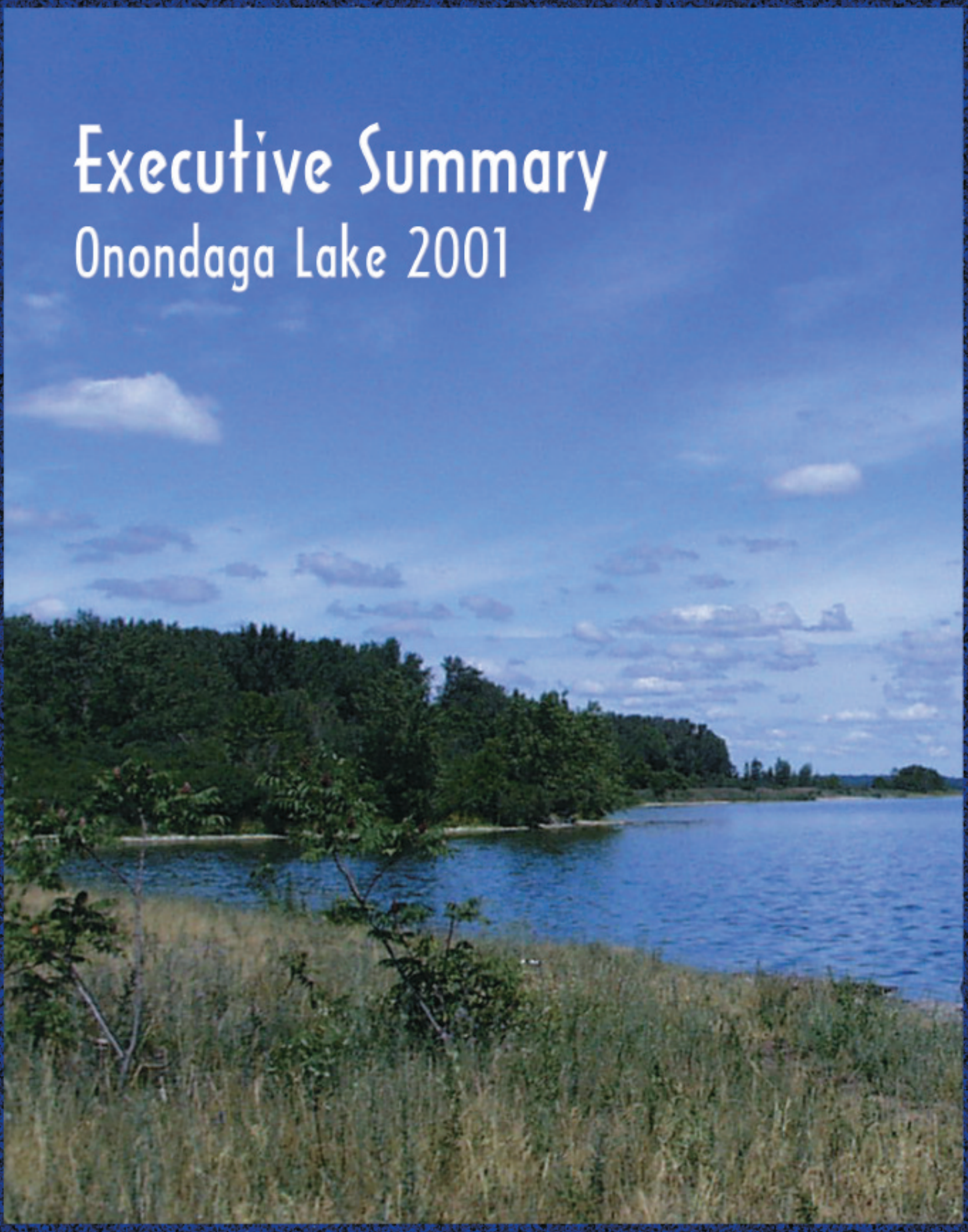
Executive Summary
Onondaga Lake 2001



Acknowledgments

The Onondaga County Department of Water Environment Protection (formerly, Onondaga County Department of Drainage and Sanitation) is responsible for implementing the Ambient Monitoring Program (AMP). Funds for the Ambient Monitoring Program are provided primarily by Onondaga County. The Onondaga Lake Technical Advisory Committee (OLTAC) has been assembled to provide technical assistance to the County. OLTAC members include:

Dr. Raymond Canale (EnginComp Software, Inc.): modeling, Seneca River

Dr. Charles Driscoll (Syracuse University): water and sediment chemistry, mercury

Dr. Edward Mills (Cornell University): food web, phytoplankton and zooplankton

Dr. Elizabeth Moran (EcoLogic, LLC): monitoring program, limnology

Dr. Lars Rudstam (Cornell University): food web, fish community

Dr. Kenton Stewart (SUNY Buffalo): physical limnology

Dr. William Walker, Jr. (Environmental Engineer): statistical design, mass-balance modeling

Many agencies provide oversight and technical assistance to the County, including:

- New York State Department of Environmental Conservation
- United States Environmental Protection Agency
- New York State Attorney General, Environmental Protection Bureau
- United States Army Corps of Engineers and the Onondaga Lake Partnership
- Atlantic States Legal Foundation

Joseph J. Mastriano of Onondaga County Department of Water Environment Protection administers the AMP. Jeanne C. Powers oversees program implementation. Mr. Mastriano and Ms. Powers are supported by Nicholas Capozza (field program leader and biological program oversight), Michael Gena (director of Onondaga County's state-certified Environmental Laboratory), Janaki Suryadevara (water quality program oversight) and Antonio D. Deskins (data compilation, calculations, and plotting).

EcoLogic LLC, Quantitative Environmental Analysis LLC, Dr. William Walker, Dr. Edward Mills, and Beak Consultants Inc. prepared sections of the 2001 Annual Report. The Executive Summary was prepared by EcoLogic LLC with design and layout by Nichols Graphic Design of Lakeville, NY.

August 2002

The Onondaga County Department of Water Environment Protection is responsible for collecting and treating wastewater from homes and businesses throughout the County. As Commissioner, I am proud to lead our talented and dedicated staff under a name reflecting our strong commitment to protecting the water resources we all share.

The Department performs an intensive survey of water quality conditions in the Onondaga Lake watershed each year. This publication is a summary of the findings of the 2001 Onondaga Lake Ambient Monitoring Program, the 32nd year of County monitoring of the lake and adjacent waters. Current conditions and trends in water quality and the lake's biological community are highlighted in this summary document. A complete report of the 2001 monitoring effort is available from the Department upon request.

Onondaga County is required by State and Federal regulations to monitor the lake and its tributary streams. The January 1998 Amended Consent Judgment (ACJ) required the Department to develop an ambient monitoring program to measure water quality conditions and assess progress towards compliance with state and federal standards.

Employees of the Department sample Onondaga Lake, major streams flowing to the Lake, and the Seneca River. Water samples are analyzed in the County's state-certified environmental laboratory and results are used to calculate the input of sediment, chemicals, and bacteria to the lake. Results of the monitoring program are used to track how Onondaga Lake and the Seneca-Oneida-Oswego River system respond to pollution abatement activities. The data are compared with applicable water quality standards developed to protect the aquatic ecosystem and ensure that the waters are safe for recreational uses.

In 1998, the County's annual monitoring program was redesigned to focus specifically on the water quality and ecological improvements brought about by the required improvements to the Syracuse Metropolitan Wastewater Treatment Plant (Metro) and Combined Sewer Overflows (CSOs) that are underway. Results of the monitoring program will help the New York State Department of Environmental Conservation (NYSDEC) and the federal Environmental Protection Agency (EPA) determine whether further actions are needed to meet community goals and standards.

Comments on this report are encouraged and may be directed to Joseph J. Mastriano, Operations Manager, at 315-435-2260.

Very truly yours,

Richard L. Elander, P.E.
Commissioner

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2001 Water Quality Synopsis

Onondaga County measures many characteristics of Onondaga Lake and its adjacent streams to assess water quality conditions. Results of these measurements help determine whether the lake is safe for water contact recreation, and whether conditions are adequate to protect the health of the lake's community of plants and animals. These concerns reflect the national goal for all surface water, often referred to as the "swimmable fishable" goal. The County monitors indicators of human health and safety, such as sewage-related coliform bacteria and water clarity, along with ecological indicators, such as oxygen and nutrient levels, abundance of plant life, and the success of fish reproduction. Highlights of the 2001 monitoring results are summarized below.

Regional lakes and streams have been affected by the dry conditions which persisted through 2001. Total rainfall for the year was 4.6 inches below normal. The dry conditions contributed to late summer algal blooms in Onondaga Lake. Between June 1 and August 31, 2001 **chlorophyll-*a*** concentrations averaged 17.9 micrograms per liter (µg/l), a unit of measure equivalent to one part per billion. Chlorophyll-*a* is a plant pigment measured to estimate the abundance of algae in lake water. Lake users will perceive a definite green tinge to the water when chlorophyll-*a* concentrations exceed about 13 µg/l. This level of algal abundance makes the lake appear less attractive for recreational use.

Water transparency is assessed using a small disk (the Secchi disk) lowered through the water column until it's no longer visible. Deeper **Secchi Disk transparency** values indicate clearer water. Weekly Secchi disk transparency measurements from June through September 2001 averaged 2.5 meters (m). Lake water clarity met the swimming safety guidance of 1.2 meters from June to mid-August, until algal blooms limited water clarity. Low transparency conditions persisted through September 2001.

In 2001, the summer average concentration of **phosphorus**, the limiting nutrient for algal growth in Onondaga Lake, was the lowest ever recorded. The summer average concentration (36 µg/l in the upper waters) is consistent with the designation of Onondaga as a eutrophic lake (that is, a productive lake with high levels of plant growth).

Nearby Oneida Lake is a large, shallow, productive lake renowned for its perch and walleye fishery. The Cornell Biological Field Station monitors water quality conditions in Oneida Lake. Comparing the results of the summer 2001 monitoring efforts for the two lakes illustrates the higher concentrations of phosphorus and chlorophyll-*a*, and the lower water clarity evident in Onondaga Lake.

Comparison of Onondaga and Oneida Lakes

	Onondaga Lake 2001	Oneida Lake 2001
Summer Phosphorus:	36 µg/l	24.3 µg/l
Secchi Disk Transparency:	2.5 m	4.2 m
Summer Chlorophyll-*a*:	17.9 µg/l	13.7 µg/l

Dissolved oxygen was absent from the lower waters of Onondaga Lake during the summer of 2001. This condition of anoxia, which is typical of productive lakes, recurs each year. Without adequate oxygen in the cool deep waters, fish and other aquatic animals are restricted to the warmer upper waters where oxygen is present year-round. As a consequence, productive lakes tend to have a fish community dominated by warm water species, such as bass and sunfish.

As the lake cools each fall, temperature differences between the upper and lower waters begin to disappear and the wind mixes the lake from top to bottom. Water from deep in Onondaga Lake contains chemicals such as hydrogen sulfide, iron, and methane that accumulate during summer anoxia. These chemicals are distributed throughout the lake during the fall mixing period and can cause a dramatic decline in lake-wide oxygen levels (a phenomenon known as oxygen sag). In 2001, the fall oxygen sag continued to show improvement; daily average dissolved oxygen concentrations met state standards during the fall mixing period.

Ammonia nitrogen concentrations in the lake's upper waters continued to decline in response to major loading reductions at Metro. Treated wastewater from the Metro plant is the single largest source of ammonia to the lake, contributing more than 85% of the external load in 2001. The water quality benefits of improved ammonia treatment at Metro and

successful operation of the pretreatment facility at Bristol-Myers Squibb were evident in the lake in 2001. Concentrations of ammonia approached the upper allowable limits for only a very brief period in the spring. Summer concentrations measured in the upper waters met the New York State standards, falling well below critical levels for fish and other sensitive aquatic organisms.

Fecal coliform bacteria levels are measured at multiple sites in Onondaga Lake to assess whether the water is safe for contact recreation. Fecal coliform bacteria are used as indicators of the potential presence of pathogenic (disease-causing) microorganisms. The 2001 data indicate that bacteria levels in the southern basin, near the CSOs and major streams, are frequently elevated. However, water quality improves in the northern basin, and areas near Maple Bay and Willow Bay are generally safe for contact recreation.

Fish are a recent addition to the County's monitoring program. Annual surveys are completed to enumerate nests, determine the number and types of larval and juvenile fish, and track the community composition and growth rate of the adult fish community. Results from 2001 indicate that the lake supports a diverse community of warm water fish species such as largemouth bass, smallmouth bass, and sunfish.

Trends in Water Quality

The 2001 results provide a snapshot of "The State of the Lake" and help managers assess how conditions during this year met the goals for a swimmable, fishable lake. Throughout the community, there is also deep interest in how the lake has changed over time. The County is closely tracking changes in water quality and relating these changes to the improvements in the wastewater collection and treatment system that are underway. As part of the AMP, data collected each year are analyzed for trends over time. These results help gauge how the lake is changing in response to the substantial public investment in improvements to the wastewater collection and treatment system.

Water Quality Issue	Trend	Comment
Phosphorus Levels	⇩	Declining in response to controls on inputs.
Water Clarity	⇧	Increasing with lower algal abundance and proliferation of zebra mussels.
Algal Blooms	⇩	Still present, but for shorter periods.
Ammonia Levels	⇩	Dramatic decrease in response to improvements at Metro.
Nitrite Levels	⇩	Decreased concentrations related to Metro improvements in ammonia treatment.
Chloride Levels	⇔	Steep decline with closure of AlliedSignal facility in mid-1980s, now stable.
Dissolved Oxygen	⇧	Increased levels at fall mixing, shorter duration of anoxia.
Aquatic plant (weed) growth	⇧	Increasing. This will improve habitat for aquatic life and help stabilize shallow sediments.
Fish Reproduction	⇧	Evidence of more fish and better survival.
Fish Contaminant Levels	⇔	Fish advisory in place based on mercury levels.
Bacteria Levels	⇔	Limited data. Problems persist in southern area. Outlook good as controls on combined sewers are implemented.

The Ambient Monitoring Program

The primary objective of the County's monitoring effort is to provide the data and information needed to assess the effectiveness of the extensive improvements to the wastewater collection and treatment system that are underway. A number of specific objectives are incorporated into the design of the tributary, lake, and river components of the Ambient Monitoring Program (AMP).

The **tributary stream monitoring program** is designed to quantify the flow of water, chemicals, sediment, and microorganisms into Onondaga Lake. Accurate estimates are a critical component of the AMP, since they underlie many of the management decisions facing Onondaga County.

Loading estimates are needed to understand the relationships between pollutants entering the lake and the resulting water quality conditions. The New York State Department of Environmental Conservation (NYSDEC) and others will use these relationships to set an acceptable level of treatment for the Metropolitan Wastewater Treatment Plant (Metro) and the Combined Sewer Overflows (CSOs). CSOs discharge a mix of storm water and untreated wastewater when flows exceed the capacity of the pipes in the sewer system.

The stream monitoring efforts can provide a basis for estimating the relative importance of sources of phosphorus. Understanding the role of the watershed in contributing phosphorus to the lake from various sources, such as urban stormwater and agriculture, will help managers clarify the need for additional treatment or relocation of the Metro effluent to meet water quality and aesthetic goals for the lake.

Collecting stream samples during rainstorms and snowmelt is an important component of the tributary monitoring program. Monitoring has documented that most of the pollutants enter the lake during these infrequent high flow periods. Although challenging for the field and laboratory staff, the storm event monitoring program is collecting valuable data to assess the effectiveness of the CSO remediation program. Storm event monitoring is designed around the construction schedule for the major CSO facilities that will collect and treat overflows on Onondaga Creek, Harbor Brook, and Ley Creek. Storm event monitoring on Nine Mile Creek will help managers understand the effects of urban stormwater (without CSOs) on stream quality.

Because physical features affect the distribution and abundance of life in streams, the County is evaluating habitat as well as water quality conditions in the Onondaga Lake watershed. Surveys of physical characteristics of the streams are underway, along with periodic sampling of the macroinvertebrate community. As in all components of the AMP, Onondaga County is committed to evaluating the data as they are collected. Sufficient flexibility is incorporated to reallocate sampling and analytical resources as new information becomes available.

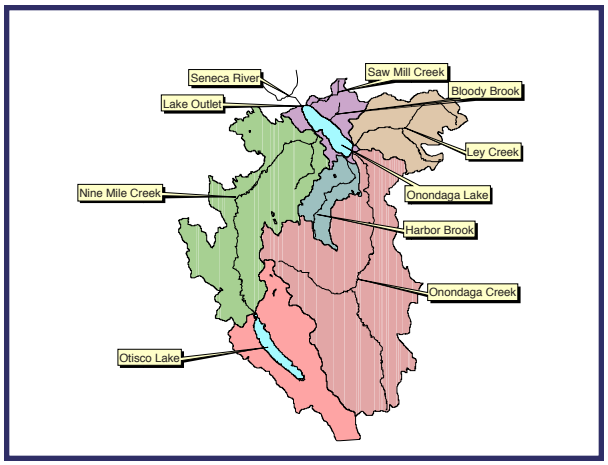
The **lake monitoring program** is designed to measure the effectiveness of controls on Metro and the CSOs. Data are used to assess compliance with water quality standards and community goals. Experts in statistics have carefully reviewed the monitoring program design to ensure that managers will be able to draw firm conclusions regarding the effectiveness of the control measures.

An important feature of the AMP is the greatly enhanced program of biological monitoring. Monitoring of the macrophyte (rooted aquatic plants and algae) community is underway, along with assessment of other major components of the lake's food web: phytoplankton, zooplankton, macroinvertebrates, and the fish community.

The third major component of the AMP is the **Seneca River monitoring program**. Water quality in the Seneca River is relevant to the AMP in two important areas. First, the river and lake are hydrologically connected. Water quality improvements in Onondaga Lake will be realized in the river as well, since the lake outflow affects the river. Second, if the improvements to Metro do not result in improved water quality conditions, future diversion of all or a portion of the Metro effluent to the Seneca River will be evaluated as an alternative. The assessment of this diversion alternative is to be made by February 1, 2009. Quantitative Environmental Analysis, LLC (QEA) is developing a mathematical water quality model of the Seneca River that will be used to help evaluate the environmental feasibility of diverting Metro discharge to the river.

Onondaga Lake and Its Watershed

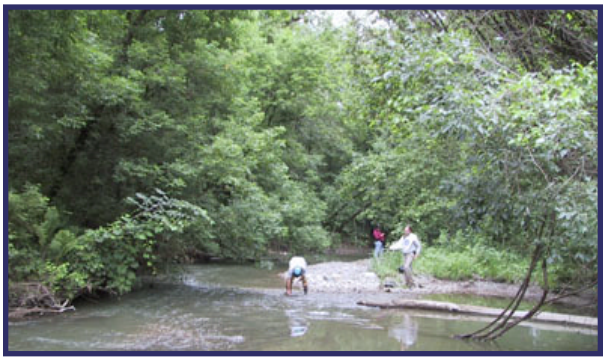
The Onondaga Lake drainage basin encompasses approximately 642 square kilometers (248 square miles) and lies almost entirely in Onondaga County. The drainage basin includes six natural sub-basins: Nine Mile Creek, Harbor Brook, Onondaga Creek, Ley Creek, Bloody Brook, and Saw Mill Creek. The outlet of Onondaga Lake flows north to the Seneca River and ultimately into Lake Ontario.



Land use in the watershed is a mixture of agriculture (32%), forests (43%), and urban areas (22%). Urban areas of Syracuse surround the lake. Sediment and pollutants from the entire drainage basin make their way to the lake.

The Metro wastewater treatment plant is a major source of nitrogen, phosphorus, and organic (oxygen-demanding) material to the lake. Metro is an advanced secondary treatment plant, operated to enhance conversion of ammonia to nitrate during warm weather (in a process known as nitrification) and removal of phosphorus. The plant is being upgraded to provide year-round nitrification to increase removal of ammonia, phosphorus, and oxygen-demanding material. To minimize the use of chlorine, which is potentially harmful to aquatic life, ultraviolet (UV) disinfection is being installed to treat flows up to 126.3 million gallons per day (mgd). This process will kill microorganisms without the use of chlorine. The UV disinfection system will allow Metro to meet the state's mandated chlorine residual limits. Flows between 126.3 and 240 mgd will still be disinfected using liquid sodium hypochlorite (bleach) and dechlorinated using sodium metabisulfite.

Onondaga County's trained technicians collect water quality and biological samples at a number of key locations in the watershed. Streams flowing into Onondaga Lake are monitored close to the lake to estimate the annual input of water and materials including nutrients, sediment, salts, and bacteria. Samples are collected further upstream to help pinpoint sources of pollution. The lake's outlet to the Seneca River is monitored throughout the year, except when ice cover prevents access. Periodically, the field teams sample over a 20-mile stretch of the Seneca River, upstream and downstream of the lake outlet.



Sampling in Onondaga Creek.

Onondaga Lake is relatively small, especially compared with the nearby Finger Lakes and Oneida Lake. The shoreline is highly regular, with few embayments. Much of the shoreline is owned by Onondaga County and is maintained as part of a popular park and trail system. The lakeside park is used for recreational activities such as jogging, biking, roller-blading, shoreline fishing, and cultural entertainment. The lake is used for secondary water contact recreation such as boating. In 2001, a fishing derby was held on Onondaga Lake, attracting thousands of anglers to the lake and its shoreline. The lake is becoming a popular fishing spot.

Fishing was banned in the lake in 1972 due to mercury contamination. The ban was lifted in 1986 and modified into a "catch and release fishery"; that is, recreational fishing was permitted but possession of lake fishes was not. In 1999, the New York State Department of Health (NYSDOH) revised its advisory regarding consumption of gamefish from Onondaga Lake. The current recommendation is to eat no walleye from the lake, and restrict consumption of all other fish species to no more than one meal per month. The fish advisory continues to be based on mercury levels in fish flesh. As in all New York

Onondaga Lake Facts

Surface area:	11.7 km² (4.5 mi²)
Average depth:	10.9 m (36 ft)
Maximum depth:	19.5 m (64 ft)
Volume:	131 million cubic meters (34,600 million gallons)
Average water residence time:	4 months
Largest tributaries:	Onondaga Creek and Nine Mile Creek
Fish:	Warmwater community

waters with health advisories, the Health Department advises that women of childbearing age, infants, and children under the age of 15 eat no fish from these waters.

NYSDEC is responsible for managing water resources throughout the State. Lakes and streams are classified according to their designated best use (for example, water supply, swimming, fish propagation, aesthetic enjoyment, and fish survival). Results of water quality and biological monitoring are evaluated to determine if designated uses are supported. Because water quality and habitat conditions limit their use for swimming and aquatic life protection, Onondaga Lake and the Seneca River are among the State's top priorities for water quality improvement.

Water bodies that do not meet their designated uses may require a watershed approach to water quality protection or restoration. A watershed approach examines all point and nonpoint sources of pollution and develops an integrated strategy for improvement. Point source discharges to Onondaga Lake include effluent from Metro and the CSOs, treated industrial wastewater from Crucible Specialty Metals, and non-contact cooling water from several industries at the former AlliedSignal complex. Metro receives and treats wastewater from residential, commercial, and industrial sources. Certain industries, such as Bristol-Myers Squibb, provide some treatment to their wastewater before directing it to Metro, where it mixes with the rest of the inflowing wastewater for additional treatment and discharge to Onondaga Lake.

Nonpoint sources, such as runoff from agricultural and urban areas, also contribute contaminants. Nutrients, sediment, bacteria, metals, and pesticides reach surface and groundwater resources from these diffuse sources. Industrial residuals in the watersheds of individual tributaries, such as polychlorinated biphenyls (PCBs) in the Ley Creek basin and the AlliedSignal waste beds in the Nine Mile Creek basin, continue to enter the lake through surface runoff and infiltrating groundwater. Lake sediments contain elevated concentrations of mercury and organic chemicals.

Water Quality Issues

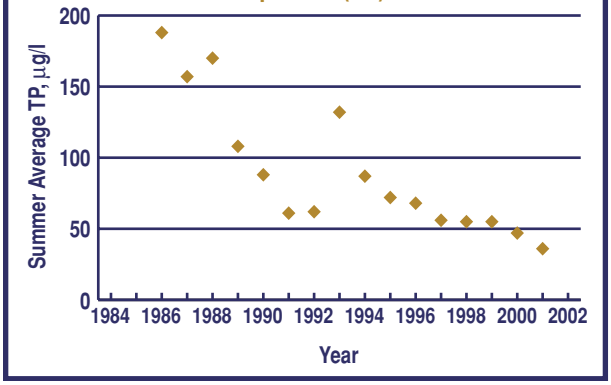
Phosphorus

Phosphorus is naturally present in all waters and is an essential nutrient for life. In most lakes, phosphorus is the limiting nutrient for algal growth; that is, phosphorus concentration is positively correlated with algal abundance. Until recently, phosphorus concentrations in Onondaga Lake were so high that algal growth was limited by other factors, such as light levels. Reductions in phosphorus loading achieved since the mid-1990s have shifted the lake to a phosphorus limited system. This is evidence of improving water quality conditions.

Excessive algae will make a lake appear turbid or green and diminish its attractiveness for recreational use. Decay of algae can reduce the concentration of dissolved oxygen in a lake's lower waters. Consequently, lake managers focus on controlling phosphorus inputs to protect recreational use and aquatic life.

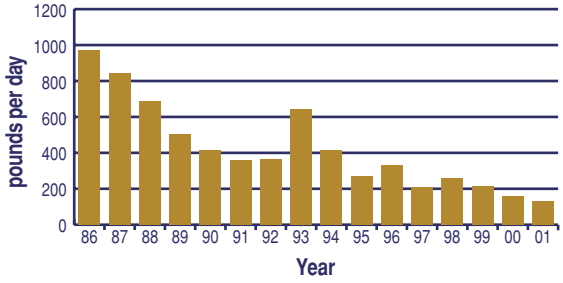
A fifteen-year record of summer average concentration of phosphorus in the upper waters of Onondaga Lake (the zone where plants and algae grow) is displayed in Figure

Figure 1. Onondaga Lake Summer Phosphorus (TP) 1986-2001



1. Improvements in phosphorus removal at Metro were implemented in the late 1980's, and the lake responded quickly to this reduction in load. Construction-related bypasses of wastewater caused the high concentration in 1993 from Metro during this extremely wet year. In recent years, summer concentrations have ranged from 35 - 60 µg/l.

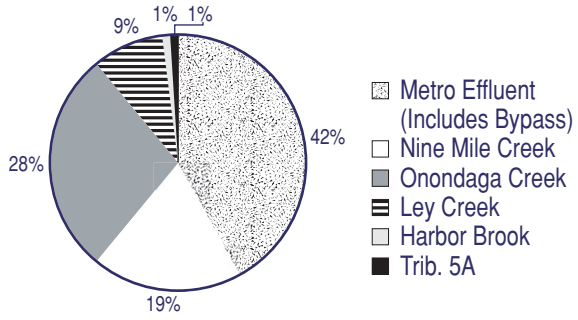
Figure 2. Annual Phosphorus Discharge from Metro, 1986-2001



Phosphorus removal at Metro is achieved using chemicals, such as iron salts and polymers, to coagulate and precipitate the nutrient and enhance its settling from the wastewater. Because of the importance of phosphorus to lake ecology, its removal from wastewater has been a central focus of the engineering improvements at Metro. Since 1987, the County has experimented with the amounts and types of chemicals added to the wastewater to maximize phosphorus removal. Note the decline in annual phosphorus loading from the treatment plant plotted in Figure 2.

A phased limit for phosphorus discharged from Metro is included in the Amended Consent Judgment (ACJ) governing the lake cleanup projects. The current (Stage I) maximum phosphorus discharge from Metro is 400 pounds per day. A Stage II limit of 0.12 mg/l (less than 90 pounds per day) is to be met by April 1, 2006. The County's currently planned improvements at Metro will result in meeting the Stage II limits or better by mid- 2004, well ahead of schedule. Small-scale tests (pilot tests) to determine how much additional phosphorus can be removed from the wastewater have been conducted. Results of the pilot tests, which were conducted six years ahead of schedule, are very encouraging.

Figure 3. Percent Total Phosphorus Loading to Onondaga Lake in 2001



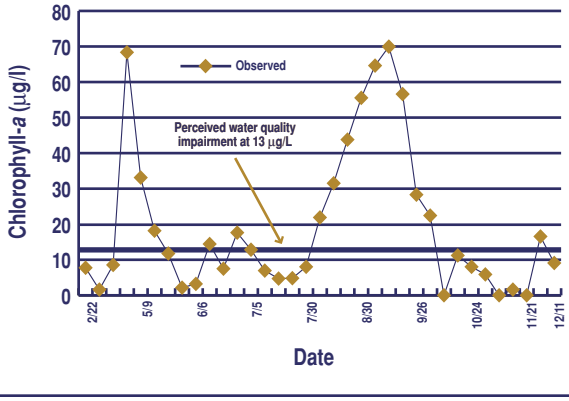
The focus on Metro phosphorus reflects its importance to the overall phosphorus budget of Onondaga Lake. Treated effluent from Metro is the largest point source of phosphorus, contributing around 40 - 60% of the external phosphorus load to the lake each year. As displayed in Figure 3, the 2001 data indicate that approximately 42% of the phosphorus input came from Metro during this dry year.

Algae and Water Clarity

The concentration of chlorophyll-*a*, the major photosynthetic pigment in plants, is used to estimate algal abundance in water. Chlorophyll-*a* concentration is used by water resources management agencies to compare algal abundance between lakes, because of its ease of measurement. It is also used to track changes over time in individual lakes. Some agencies have established guidelines on maximum concentrations of chlorophyll-*a* in an effort to protect recreational uses of lakes. In New York, concentrations exceeding 13 µg/l are considered to diminish a lake's suitability for recreational use.

Chlorophyll-*a* concentration in the upper waters of Onondaga Lake averaged 17.9 µg/l during the summer of 2001. There was a tremendous amount of variability in this parameter, as plotted in Figure 4. A spring algal bloom was followed by a relatively clear

Figure 4. Chlorophyll-*a* at Mid-Lake Station Onondaga Lake 2001



water phase from June through mid-August. A second bloom occurred in mid-August and persisted through September 2001. The 2001 chlorophyll data were within the range of historical data, as evident from the data displayed in Figure 5.

The 2001 Secchi disk transparency measurements in Onondaga Lake are plotted in Figure 6. Note the high water clarity during June and July (deeper Secchi disk transparency) when algal density was low. This is a typical result for lakes where algal cells are causing the water to appear turbid or green. Comparing this graph to the 2001 chlorophyll results plotted in Figure 5 highlights the importance of algal biomass in limiting water clarity in Onondaga Lake.

Similar to the chlorophyll results, year-to-year changes in Secchi disk transparency can be dramatic. Water clarity in Onondaga Lake, although highly variable, has improved since 1986 as displayed in Figure 7. This improved water clarity is due in part to reduced phosphorus loading from Metro. However, changes to the lake's food web were triggered with the 1986 closure of the AlliedSignal facility and the dramatic reduction in chloride inputs that resulted. As chloride concentrations declined, different species of zooplankton (tiny aquatic animals that graze on algae) began to thrive in the lake. These zooplankton species are more efficient grazers of the lake's algal cells and contribute to the increased water clarity. More recently, the zebra mussel has invaded the lake. These animals also contribute to increased water clarity.

Figure 5. Summer Average Chlorophyll-*a* in Onondaga Lake, 1986-2001

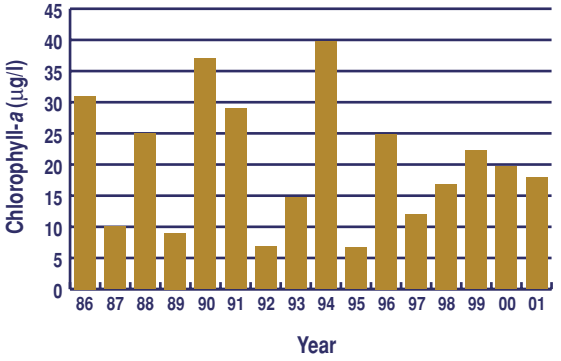
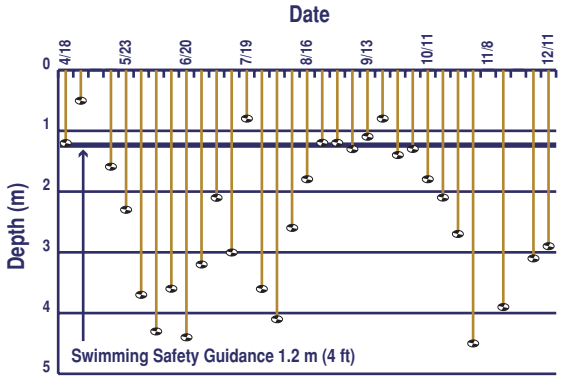


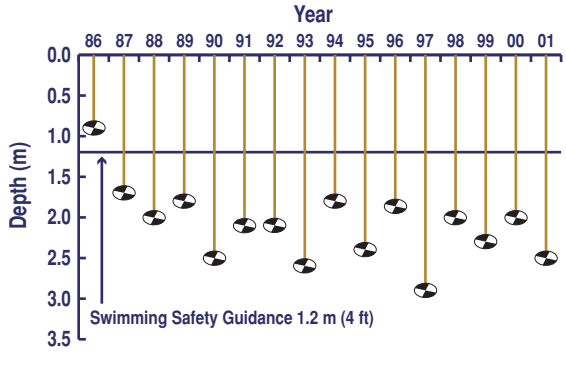
Figure 6. Secchi Disk Transparency, Onondaga Lake 2001



Dissolved Oxygen

The dissolved oxygen (DO) status of Onondaga Lake is closely linked to the annual temperature cycle. During summer, the lake's deeper waters remain isolated from the atmosphere. Light to support photosynthesis by algae or aquatic plants cannot reach the deeper waters. As a consequence, no oxygen production occurs. The existing DO in the lake's lower waters is used by bacteria and fungi; these organisms decompose organic material settling to the lake bottom from the sunlit layers above. As algal abundance increases in the upper waters, activity of the decomposers increases and DO is used up in the lower waters. When the supply of DO is depleted, the waters become anoxic. Other chemicals such as iron, ammonia, hydrogen sulfide, and methane accumulate in the anoxic lower waters, as decomposition continues in the absence of oxygen.

Figure 7. Average Summer Water Clarity, Onondaga Lake 1986-2001



When the lake cools in the fall, temperature differences that keep the water layers isolated begin to break down. Gradually, the deep anoxic waters mix with the upper waters. Chemical reactions with iron, ammonia, hydrogen sulfide, and methane can remove oxygen in the upper waters as they begin to circulate with the anoxic lower waters. As a consequence, DO concentrations are reduced. To comply with state and federal standards designed to

Figure 8. Dissolved Oxygen, Onondaga Lake 2001

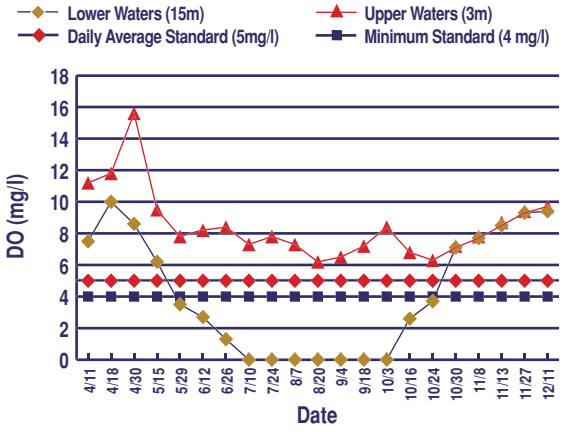


Figure 9. Minimum Dissolved Oxygen in Upper Waters during Fall Mixing, 1988-2001

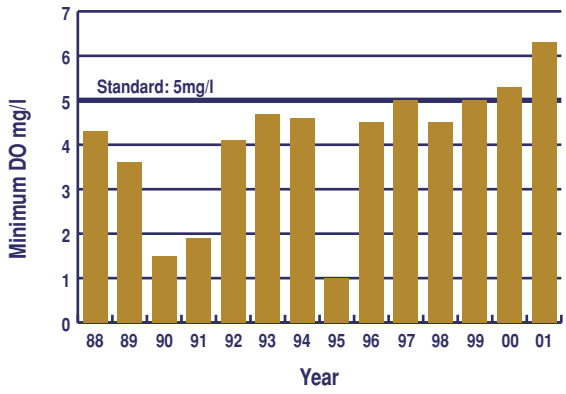
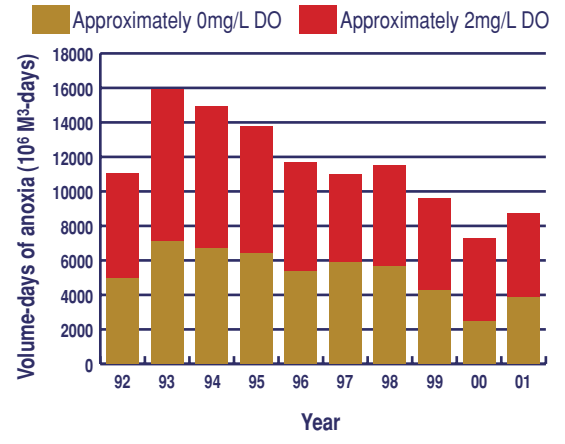


Figure 10. Volume Days of Anoxia in Onondaga Lake, 1992-2001



protect aquatic life, DO should remain above 4 - 5 mg/l in the upper waters during this critical period of fall mixing. Compliance with minimum DO standards during fall mixing is one of the restoration goals for Onondaga Lake.

Dissolved oxygen measurements obtained during the 2001 monitoring season are displayed in Figure 8. Note the rapid loss of DO in the lower waters that began in June, after thermal stratification had isolated the lower waters from the atmosphere. Note also the decline in DO in the upper waters during October. The upper waters lost about 2.0 mg/l of DO as they cooled and began to mix with the anoxic lower waters. Complete mixing occurred by late October, as indicated by convergence of the lines in Figure 8 that display data for the upper and lower waters. Concentrations of DO gradually increased as the waters continued to mix and gain oxygen from the atmosphere.

Minimum DO concentrations measured in the lake's upper waters during fall mixing since 1988 are plotted in Figure 9. Note the variability in this measurement. Some of the variability is random; minimum DO in the fall depends to a certain extent on how cool and windy is the weather. However, the pool of iron, hydrogen sulfide, ammonia, and methane that has accumulated over the summer period ultimately affects oxygen depletion in the fall. As algal biomass is reduced in response to decreased phosphorus inputs, decomposition in the lower waters will decline. Improved oxygen levels will result.

Onondaga County has installed a water quality monitoring buoy at the lake's deepest point. Suspended from the buoy is an array of state-of-the-art monitoring and recording instruments that measure water temperature, pH, dissolved oxygen, and specific conductance (a measure of dissolved salts). Results are transmitted back to a computer at the Department of Water Environment Protection offices on Hiawatha Boulevard, where they are uploaded to the County's web site. The buoy is in operation from early spring to late fall. Data can be viewed at *www.ongov.net*. This near real-time water quality measurement system represents a critical advance in our ability to monitor and interpret lake conditions, especially during critical periods such as fall mixing.

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 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. As indicated by the data summarized in Figure 10, volume-days of

anoxia in Onondaga Lake are declining, representing improved water quality conditions for the biological community.

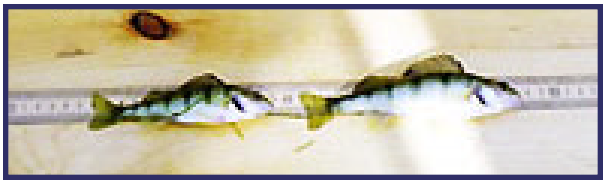
Ammonia and Nitrite Nitrogen

Ammonia and nitrite are two chemical forms of nitrogen that can be harmful to aquatic life. Young stages of aquatic animals, such as newly hatched fish, are especially sensitive. Metro is the major source of ammonia to Onondaga Lake, contributing about 85% of the annual load. The treatment plant was not designed to remove ammonia from wastewater and only recently have operational modifications been made to allow some nitrification (conversion of ammonia to nitrate, a nontoxic form of nitrogen) during warm weather. An enhanced aeration system has improved the treatment process in recent years, resulting in much less ammonia reaching the lake (Figure 11).

Major improvements to the County's wastewater treatment facility are underway to support year-round nitrification. This change in the treatment process is necessary to reduce the lake's ammonia nitrogen to safe levels for the aquatic community. The County is making excellent progress on the ammonia removal projects and is projected to meet the final effluent limits by 2004, eight years ahead of schedule.

The columns on Figure 12 display average ammonia nitrogen in Onondaga Lake's upper waters measured in recent years. Concentrations of greater than approximately 1.4 mg/l (the standard varies with pH and temperature) exceed the water quality standard for ammonia, designed to protect sensitive aquatic life. Results are variable from year to year depending on factors such as weather and algal abundance. The single most important factor governing ammonia nitrogen in the lake is the performance of Metro. The number of days of violation of the ammonia standard in the upper waters each year is plotted in Figure 13. The 2001 data demonstrate dramatic progress towards compliance.

The concentration of nitrite measured in the lake's upper waters during 2001 is displayed in Figure 14. The standard for nitrite is 0.1 mg/l, a level that scientists consider safe for a warmwater fish community. In 2001, the nitrite concentrations remained at acceptable levels until mid-September. Elevated concentrations persisted through the fall mixing period. This may represent incomplete biological transformation of



Juvenile yellow perch.

Figure 11. Metro Ammonia Discharge to Onondaga Lake, 1988-2001

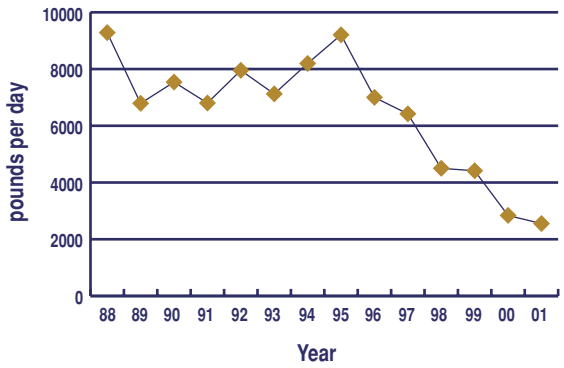


Figure 12. Average Ammonia-N in Upper Waters of Onondaga Lake, 1988-2001

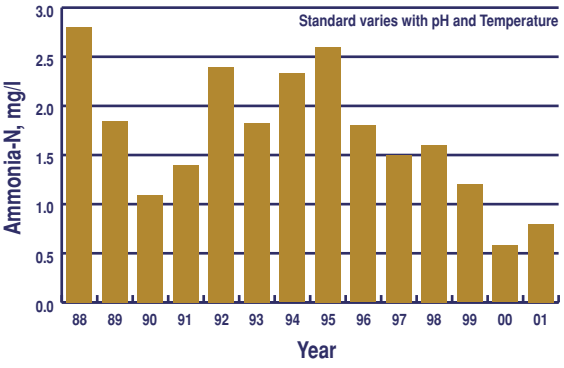


Figure 13. Days of Violation of Ammonia Standard Onondaga Lake Upper Waters, 1988-2001

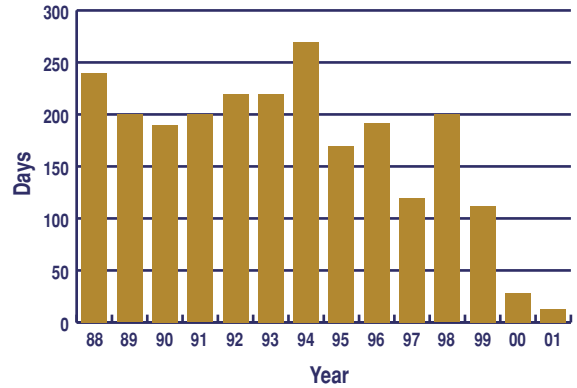


Figure 14. Average Nitrite-N in Upper Waters, Onondaga Lake 2001

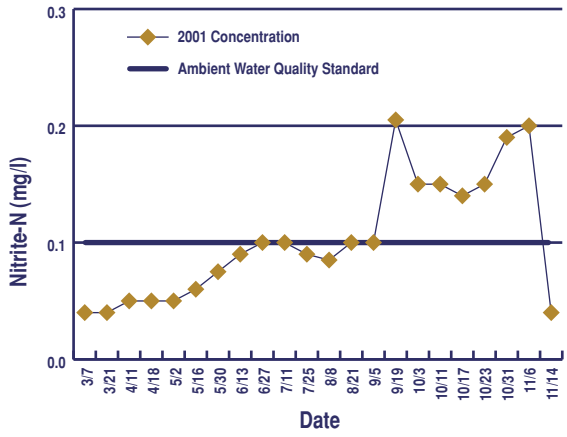
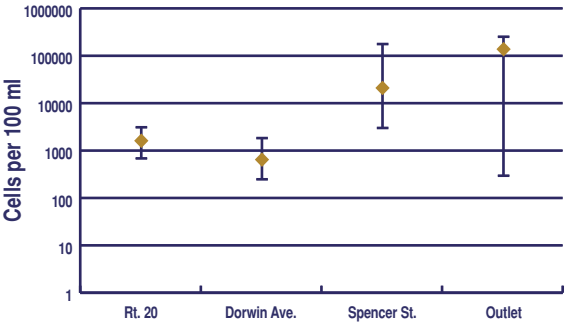
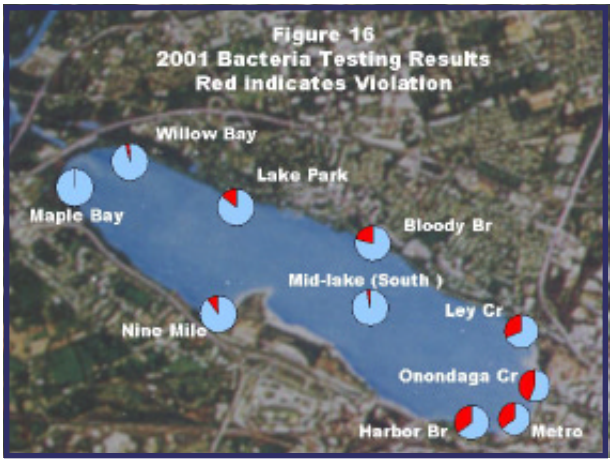


Figure 15. Average and Range of Fecal Coliform Bacteria in Onondaga Creek, Rain Event, Sept. 2001





the pool of ammonia that accumulated in the lake's lower waters. Because of the linkage between ammonia and nitrite, improvements to the Metro treatment plant to reduce ammonia are expected to reduce nitrite levels in the lake as well.

Ammonia and nitrite concentrations are major factors affecting the type and abundance of aquatic life in the lake. Reductions in concentrations of these harmful forms of nitrogen are required to meet state and federal guidelines and protect a diverse aquatic community. As ammonia and nitrite levels are reduced, the aquatic community will begin to resemble that of other regional lakes. The recent proliferation of zebra mussels in Onondaga Lake suggests that a shift in community composition is underway.

Bacteria

In 1999, Onondaga County began a storm event monitoring program designed to collect samples in the major streams during and after intense rainstorms. These data help project engineers and scientists estimate the annual input of pollutants to the lake and understand the relative contribution of CSOs to pollution loading.

Onondaga Creek is the primary focus of the storm event monitoring program, as the majority of CSOs discharge to this stream. Modifications to the wastewater collection system that will eliminate untreated overflows (for the statistical 1-year storm or lesser intensity) are underway. The storm event monitoring program included sampling during the three-year period from 1999 to 2001 to quantify baseline conditions. Sampling locations were selected to represent conditions upstream and downstream of major point and nonpoint sources. A particular focus is on the locations of the CSOs; sampling is conducted upstream and downstream of where the overflows enter the streams. Storm event monitoring is planned for 2005, 2008, and 2012, based on the construction schedule for completing major projects along the creek.

The storm event monitoring data will be used to verify mathematical models of the relationship between storm intensity and contaminant transport. Water quality of streams and the lake is measured by the abundance of indicator bacteria, such as fecal coliform bacteria. Once tested and verified with site-specific data, the mathematical models can be used to project loading and water quality under a range of future conditions.

Figure 15 displays the concentration of fecal coliform bacteria, a microorganism associated with recent sewage contamination, measured in Onondaga Creek during an intense storm in September 2001. Two of the four sample locations in Onondaga Creek, Route 20 and Dorwin Ave., are upstream of the City's urban corridor and CSO points. The other two sam-

pling locations, Spencer St. and the Onondaga Creek Outlet, are affected by CSO discharges. Note how the abundance of indicator bacteria increases downstream of the CSOs.

Restoring recreational uses of the lake is a major goal of the improvements to the County's wastewater collection and treatment system. The AMP includes sampling for indicator bacteria in nearshore areas that might one day support water contact recreation. Sampling is done during dry weather and following storms. Results of the 2001 lake bacteria monitoring effort are displayed in Figure 16. The picture displays the percent of 2001 measurements that comply with the bacteriological standards. The southern end of Onondaga Lake has unacceptably high levels of indicator bacteria following storms and does not support water contact recreation. This finding highlights the need for continued progress with the CSO projects.

Manure on riparian zone of Onondaga Creek.

However, microbiological quality improves greatly as one proceeds away from the southern tributaries. Water quality in Willow Bay, Maple Bay, and Onondaga Lake Park showed very few violations of bacteria standards for safe swimming. The County will continue to monitor nearshore areas around the lake shoreline to assess progress towards meeting the goal for safe swimming.

Biology of Onondaga Lake

Electrofishing boat used by County personnel.

A restored Onondaga Lake will have a healthy community of plants and animals. Monitoring the biological community in and around the Lake is an important part of the AMP. Special organisms, known as biological indicators, are the focus of much of the monitoring program. The presence and abundance of these biological indicators can tell managers a great deal about the overall health of the ecosystem.

Phytoplankton (tiny plants suspended in the water) and **zooplankton** (microscopic aquatic animals) have long been part of the County's annual monitoring program. Researchers from the Cornell Biological Field Station evaluate the community of phytoplankton and zooplankton each year. Abundance and species composition are evaluated from samples collected from early spring through the late fall. Zooplankton size is measured and tracked over the year, as this metric indicates the amount of grazing pressure exerted by the fish community. Results are compared with phytoplankton and zooplankton measurements from Oneida Lake.

Results of the 2001 monitoring effort indicate a shorter bloom period for cyanobacteria (blue-green algae). It is too early to tell if this is due to normal year-to-year variation or if it indicates improving lake water quality conditions.

Zooplankton density is high in Onondaga Lake, consistent with the eutrophic conditions of high nutrients and algal biomass. The average size of the lake's zooplankton declined from its maximum value in March through early summer, indicating a

surge in zooplanktivory (consumption of zooplankton by fish and other organisms). A second decrease in average size of the zooplankton was evident in late summer, when the young-of-the-year fish begin to graze them in substantial numbers.

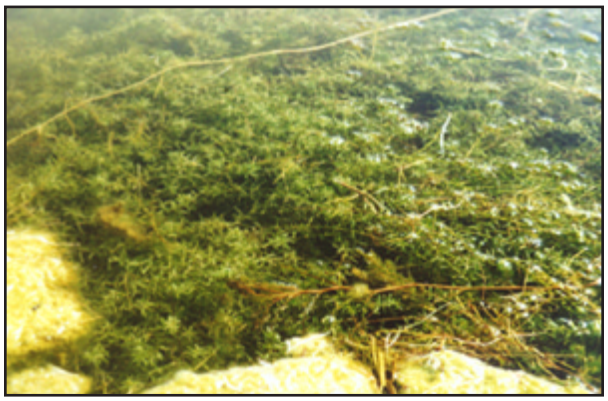
Non-native species are a visible feature of the Onondaga Lake ecosystem, as they are for lakes and streams throughout the Great Lakes Basin. Recent field investigations documented an abundance of the larval stage of zebra mussels (called veligers) and the presence of a predatory cladoceran zooplankton *Cercopagis pengoi*, which has recently been introduced to the Great Lakes from the Caspian Sea region in Asia. Ballast water from ships is the likely culprit in transporting these invasive species to North American lakes and streams.

Macroinvertebrates are small insects and worms that live in the bottom sediments of streams and lakes. They are included in the AMP because their numbers and types are closely linked to water quality and conditions of the bottom sediments. In 2000, the County and its consultants completed a baseline survey to document existing conditions of the macroinvertebrate community and provide a benchmark against which change can be assessed. This survey will be repeated in 2002; results will be discussed in next year's Executive Summary.

Macroinvertebrates collected from Onondaga Lake tributaries.

The macroinvertebrate communities of Onondaga Creek, Ley Creek, and Harbor Brook are affected to various degrees by pollution and habitat degradation. The macroinvertebrate community of Harbor Brook is the most severely impacted, based on standard indices calculated from the number and types of organisms present. Ley Creek and Onondaga Creek are affected to lesser degrees. It appears that a combination of habitat degradation, nonpoint source pollution, and oxygen-demanding material discharged by CSOs are affecting the macroinvertebrate communities of the three streams. Upstream segments of the tributaries are affected by agricultural runoff and the mud boils along Onondaga Creek, while urban stormwater and CSOs influence the community in downstream segments.

Results of the macroinvertebrate sampling of the lake's littoral (nearshore) zone reveal differences in the macroinvertebrate community between the northern and southern ends of Onondaga Lake. As expected, the macroinvertebrate community in the northern end of the lake is less affected by the pollutant inputs that dominate the southern basin: wastewater, contaminated and/or saline groundwater, and sediment. The combined influences of eutrophication and habitat degradation appear to be major structuring elements of the benthic community in the nearshore areas of Onondaga Lake.



Elodea spp. (Common waterweed)

Macrophytes will be monitored once every five years, since they are important to stabilizing the lake bottom sediments and providing food and shelter for young fish. A baseline survey was conducted during 2000. Compared with results of a survey conducted in 1991, both the number of plant species in Onondaga Lake and the percent of the lake bottom covered with plants have increased. The County supplements the field surveys with annual aerial photographs of the lake. The photos are used to estimate how much of the lake bottom is covered with macrophytes and help track changes over time.

Onondaga County Department of Water Environment Protection and EcoLogic LLC have recently entered into a contract with the NASA Affiliated Research Center at SUNY-ESF to

investigate the applicability of using satellite images to map the lake's macrophytes. The investigation will test images of differing spatial and spectral resolution. Results of the technology evaluation will be discussed in next year's Executive Summary.

Fish are a major focus of the biological monitoring program. The County is evaluating the reproductive success of the fish community using a combination of classical and innovative techniques to count nests, sample larval and adult fish, and track changes in the fish community. Data will be collected each year as improvements to wastewater collection and treatment are phased in. Cooperating anglers are recruited to keep diaries of their fishing efforts and successes. Extensive resources of field time and equipment are dedicated to the fish program.

Data are used to evaluate which species are present, which are reproducing, what is their growth rate, and how do they move between the lake and river. Standard methods are used so that the fish community of Onondaga Lake can be compared with that of other lakes. Experts in fish ecology oversee program design and implementation.

Since the program began in 2000, sampling of the juvenile and adult fish community has resulted in collection of more than 13,000 fish representing 30 species. The number of nests has exploded, demonstrating increased reproductive activity in the northern basin. Smallmouth bass nests were documented for the first time in Onondaga Lake in 2000.

Trap nets have been used to sample fish populations.

Linkages to the Seneca River

The Seneca River is an important part of the Onondaga Lake system. Water quality of the river is directly affected by the outflow of Onondaga Lake. In addition, the capacity of the river to handle additional treated wastewater is an issue that is relevant to the final alternatives for discharge of the Metro effluent in an environmentally sound manner.

Under current conditions, the Seneca River could not accept a new significant discharge of treated wastewater because dissolved oxygen levels in the river do not meet state standards. Proliferation of zebra mussels has reduced the oxygen resources. This situation has complicated what once appeared to be an acceptable management alternative for improving Onondaga Lake. Metro effluent could only be diverted to the river if the water quality of both ecosystems would be protected.

Onondaga Lake water is saltier (and thus denser) than the water flowing in the Seneca River, so water flowing out of the lake tends to remain near the bottom of the channel. Because there is very little difference in elevation, river water can puddle over the lake water in the outlet and can actually flow into the lake during dry periods when stream flows are low.

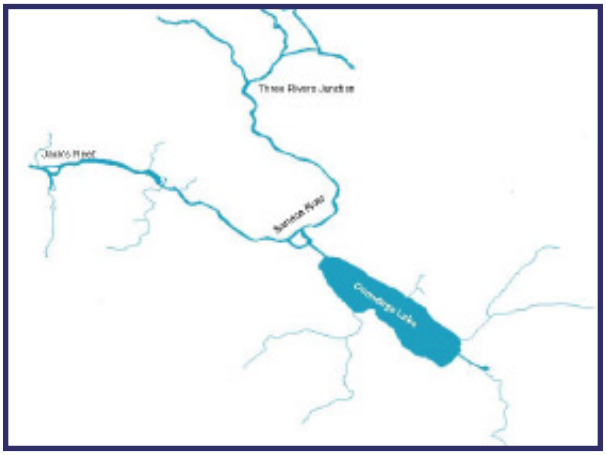
This unusual flow regime in the lake outlet affects water quality conditions in adjacent segments of the river. During some low flow conditions, the difference in density isolates the lower waters from the upper waters in the river channel. Oxygen from the atmosphere does not mix deep into the river; as a consequence DO concentrations in the river's deeper waters are low upstream and downstream of where the outlet of Onondaga Lake joins the river. The DO concentrations in this stretch of the river fall below levels considered safe for aquatic life. Ammonia concentrations in the Seneca River are also affected by lake water quality downstream of the lake outlet.

Seneca River at Onondaga Lake outlet.

The firm Quantitative Environmental Analysis LLC (QEA) is developing a water quality model of the Seneca River that projects water quality conditions under a range of future scenarios. This model specifically incorporates the activity of the zebra mussels. One objective of the river monitoring program is to collect the data needed to verify and test the water quality model. Data collection efforts are targeted during late summer and early fall when water temperature is high and river flows tend to be lowest.

Beak Consultants have also worked closely with the County on issues related to the Seneca River. Scientists from this firm have mapped the distribution and abundance of mussels along a stretch of river extending from Jacks Reef to the Three Rivers junction. These data are extremely valuable to the modeling team in assessing the importance of zebra mussel activity on water quality conditions.

Additional information about the Seneca River-Onondaga Lake system can be found at Onondaga County's web site *www.ongov.net*. From this site, follow the links to the Lake Improvement Project Office site. Here you can read monthly progress reports of the many activities underway to improve the lake and view near-real-time water quality data.



Seneca River study area.

A Look Ahead

The Ambient Monitoring Program represents a significant commitment by Onondaga County to protect and restore our water resources. The program is designed to assess progress towards community goals and determine what else is needed. Experts from many areas provide guidance and review, and we welcome input from all members of the community.

The 2001 data confirm that Onondaga Lake is on the road to recovery. Phosphorus concentrations are the lowest ever measured. Algal blooms are diminishing. Oxygen concentrations (essential for aquatic life) have shown marked improvement in the past three years. Ammonia nitrogen concentrations in lake water have decreased and approach levels that are safe for even the most sensitive aquatic organisms. These improvements are very encouraging, since a significant investment in the improvement of the wastewater collection and treatment system is well underway.

The biological programs are providing fascinating information illustrating the linkages between improved water quality and the number and types of plants and animals the lake can support. The County AMP is among the most comprehensive monitoring programs currently in place in any community. We look forward to bringing the highlights of the monitoring program to the public each year to build community appreciation and support for the restored lake and watershed.

Glossary

Amended Consent Judgment (ACJ). An agreement signed in January 1998 by New York State, Onondaga County, and Atlantic States Legal Foundation committing the County to a 15-year program of improvements to the wastewater collection and treatment system and associated monitoring.

Ambient Monitoring Program (AMP). Annual water quality and biological monitoring program conducted in Onondaga Lake, the lake tributaries, and the Seneca River.

Ammonia nitrogen. A form of ammonia that is toxic to aquatic life.

Bacteria. Single-cell or non-cellular organisms that lack chlorophyll and reproduce by fission. They are important as pathogens and for biochemical properties.

Chlorophyll-a. The primary photosynthetic pigment in algal (phytoplankton) cells, used as an index of algal abundance.

Combined Sewer Overflow (CSO). A relief point in the wastewater collection system that operates when the hydraulic capacity of the pipe is exceeded. CSOs direct a mixture of storm water and untreated sanitary wastewater to nearby water bodies.

Dissolved Oxygen (DO). The quantity of oxygen dissolved in water. DO concentrations vary with depth, season, and time of day in Onondaga Lake in response to photosynthesis and breakdown of organic matter (especially algal cells). DO levels are a major factor affecting the abundance and type of organisms living in the lake.

Eutrophic. A lake characterized by high levels of nutrients and biological productivity.

Fecal coliform. A type of bacteria whose natural habitat is the colon of warm-blooded mammals such as humans. While most fecal coliform bacteria are not harmful, they are used as an indicator of the potential presence of pathogenic (disease causing) microorganisms associated with recent fecal contamination.

Fish. Any of numerous cold-blooded aquatic vertebrates of the superclass Pisces, characteristically having fins, gills, and a streamlined body.

Macroinvertebrate. Aquatic insects and worms that spend at least part of their life cycle in sediments of streams and lakes. Numbers and types of these organisms are used to infer water quality and habitat conditions.

Macrophytes. Rooted aquatic plants and algae. Macrophytes are an important component of the lake food web.

Mesotrophic. A lake characterized by moderate levels of nutrients and biological productivity.

Metro (Syracuse Metropolitan Wastewater Treatment Plant). Treatment plant on Hiawatha Blvd.

Nitrification. The biological conversion of ammonia to nitrate.

Nonpoint source pollution. Type of pollution involving complex transport and delivery mechanisms within the lake watershed.

Oligotrophic. A lake characterized by low levels of nutrients and biological productivity.

Phosphorus. An element that is an essential macronutrient for plant growth; the limiting nutrient for phytoplankton growth in Onondaga Lake.

Phytoplankton. Microscopic algae and certain bacteria found in lake water.

Secchi disk transparency. A standard measure of water clarity obtained by lowering a 20-cm disk through the water column and recording the depth at which it is no longer visible.

Water quality criteria. Best scientific judgment of the maximum contaminant level in water that will protect a designated use (such as water supply or swimming).

Water quality standard. An enforceable limit, usually numerical, of the maximum contaminant level in water that will protect a designated use. Standards may be the same as criteria.

Zooplankton. Microscopic animals found in lake water; primary consumers of phytoplankton.

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Onondaga County
Department of Water Environment Protection

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