2014 Annual Report

ONONDAGA LAKE
AMBIENT MONITORING PROGRAM

Final, January 2016

Onondaga County

Joanne M, Mahoney, County Executive • Tom Rhoads, P.E., Commissioner

Save the Rain

Onondaga County Department of
WATER
ENVIRONMENT
PROTECTION

ONONDAGA COUNTY DEPARTMENT OF WATER ENVIRONMENT PROTECTION

VISION

To be a respected leader in wastewater treatment, stormwater management, and the protection of our environment using state of-the-art, innovative technologies and sound scientific principles as our guide.

MISSION

To protect and improve the water environment of Onondaga County in a cost-effective manner ensuring the health and sustainability of our community and economy.

CORE VALUES

Excellence
Teamwork
Honesty
Innovation
Cost-Effectiveness
Safety

Onondaga County Department of WATER ENVIRONMENT PROTECTION

Save the Rain

http://www.savetherain.us

ONONDAGA LAKE AMBIENT MONITORING PROGRAM
2014 ANNUAL REPORT

ONONDAGA COUNTY, NEW YORK

Final, January 2016

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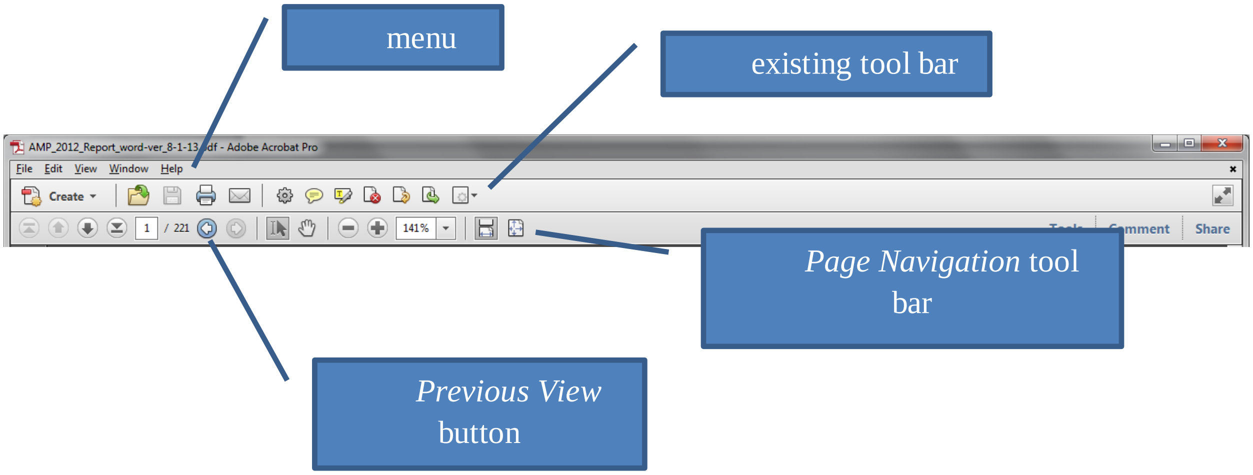

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Table of Contents

Appendices

LIST OF TABLES

LIST OF FIGURES

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Onondaga Lake from the northeast shore.

Executive Summary

Introduction

This Annual Report of Onondaga County's Ambient Monitoring Program (AMP) describes the state of Onondaga Lake and its tributaries in 2014. Conducted annually since 1970, the County's monitoring program provides water resource managers, public officials, state and federal regulators, and the entire community a window into the substantial improvements evident in Onondaga Lake – both in the lake's water quality conditions and in its biological community.

Changes in the lake ecosystem are the result of multiple factors. Some of these factors reflect human intervention, most notably the significant investment in improved wastewater treatment technology and the ongoing efforts to remediate legacy industrial wastes. Other changes in the Onondaga Lake ecosystem reflect biological factors such as the fluctuating population of the Alewife and its cascading effects on the food web. The 2014 Annual Report documents the input of water and materials (bacteria, sediment, nutrients, and salts) to Onondaga Lake from the watershed and the Metropolitan Syracuse Wastewater Treatment Plant (Metro). The response of the lake to these inputs is a focus of the annual program. The AMP evaluates water quality conditions, compliance with New York State ambient water quality standards (AWQS), and long-term trends. The AMP also tracks the species composition and abundance of fish, phytoplankton, zooplankton, benthic invertebrates, aquatic macrophytes, and dreissenid (zebra and quagga) mussels.

Report Format

This report is a scientific summary of the major findings of the AMP in 2014, supported by graphs and tables of current and historic data. This paperless format was developed to advance two objectives: first, to reach a broader audience, and second, to continue to find ways to reduce our environmental footprint through a commitment to green initiatives (for more information on Onondaga County's green initiatives visit http://www.savetherain.us). This format was envisioned as a means to enable Onondaga County leaders and citizens to learn about the condition of Onondaga Lake and its watershed. Additional program information is available on the County web site http://www.ongov.net/wep/we15.html. Annual reports from prior years are posted at http://www.ongov.net/wep/we1510.html.

Regulatory Framework

The 2014 AMP annual report has been prepared to comply with a judicial requirement set forth in the 1998 Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation (ASLF). The ACJ requires upgrades to the County's wastewater collection and treatment infrastructure and an extensive monitoring program (the AMP) to document related environmental improvements. Onondaga County

Department of Water Environment Protection (WEP) is responsible for implementing the AMP and reporting its findings. Links to the ACJ and its amendments are posted on the Onondaga County web site http://www.ongov.net/wep/we15.html.

Two important regulatory milestones were reached in 2012 that provide important context for the 2014 AMP results. First, New York State Department of Environmental Conservation (NYSDEC) issued a new State Pollution Discharge Elimination System (SPDES) Permit for Metro on March 21, 2012. Second, a total maximum daily load (TMDL) allocation for phosphorus inputs to Onondaga Lake was approved by USEPA on June 29, 2012. Upon TMDL approval, a total phosphorus concentration limit of 0.10 mg/L on a 12-month rolling average basis became effective for Metro outfall 001. In addition, phosphorus loading reductions are to be implemented for other SPDES permits by 1/1/2016, CSOs and Metro outfall 002 by 12/31/2018, agricultural lands by 12/31/2022, and for municipal separate storm sewer systems (MS4) areas by 12/31/2025. Phosphorus loading reductions from small farms are voluntary and incentive based.

The Fourth Stipulation of the ACJ required the County to submit a plan, with a schedule for implementation, for proposed modifications to the tributary component of the County's established AMP. These modifications, referred to as the Post-Construction Compliance Monitoring (PCCM) Program. The primary objective of the PCCM, in the context of the recently constructed gray project milestones, is to demonstrate that the abated CSOs are not causing or contributing to violations of water quality standards in the receiving water. The ultimate goal of the PCCM program is to determine whether Onondaga Creek and Harbor Brook are meeting the NYS AWQS and their designated uses. A detailed presentation of the scope and schedule of the PCCM Program was made in the 2013 AMP Report.

Onondaga County Actions and Progress with Related Initiatives

The County completed a number of "gray" and "green" infrastructure projects in 2014 that will reduce wet weather discharges from combined sewer overflows (CSOs) into Onondaga Lake and its tributaries. Gray infrastructure projects include sewer separation, capture of floatable materials, and maximization of system storage capacity. In 1998, there were 72 active CSOs (outfall points with the potential to discharge combined sewage) in the collection system discharging to Onondaga Creek, Harbor Brook, and Ley Creek. Through 2014, 47 of the County's 72 pre-ACJ CSOs have been closed or abated as a result of ACJ projects. In addition, green infrastructure projects are capturing hundreds of millions of gallons of stormwater runoff annually before it can enter the combined sewer system. Results from the County's recently calibrated Storm Water Management Model (SWMM) show that the annual capture percentage for the 2014 system conditions exceeded 95 percent and is ahead of schedule with respect to the mandated compliance milestones.

A number of significant gray infrastructure milestones were achieved in 2014, including the following major projects. The contractor's one year performance period began for both the Clinton Storage Facility and the Lower Harbor Brook Storage Facility in 2014, and both facilities are now fully operational in automatic mode. Onondaga County completed the bidding process and began construction on the CSO 063 Conveyances Project in 2014. This project will provide for the transmission of wet weather flow from CSO 063 to the Lower Harbor Brook Storage Facility. In 2014, the County initiated the planning and design phase for separation of sanitary and storm flow within the CSO 061 basin.

Green infrastructure solutions are being implemented at County facilities and in other urban areas to help capture and reuse urban storm runoff before it enters the CSO system. To-date, 169 green infrastructure projects have been completed as part of the "Save the Rain" initiative (http://savetherain.us/), reducing inputs of stormwater runoff and pollution to Onondaga Lake and its tributaries by 108 million gallons annually and providing CSO reduction of approximately 51 million gallons per year according to SWMM simulations. Twenty-two green infrastructure projects were completed as part of the "Save the Rain" program in 2014. These projects included replacement of traditional pavement with porous pavement, construction of green roofs, installation of bioretention and infiltration systems, removal of pavement from some areas, and other techniques to reduce stormwater runoff.

Honeywell International, with oversight by the federal Environmental Protection Agency, is proceeding with a number of projects to address industrial contamination issues in and around Onondaga Lake. Dredging and capping of Onondaga Lake sediments continued in 2014. About 2.2 million cubic yards of contaminated sediment were removed from the lake by hydraulic dredging, which was completed in 2014, a year ahead of schedule. About 450 acres of the lake bottom are being capped to provide a new habitat layer, prevent erosion, and isolate remaining contaminants. Capping is scheduled to continue into 2016. To date, 44 acres of wetlands have been restored at Geddes Brook, Harbor Brook, Nine Mile Creek, the former LCP Chemicals site, and along the western shoreline of Onondaga Lake. More than 110 species of fish, birds, and mammals have returned to restored wetlands, including mink, bald eagles, and northern pike. About 1.1 million plants, shrubs, and trees are being planted to enhance habitat for fish and wildlife in the Onondaga Lake watershed. Following a successful three year pilot test during 2011–2013, nitrate was again added to the deep waters of Onondaga Lake in 2014 with the objective of limiting release of methylmercury from the profundal sediments to the hypolimnion. Additional information on Honeywell's remediation activities is available on their project website (http://www.lakecleanup.com).

New Recreational Opportunities

A variety of new recreational opportunities have emerged in and around Onondaga Lake in response to water quality improvements. Although there is no public bathing beach at Onondaga

Lake, bacteria levels and water clarity consistently meet regulatory standards for swimming throughout most of the lake. Primary contact recreation remains limited in the extreme southern end of the lake following runoff events due to elevated turbidity and high fecal coliform concentrations. Onondaga Lake Park offers paved, vehicle-free trails, special events, sporting competitions, and festivals, and attracts over 1 million visitors annually. The new West Shore Trail, located along the scenic western shore of Onondaga Lake, meanders through over two miles of wind-sheltered woodlands. The 2.6 mile Onondaga Creekwalk is currently complete from the historic Armory Square district in Downtown Syracuse to the southern shore of Onondaga Lake. Construction will begin in 2015 on the "Onondaga Lake Lounge", a 1,350-square-foot wooden deck that will be built at the end of the Onondaga Creekwalk near Destiny USA, providing views of the lake and Onondaga Creek. The Lakeview Amphitheater Facility, an outdoor event complex located on the western shore of Onondaga Lake, hosted its first concert during the 2015 New York State Fair. Recreational and organized sport fishing has become increasing popular at Onondaga Lake over the past 15 years and continues to expand.

Tributary Water Quality

Precipitation is the primary driver of stream flow and the single most important meteorological attribute affecting material loading from the tributaries to Onondaga Lake. Annual precipitation totaled 40.5 inches in 2014, 4% higher than the 30-year historic (1984–2013) average of 38.8 inches and nearly equivalent to the 40.4 inches received in 2013. Above average precipitation during most of 2014 resulted in an annual average flow for Onondaga Creek that was 13% higher than the 1971–2014 average.

The largest total phosphorus (TP) loads to Onondaga Lake were delivered by the two largest tributaries, Onondaga and Ninemile Creeks, and the Metro effluent. The Metro bypass (002) load was estimated to be the fifth highest input of total phosphorus, following Ley Creek. Annual total phosphorus loads in 2014 were 5% higher than in 2013, consistent with slightly higher precipitation and streamflow in 2014. Onondaga Creek, Ninemile Creek, and the Metro effluent also had the highest total dissolved phosphorus (TDP) loads in 2014.

The Metro effluent was the leading source of total nitrogen (TN) and second largest source of ammonia nitrogen (NH_3-N) to Onondaga Lake in 2014. The largest source of ammonia in 2014 was Ninemile Creek. The total suspended solids (TSS) load was dominated by inputs from Onondaga Creek and Ninemile Creek, which combined to account for 95% of the total load to Onondaga Lake. Inputs of clay particles from the mud boils in upstream portions of the watershed contribute substantially to the high TSS contribution from Onondaga Creek. The TSS contribution from Ninemile Creek decreased from 45% in 2013 to 20% in 2014. This reduction in TSS loading is attributable to the completion of in-stream remediation activities conducted as part of the Honeywell cleanup. The primary sources of fecal coliform bacteria were Onondaga Creek and Ninemile Creek. However, the Metro bypass and Ley Creek also made noteworthy contributions. The combined loading from these four sources accounted for approximately 92% of the total fecal coliform load to Onondaga Lake.

Metro continued to perform at a high level in 2014, meeting permit limits for total phosphorus and ammonia throughout the year, and often by a wide margin. Since mid-2008 the 12-month rolling average total phosphorus concentration in the Metro effluent has remained below 0.10 mg/L. The 12-month rolling average total phosphorus concentration has remained below 0.07 mg/L since May 2013. The average total phosphorus concentration in the Metro effluent during 2014 was 0.062 mg/L. Headworks bypasses of the full treatment process, which are sometimes required during intense runoff events, receive little or no treatment prior to discharge. In 2014, 15 headworks bypasses summed to 33 million gallons. All of the headworks bypasses during 2014 were associated with reduced capacity due to the Grit Improvement Project, which has an anticipated completion date of 10/15/15. An additional 442 million gallons were discharged as a result of 86 secondary bypasses and another 19 million gallons were discharged as a result of tertiary bypasses. A detailed description of headworks, secondary, and tertiary bypasses is provided in Section 4.4.

The 2014 tributary data continued to indicate that the major tributaries were generally in compliance with New York State ambient water quality standards (AWQS). The primary exceptions in meeting AWQS in the tributaries were total dissolved solids (TDS) and fecal coliform bacteria (FC). Contravention of the AWQS for TDS is primarily associated with the natural hydrogeology of the watershed and not with anthropogenic effects. The largest source of fecal coliform bacteria to Onondaga Lake in 2014 was Onondaga Creek. However, the Metro bypass (002) and the other primary tributaries made noteworthy contributions as well. Compliance with the AWQS for fecal coliform bacteria was achieved for less than 50% of the monthly geometric means at Harbor Brook at Hiawatha (30%), Ley Creek (0%), Ninemile Creek at Lakeland (44%), Onondaga Creek at Kirkpatrick (22%), Onondaga Creek at Dorwin (44%), and Bloody Brook (33%).

An exploratory analysis was conducted to look for evidence of reduced urban storm flow in Onondaga Creek and Harbor Brook associated with runoff capture from green and gray infrastructure projects, including the Clinton and Lower Harbor Brook CSO storage facilities which were operational in 2014. Hydrograph separation techniques were used to delineate the urban component of the hydrograph for both streams, based on 15-minute USGS flow data. Results from this analysis suggest that green and gray infrastructure improvements have resulted in the capture of urban runoff and reduction in flow peaks in both Onondaga Creek and Harbor Brook. However, the results of this exploratory analysis should be considered preliminary as they are based on highly variable pre-construction data and a single year of post-construction data (2014 only).

Onondaga Lake Water Quality

Trained Water Environment Protection (WEP) technicians collect samples from various locations and depths within Onondaga Lake to characterize physical, chemical, and biological conditions. Most sampling occurs between April and November when the lake is free of ice. The data are used to track seasonal and long-term trends and to assess status with respect to ambient water quality standards.

Long-term trends in total phosphorus (TP) concentrations in the upper waters of Onondaga Lake continue to depict major decreases since the early 1990s. The 2014 summer (June-September) average TP concentration in the upper waters of the lake was 22 micrograms per liter (µg/L), slightly higher than the NYSDEC guidance value of 20 µg/L. The lake is listed as impaired by phosphorus, which has been addressed by the approved TMDL. Dissolved oxygen (DO) concentrations met the AWQS in the upper waters of Onondaga Lake throughout the 2014 sampling period. Anoxic conditions prevailed in the lower waters during most of the summer stratified period. However, this situation is not uncommon in stratified lakes where the volume of the lower stratum (the hypolimnion) is relatively small. In New York, an estimated 70% of assessed lakes do not meet the AWQS for DO in the deep waters.

The summer average chlorophyll-*a* (Chl-*a*) concentration in the upper waters of the lake was 8.5 µg/L in 2014, somewhat lower than the 2013 average of 9.1 µg/L. The average and peak concentrations of this measure of algal biomass have declined substantially since the phosphorus treatment upgrade at Metro in 2005. According to the criteria adopted by the AMP (15 µg/L and 30 µg/L for minor and major blooms, respectively), and based on biweekly laboratory measurements, there was one minor algal bloom identified in Onondaga Lake during the summer recreational period (June–September) of 2014. The infrequent occurrence of algal blooms in Onondaga Lake stands in contrast to the widespread occurrence of blue-green harmful algal blooms in lakes across New York State (see http://www.dec.ny.gov/chemical/77118.html for more information). The AMP has established a minimum summer average Secchi disk transparency of 1.5 meters at South Deep as a target for improved aesthetic appeal. During the summer of 2014, Secchi disk values ranged from 1.2 to 2.9 meters and averaged 1.9 meters.

The mass of phosphorus accumulated in the hypolimnion during the summer stratification interval has decreased by 90% since the 1990s as a result of lower primary production following the Metro phosphorus treatment upgrade and the increase in nitrate from year-round nitrification. The supply of nitrate to the lower waters in summer has been augmented by Honeywell since 2011 to control sediment release of mercury. Release of both phosphorus and mercury from the sediments is blocked by maintenance of high nitrate concentrations in the hypolimnion. The absence of noteworthy sediment phosphorus release under the high nitrate concentrations of 2011–2014 clearly demonstrates the positive effect of nitrate on phosphorus cycling.

The 2014 monitoring results indicate that the open waters of Onondaga Lake were in compliance with most AWQS. The lake is now in full compliance with the AWQS for ammonia, and in 2008 was officially removed from the New York State's 303(d) list of impaired waterbodies for this water quality parameter. Exceedances of the AWQS for nitrite now only occur in the lower layers of the lake when hypoxic conditions prevail. These conditions reflect incomplete nitrification of ammonia within those lower lake depths rather than excessive external loading of nitrite.

Fecal coliform bacteria levels in Class B areas of Onondaga Lake did not exceed the standard established for contact recreation during the April to October interval of 2014. Bacteria levels at three nearshore sites, located within the Class C segment in the southeastern portion of the lake, exceeded the standard during the month of April. One of these sites also exceeded the standard in June and another site exceeded the standard in October. The NYSDOH swimming safety guidance value for water clarity was met in Class B waters throughout the summer recreational period of 2014. Monitoring locations in the southern end of the lake, near the mouths of Onondaga Creek, Harbor Brook, and Ley Creek, regularly failed to meet this guidance value.

The concentration of total dissolved solids (TDS) in Onondaga Lake routinely exceeds the AWQS of 500 mg/L by a wide margin. Exceedance of this standard is associated with the natural hydrogeology of the lake and not with anthropogenic effects. The bedrock in Onondaga County is comprised of sedimentary rocks with high concentrations of calcium and sulfate, which contribute to the high TDS levels in Onondaga Lake and its tributaries.

Biology and Food Web

As phosphorus concentrations in Onondaga Lake have declined to mesotrophic levels, biological conditions have responded. Improved light penetration, a consequence of lower algal abundance, has resulted in expansion of macrophyte beds. This expanded coverage of macrophytes throughout the littoral zone has improved habitat and shelter for many fish and other aquatic organisms.

The algal biomass in Onondaga Lake has been below 2 mg/L (April through October averages) since 2007, and 2014 was no exception with an average phytoplankton biomass of 1.06 mg/L. This is lower than expected from meso-eutrophic systems (3-5 mg/L, Wetzel 2001). Average biomass in 2014 was the lowest on record since 2008 and peak biomass did not exceed 3 mg/L. With the exception of relatively high dinoflagellate abundances, the dominant algal genera in 2014 were similar to those of past years.

The size structure of the zooplankton community (i.e., the relative abundance of small and large species), is a consequence of the grazing pressure exerted on zooplankton by fish. The average total zooplankton biomass in 2014 is the lowest value on record in Onondaga Lake.

Zooplankton biomass has been low since 2010 and there is an overall long-term decline. The temporal changes in the zooplankton community are linked to changes in predation by the dominant fish planktivore in the lake, the Alewife (*Alosa pseudoharengus*).

Quagga mussels (*Dreissena rostriformis bugensis*) have displaced zebra mussels (*Dreissena polymorpha*) in a number of North American lakes, but the mechanism(s) giving quagga mussels an advantage over zebra mussels are not known and may vary across systems. Most North American lakes where quagga mussels have become dominant are deep and oligotrophic with oxygenated hypolimnion suggesting that the ability of quagga mussels to colonize deeper waters or their ability to grow in low productivity systems may be key factors. Both of these mechanisms should be less important in eutrophic Onondaga Lake, which experiences summer anoxia in the hypolimnion. The mussel population was sampled in 2000, 2002 and annually from 2005 to 2014. Both mussel species were present in 1992 but remained rare through 1998. Zebra mussels increased in abundance first and dominated collections in 2000, 2002 and 2005–2007. Quagga mussels were rare in 2002, increased from 2006 to 2008 and largely replaced zebra mussels in water 3–6 m (>90% of the biomass) by 2009, indicating that quagga mussels can go from being a subdominant to a dominant species within three years. However, zebra mussels remained co-dominant with quagga mussels in shallower water. The proportion of quagga mussel by biomass in water shallower than 3 m ranged from 24 to 66% in 0–1.5 m and from 21 to 80% in 1.5–3 m with no time trend between 2008 and 2014. Quagga mussels were larger than zebra mussels at all depths suggesting that faster growth rates of quagga mussels are not limited to oligotrophic systems and contribute to the dominance of quagga mussels also in eutrophic lakes. The continued coexistence of both species in 0–3 m depths may be related to the advantage of greater attachment strength of zebra mussels in areas more affected by wave action. Dreissenid biomass and density in 0–6 m deep water has ranged between 6.9 and 31.0 g ash free dry weight/m^2 and between 2,603 and 13,782/m^2 from 2007 to 2014 with the highest values in 2011 and the lowest in 2013. For 2014, biomass was 12.5 g AFDW/m^2 and density 8,725/m^2. Density increased more than biomass in 2014 as most mussels present in 2014 were settled that year. Low values in 2013 were partly due to dredging at two of the standard locations although the decline was also evident at locations not affected by dredging. It remains to be seen if the larger number of small mussels present in 2014 will survive to 2015 or be affected by predation by increasing numbers of Round Goby (*Neogobius melanostomus*), which arrived to the lake in 2010.

Changes in the fish community of Onondaga Lake have occurred as water quality and habitat conditions have improved. Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Pumpkinseed (*Lepomis gibbosus*), Bluegill (*Lepomsis macrochirus*), Rock Bass (*Ambloplites rupestris*), and Brown Bullhead (Ameiurus nebulosus) construct nests in the littoral zone of the lake. In 2014, 1,619 nests were observed with the majority of the nest occurring in the north basin compared to the south basin (81% and 19%, respectively). Since

2000, most fish nests in Onondaga Lake have been documented in the north basin (average 69%, range 46% to 100%), presumably because of better habitat conditions there. This is consistent with the spatial pattern in the early 1990s when approximately 75% of nests documented in that study were found in the north basin. More recently (2008–2013) nests have been more evenly distributed between the north and south basins. The increased nesting activity observed in the southern basin of the lake (2008–2013) was likely influenced by the increased macrophyte coverage of the littoral zone over the last decade. The lack of nesting in the south basin in 2014 was likely due to the Honeywell's dredging and capping activities in that area of the lake.

A total of 1,828 larval fish representing 10 species was collected during the 2014 larval seine events. Brook Silverside (*Labidesthes sicculus*) were the most common fish collected composing 37% of the lakewide catch followed by Lepomis species (Bluegill and Pumpkinseed) 35%, Banded Killifish (*Fundulus diaphanus*) 13%, and Alewife 9%. Smaller numbers of Bluntnose Minnow (*Pimephales notatus*), Golden Shiner (*Notemigonus crysoleucas*), Common Carp (*Cyprinus carpio*), Round Goby, and Largemouth Bass were also collected. Overall catch per unit effort (CPUE) was lower in 2014 compared to 2013 but higher than those reported from 2000 through 2003, and the number of species collected in 2014 (10) was lower than 2013 (12).

A total of 564 young-of-year fish representing seven species (Bluegill, Pumpkinseed, Rock Bass, Largemouth Bass, Brown Bullhead, Longnose Gar and Golden Shiner) were captured in 2014. Largemouth Bass and Lepomis species (Pumpkinseed and Bluegill) young-of-year were the most abundant species collected composing 89% and 6% of the total catch, respectively. The most apparent change in 2014 was the increase in catch rates for young-of-year Largemouth Bass compared to previous years. In 2014 the catch per unit effort for Largemouth Bass was 11.2, the highest since 2000 except for 2005 when the catch rate was 17.0.

A total of 3,524 fish representing 26 species was collected during the 2014 fall boat electrofishing event. Eight of the 26 species accounted for 93.8% of the catch. Gizzard Shad was the most abundant species collected making up 42% of the catch, followed by Alewife (14% of catch), Pumpkinseed (16%), Yellow Perch (9%), Largemouth Bass (8%). Brown Bullhead (5%), Bluegill (4%), and Round Goby (2%). Eighteen of the 26 species collected together constituted 6.2% of the catch. Overall CPUE was 1,016 fish per hour. The black bass population is increasingly dominated by Largemouth Bass in both adult and young-of-year life stages. Smallmouth Bass catch rates continue to decline, likely indicative of the changing conditions in the littoral zone with increased macrophyte coverage more suitable for Largemouth Bass.

Overall trends in catch rates have varied by fish species since 2000. Several species have increased recently, including Largemouth Bass, Gizzard Shad, Brown Bullhead, and Yellow Perch; while catch rates of Smallmouth Bass, Pumpkinseed, White Perch, and Common Carp have declined. These patterns likely reflect biological interactions within the fish community and changing habitats in the lake, including increased macrophyte coverage and increased mussel abundance. In Onondaga Lake, fish species richness has gradually increased since 2000. In 2014, a total of 32 species were captured during electrofishing, and seining surveys. Since the monitoring program started in 2000, 53 fish species have been identified in the lake.

DELTFM (Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies) began declining in 2010, steadily decreased to 2% in 2013, and increased to 3.9% in 2014. The majority of abnormalities in the Onondaga Lake fish community in 2014 were lesions (44%) and deformities (44%). Twelve species of adult fish were identified with DELTFM abnormalities in 2014, similar to 2013 and recent years.

Pier at Onondaga Lake Park

Section 1. Introduction to the AMP

1.1 Regulatory Requirements

The 2014 Annual Ambient Monitoring Program (AMP) report has been prepared and submitted to the New York State Department of Environmental Conservation (NYSDEC) to comply with a judicial requirement set forth in the 1998 Amended Consent Judgment (ACJ) between Onondaga County, New York State, and the Atlantic States Legal Foundation. The parties have modified the ACJ four times since 1998, most recently by stipulation in November 2009. The ACJ requires a series of improvements to the County's wastewater collection and treatment infrastructure, and an extensive monitoring program (the AMP) to document the improvements achieved by these measures. Onondaga County Department of Water Environment Protection (WEP) is responsible for implementing the AMP and reporting its findings. Links to the ACJ and the Fourth Stipulation are posted on the Onondaga County web site http://www.ongov.net/wep/we15.html.

1.2 Classification and Best Use

NYSDEC classifies surface waters, including lakes, rivers, streams, embayments, estuaries, and groundwater with respect to their best use. Onondaga Lake and its tributaries are currently classified as Class B and Class C waters (Table 1-1; Figure 1-1). The best usages of Class B waters are primary and secondary water contact recreation and fishing (New York Codes, Rules and Regulations (NYCRR) Part 701.7). Primary water contact recreation includes activities that immerse the body in the water, such as swimming; secondary water contact recreation includes activities without full immersion, such as boating. In addition, Class B waters shall be suitable for fish, shellfish, and wildlife propagation and survival (NYCRR Part 701.7). The best usage of Class C waters is fishing. These waters shall also be suitable for fish, shellfish and wildlife propagation and survival. Class C waters shall be suitable for primary and secondary water contact recreation, although other factors may limit the use for these purposes (NYCRR Part 701.8). A listing of water quality impairments in Onondaga Lake and its watershed is provided in Table 1-2.

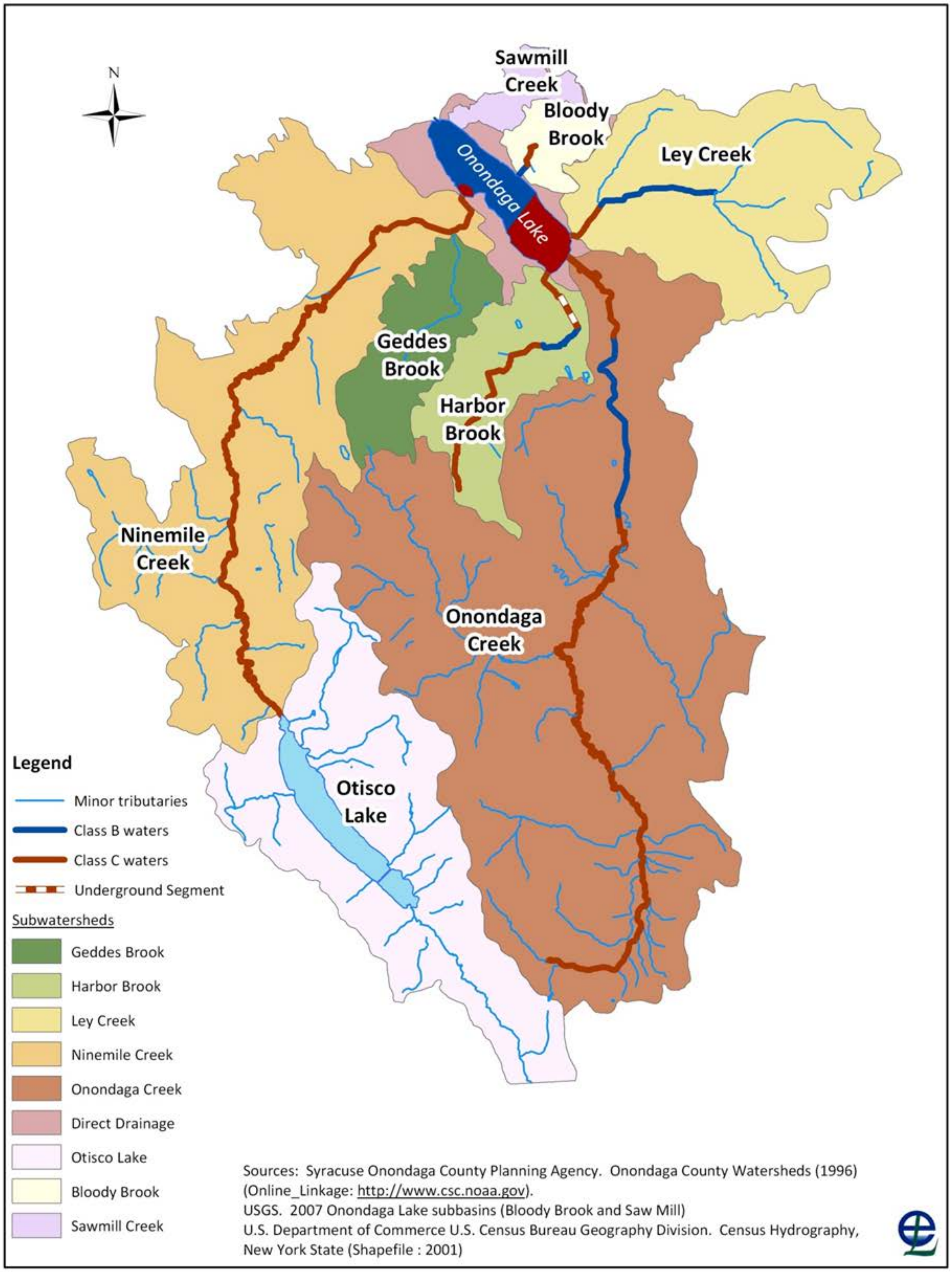
1.3 AMP Objectives and Design

Onondaga County Department of Water Environment Protection (WEP) designed the AMP to meet several specific objectives related to the effectiveness of the required improvements to the wastewater collection and treatment infrastructure. Trained field technicians collect representative samples from a network of permanent sampling locations in nearshore and deep regions of Onondaga Lake (Figure 1-2) and along the lake tributaries (Figure 1-3). These samples are used to evaluate water quality conditions and the nature of the biological community. In addition, these data are interpreted to determine whether designated uses are, in fact, supported in these waters.

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

Lake/Stream	Description of Lake/Stream segment	Regulatory Classification	Standards
Onondaga Lake	northern 2/3 of lake, excluding the area adjacent to Ninemile Creek	B	B
	southern 1/3 of lake and waters adjacent to the mouth of Ninemile Creek	C	C
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 approximately 2.25 miles from lake outlet along west shore of lake. From mouth to Allied Chemical Corp. water intake located on creek 0.6 mile upstream of Airport Rd and 0.6 mile downstream of Rt. 173 bridge at Amboy	C	C
	from water intake between Airport Rd and Rt. 173 to outlet of Otisco Lake	C	C(T)
Harbor Brook	enters Onondaga Lake at the southernmost 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 3-1B 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:
6 NYCRR Part 895 Onondaga Lake Drainage Basin, on-line at http://www.dec.ny.gov/regs/4539.html



Sources: Syracuse Onondaga County Planning Agency. Onondaga County Watersheds (1996) (Online_Linkage: http://www.csc.noaa.gov).
USGS. 2007 Onondaga Lake subbasins (Bloody Brook and Saw Mill)
U.S. Department of Commerce U.S. Census Bureau Geography Division. Census Hydrography, New York State (Shapefile : 2001)

Figure 1-1. Tributary and lake regulatory classifications (6 NYCRR) and subwatershed boundaries.

Table 1-2. Listing of water quality impairments in Onondaga Lake, its tributaries, and Seneca River.

Waterbody Name	Category of Impairment	Cause/Pollutant	Source	Year Listed
Onondaga Lake, northern end	fish consumption advisory	dioxin, mercury, PCBs, other toxics	contaminated sediments	1998
Onondaga Lake, northern end	TMDL development is not necessary because a TMDL has already been established	phosphorus	municipal	1998
Onondaga Lake, northern end	pending verification of use impairments/pollutants/sources	dissolved oxygen	–	2012
Onondaga Lake, southern end (including Ley Creek)	fish consumption advisory	dioxin, mercury, PCBs, other toxics	contaminated sediments	1998
Onondaga Lake, southern end	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Onondaga Lake, southern end	TMDL development is not necessary because a TMDL has already been established	phosphorus	municipal	1998
Onondaga Lake, southern end	pending verification of use impairments/pollutants/sources	dissolved oxygen	–	2012
Bloody Brook and tribs	requires verification of cause/pollutant/source	aquatic toxicity	unknown	2010
Bloody Brook and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	municipal, urban runoff	2008
Geddes Brook and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	ammonia	municipal, urban runoff	1998
Harbor Brook, lower, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Harbor Brook, lower, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	1998
Harbor Brook, lower, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	1998
Harbor Brook, lower, and tribs	TMDL is not appropriate because the sole impairment is the result of pollution, rather than a pollutant that can be allocated through a TMDL	habitat	habitat modification	--
Ley Creek and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	municipal, urban runoff	2008
Ley Creek and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	1998
Ley Creek and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	1998

Table 1-2. Listing of water quality impairments in Onondaga Lake, its tributaries, and Seneca River.

Waterbody Name	Category of Impairment	Cause/Pollutant	Source	Year Listed
Ley Creek and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	cyanide	municipal, urban runoff	2008
Minor tribs to Onondaga Lake	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Minor tribs to Onondaga Lake	TMDL is deferred pending development/implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	2008
Minor tribs to Onondaga Lake	TMDL is deferred pending development/implementation/evaluation of other restoration measures	nitrogen (ammonia, nitrite)	CSOs, municipal, urban runoff	2008
Minor tribs to Onondaga Lake	TMDL is deferred pending development/implementation/evaluation of other restoration measures	cyanide	CSOs, municipal, urban runoff	2008
Ninemile Creek, lower, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	municipal, urban runoff	2008
Ninemile Creek, lower, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	nutrients (phosphorus)	municipal, urban runoff	1998
Onondaga Creek, lower, and tribs	requires verification of impairment	turbidity	streambank erosion	2010
Onondaga Creek, lower, and tribs	TMDL is not appropriate because the sole impairment is the result of pollution, rather than a pollutant that can be allocated through a TMDL	habitat	habitat modification	--
Onondaga Creek, lower	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Onondaga Creek, lower	TMDL is deferred pending development/implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	1998
Onondaga Creek, lower	TMDL is deferred pending development/implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	1998
Onondaga Creek, middle, and tribs	requires verification of impairment	turbidity	streambank erosion	2008
Onondaga Creek, middle, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	pathogens	CSOs, municipal, urban runoff	2008
Onondaga Creek, middle, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	nutrients (phosphorus)	CSOs, municipal, urban runoff	2008
Onondaga Creek, middle, and tribs	TMDL is deferred pending development/implementation/evaluation of other restoration measures	ammonia	CSOs, municipal, urban runoff	2008
Onondaga Creek,	TMDL is not appropriate because the	habitat	habitat	--

Table 1-2. Listing of water quality impairments in Onondaga Lake, its tributaries, and Seneca River.

Waterbody Name	Category of Impairment	Cause/Pollutant	Source	Year Listed
middle, and tribs	sole impairment is the result of pollution, rather than a pollutant that can be allocated through a TMDL		modification	
Onondaga Creek, upper, and tribs	requires verification of impairment	turbidity	streambank erosion	2008
Seneca River, lower, main stem	fish consumption advisory	PCBs, other toxics	contaminated sediments	2014
Seneca River, lower, main stem	requires verification of impairment	pathogens	onsite WTS	1998
Seneca River, lower, main stem	requires verification of cause/pollutant/source	oxygen demand	invasive species, agriculture	1998

Source:
The Final New York State 2014 Section 303(d) List of Impaired Waters Requiring a TMDL/Other Strategy, on-line at http://www.dec.ny.gov/docs/water_pdf/303dlistfinal2014.pdf

Kids admiring a Largemouth Bass from Onondaga Lake
at the 2014 Clean Water Fair, September 6, 2014 at Metro

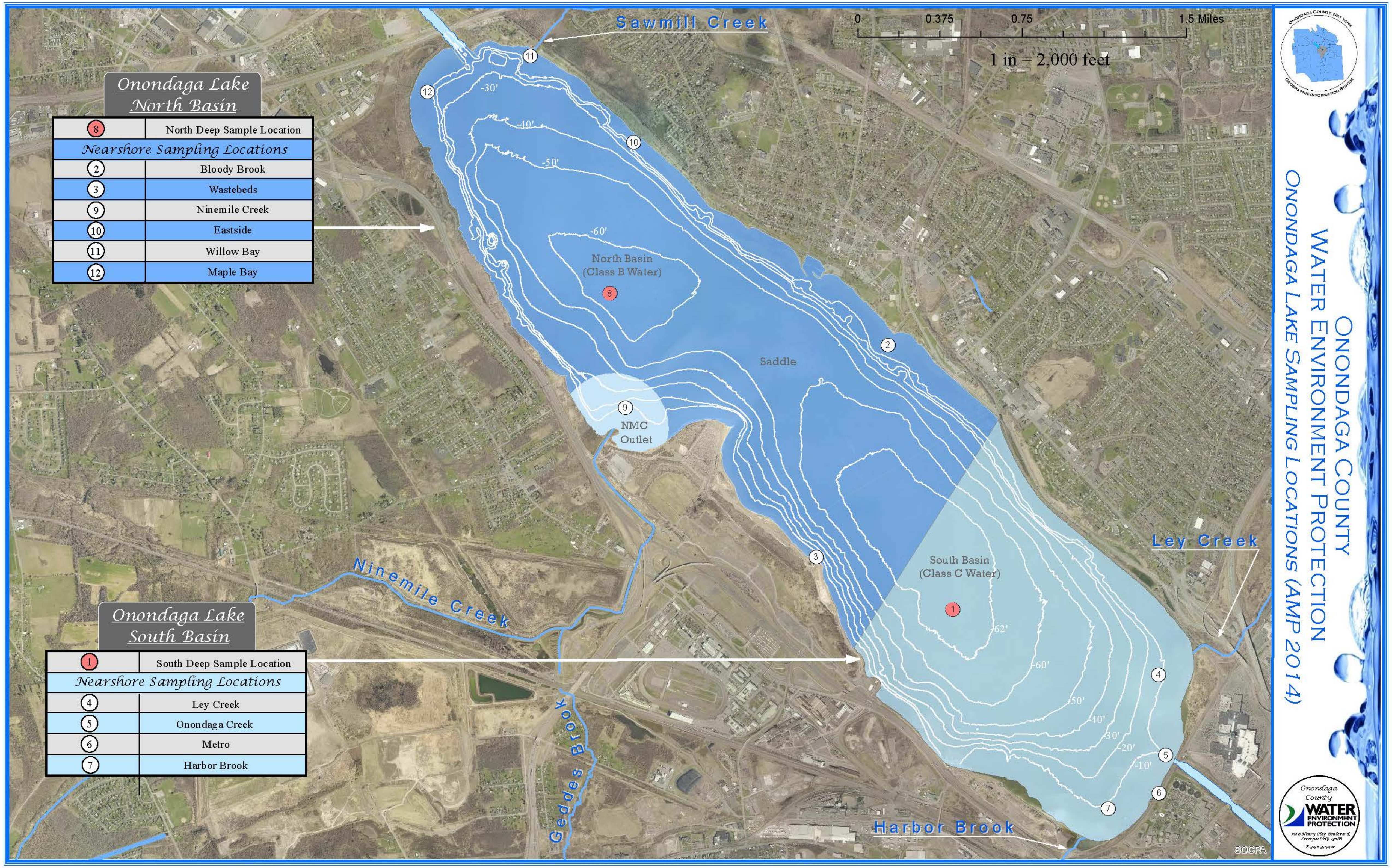


Figure 1-2. Map of AMP monitoring locations in Onondaga Lake.

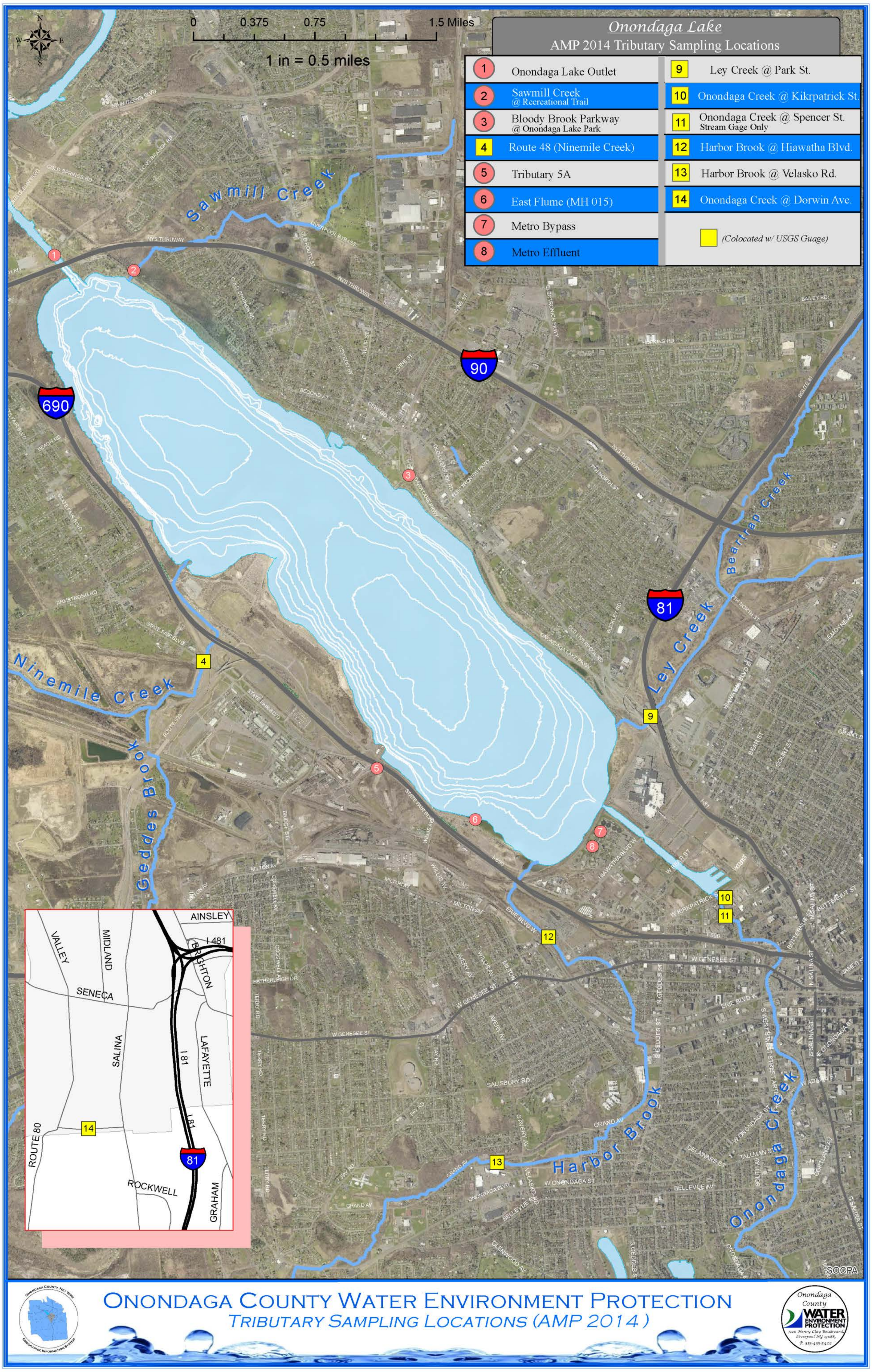


Figure 1-3. Map of AMP tributary monitoring locations.

In addition to the overall assessment of use attainment, Onondaga County personnel rely on the AMP data for several related objectives:

- to identify and quantify sources of materials (nutrients, sediment, bacteria and chemicals) entering the lake
- to evaluate stream and lake water quality conditions with respect to compliance with ambient water quality standards (AWQS) and guidance values
- to track the nature of the biological community
- to support development of mechanistic models for managing water quality conditions

The design of the AMP is presented in the AMP Five-Year Work Plan (2014–2018), which is subject to NYSDEC review and approval. The Five-Year Work Plan may be amended annually to address the changing needs of the AMP and new information. The parameters included in the 2014 AMP are used to support a variety of activities, including compliance assessment, loading calculations, and analysis of lake ecology (Table 1-3).

The five-year AMP work plan, which serves as a roadmap for monitoring and assessment of Onondaga Lake and its tributaries during the 2014–2018 period, was developed in consultation with members of the County’s Onondaga Lake Technical Advisory Committee (OLTAC), representatives of NYSDEC (Region 7), ASLF, Onondaga Environmental Institute (OEI), and Parsons (Honeywell’s project consultant). The work plan is intended to comply with the requirements of the Fourth Stipulation to the ACJ and the SPDES permit for Metro.

It is the County’s goal to supplement this Five-Year AMP Workplan annually, with updates submitted to NYSDEC and ASLF each year. These updates will reflect findings from the previous year’s sampling efforts and any changes in the NYS AWQS or guidance values. The sampling program will continue to incorporate the flexibility necessary to respond to new data and information. It is the County’s goal to ensure all elements of the AMP provide meaningful data in a scientifically defensible and cost-effective manner. Program modifications implemented in 2014 included the following:

- AMP water quality sampling program changes as approved by the NYSDEC in 2013
- Additional changes in water quality monitoring proposed for the Annual Tributary and Lake sampling programs, as approved by the NYSDEC in 2014
- Changes in the biological monitoring program and schedule, relating to the Annual Fisheries sampling program (reflecting a reduced annual sampling effort), Macroinvertebrate program (Lake and Tributary), and Macrophyte assessment program, as approved by the NYSDEC in 2014
- Discontinuation of the annual Three Rivers monitoring program as part of the AMP, as approved by the NYSDEC in 2014

- Coordination of efforts with Honeywell during the five-year period related to on-going and planned Onondaga Lake monitoring programs relating to:
    - The utilization of the UFI's monitoring buoy data, funded by Honeywell, at Onondaga Lake South Deep station, as available during this five-year period.
    - Coordination with Honeywell for the sample collection and analysis of the Onondaga Lake benthic macroinvertebrate assessment program (planned in 2015).
    - Coordination efforts planned during the five-year period with Honeywell for the Littoral Zone Macrophyte Survey, potentially eliminating the need for an additional survey by the County.
- Changes to the Enhanced Tributary Sampling Program, as outlined in the December 2011, NYSDEC approved work plan. These changes, as approved by the NYSDEC in 2013, reflect the findings of the two (2) sampling events conducted in May 2012 (Event #1 and #2), following the completion of GC Modifications for the Erie Boulevard Storage System (EBSS), as required by the ACJ Fourth Stipulation.
- A tentative sampling program schedule over the five-year period, in the context of the recently completed major CSO gray project milestones completed in 2013, and sampling plan related to Post-Construction Compliance Monitoring Program (PCCMP) for the three (3) sewer separation and one (1) conveyances project.

Each year, Onondaga County reviews the laboratory data for quality assurance/quality control criteria (Appendix B-1) prior to uploading the analytical data set to the long-term water quality database. This custom database archives the complete set of Onondaga Lake and tributary monitoring results since 1970. In addition, field activities associated with tributary (Appendix B-2) and lake (Appendix B-3) water quality and biological (Appendix B-4) monitoring programs are audited annually to ensure that they are carried out in accordance with the approved work plan. The Onondaga County Laboratory participates in a program of Environment Canada documenting proficiency of low-level total phosphorus and low-level total mercury analyses (Appendix B-5) in natural waters. Based on proficiency testing studies conducted by Environment Canada, the Onondaga County Laboratory was rated as "very good", the highest laboratory performance rating available.

The County maintains a bibliography of published materials related to Onondaga Lake (Appendix G-1). The bibliography serves the AMP team and the community at large by compiling references to investigations by agencies of local government, regulatory agencies, university researchers, and private companies working on various aspects of the Onondaga Lake restoration effort. The findings of these investigations help inform the AMP team in data analysis and interpretation.

Table 1-3. Overview of the 2014 AMP parameters and their uses.

Parameters	Sampling Locations	Compliance	TMDL Analysis	Trend Analysis	Trophic Status	Load Analysis	Use Attainment	Effectiveness of CSO Control Measures	Indicator of Water Clarity	Nutrient Cycling	Habitat Conditions	Lake Ecology
Chemical												
Alkalinity	L,T			✓								
Bacteria	L,T	✓		✓		✓	✓	✓				
BOD-5	T			✓		✓						
Carbon	L,T			✓	✓	✓						
Dissolved oxygen	L,T	✓		✓	✓		✓					✓
Mercury	L,T	✓		✓								
Metals/Salts	L,T	✓		✓		✓						
Nitrogen	L,T	✓	✓	✓	✓	✓	✓			✓	✓	✓
Phosphorus	L,T	✓	✓	✓	✓	✓				✓		✓
Salinity	L,T			✓			✓					
Silica-dissolved	L,T				✓							✓
Solids	L,T	✓		✓								
Specific conductance	L,T			✓			✓					
Optical												
Secchi Disk transparency	L	✓		✓	✓		✓		✓			✓
Turbidity	L,T			✓					✓			
Biological												
Chlorophyll-*a*/ algae	L			✓	✓		✓					✓
Zooplankton	L			✓								✓
Macrophytes	L			✓							✓	✓
Fish	L			✓							✓	✓
Visual Observation												
Floatables	T							✓				
Locations: L = Lake; T = Tributaries												

1.4 Amended Consent Judgment Milestones

The ACJ stipulates a series of specific engineering improvements to the County's wastewater collection and treatment infrastructure. Onondaga County has agreed to undertake a phased program of Metro improvements (Table 1-4). Combined sewer overflows (CSOs) serve older portions of the City of Syracuse. These utilities carry both sewage and storm water in a single pipe. During heavy rain and snowmelt, the pipes can overflow, and a mixture of storm water and untreated sewage flows into creeks and ultimately reaches Onondaga Lake. When these overflows occur, CSOs carry bacteria, floating trash, organic material, nutrients and solid materials through the CSOs to the waterways. Improvements to the wastewater collection and treatment infrastructure are scheduled through 2018. The 4th Stipulation of the ACJ requires phased reductions of CSO volume.

Table 1-4. Metro compliance schedule for ammonia and total phosphorus.
(lb/d = pounds per day; mg/L = milligrams per liter; WLA = waste load allocation)

Parameter	SPDES Limit	Effective Date	Achieved Date
Ammonia	Interim limit: 8,700 lb/d (7/1-9/30) 13,100 lb/d (10/1-6/30)	January 1998	January 1998
	Interim limit: 2 mg/L (6/1-10/31) 4 mg/L (11/1-5/31)	May 2004	February 2004
	Final limit: 1.2 mg/L (6/1-10/31) 2.4 mg/L (11/1-5/31)	March 21, 2012 to March 20, 2017	February 2004
Total Phosphorus*	Interim limit: 400 lbs/day (12-month rolling average)	May 1, 2004 to March 31, 2006	January 1998
	Interim limit: 0.12 mg/L (12-month rolling average)	April 1, 2006 to November 15, 2010	April 2006
	Interim limit: 0.10 mg/L (12-month rolling average)	November 16, 2010 to June 30, 2012	November 2010
	Final limit: 0.10 mg/L (12-month rolling average) Final loading limit Outfall 001 – 21,511 lbs/yr	After June 30, 2012	November 2010
	Final limit: 0.10 mg/L (12-month rolling average) Final loading limit Outfall 001 – 27,212 lb/yr	After December 31, 2018	
	WLA for 002 is 7,602 lb/yr WLA for bubble is 27,212 lb/yr	After December 31, 2018	

* This is the final limit determination based on lake/watershed models and subsequent TMDL analysis and allocation process, approved by the USEPA, June 29, 2012.

The schedule of the percentage of CSO volume that must be captured or eliminated on a system-wide annual average basis is provided in Table 1-5. The 2014 annual stormwater management model (SWMM) update reflects projects completed by December 31, 2014. The model was calibrated using flow monitoring data collected in 2014; this update of the model is referred to as the "2014 condition model." SWMM results showed that the annual combined sewage percent capture for the "2014 system condition" was 95.3%, which exceeded 95% and is ahead of schedule with respect to the mandated Stage IV compliance milestone.

Table 1-5. CSO compliance schedule.

Project Phase	Goal	Effective Date
Stage I	Capture for treatment or eliminate **89.5%** of combined sewage* during precipitation, within the meaning of EPA's National CSO Control Policy	Dec 31, 2013
Stage II	Capture for treatment or eliminate **91.4%** of combined sewage during precipitation, within the meaning of EPA's National CSO Control Policy	Dec 31, 2015
Stage III	Capture for treatment or eliminate **93%** of combined sewage during precipitation within the meaning of EPA's National CSO Control Policy	Dec 31, 2016
Stage IV	Capture for treatment or eliminate **95%** of combined sewage during precipitation within the meaning of EPA's National CSO Control Policy	Dec 31, 2018
* on a system-wide annual average basis (per Fourth Stipulation to ACJ, Nov. 2009)		

A total maximum daily load (TMDL) allocation for phosphorus inputs to Onondaga Lake was developed by NYSDEC and approved by USEPA on June 29, 2012. A total phosphorus concentration limit of 0.10 mg/L on a 12-month rolling average basis was established for Metro outfall 001, and became effective upon TMDL approval. In addition, phosphorus loading reductions are to be implemented for other SPDES permits by 1/1/2016, CSOs and Metro outfall 002 by 12/31/2018, agricultural lands by 12/31/2022, and for MS4 areas by 12/31/2025. Phosphorus loading reductions from small farms are voluntary and incentive based. NYSDEC used an ensemble modeling approach to evaluate the environmental benefits associated with additional phosphorus removal from Metro and other sources. The Onondaga Lake Water Quality Model (OLWQM) was a key component of this modeling ensemble. OLWQM was developed and calibrated using data from the AMP, and was subject to outside expert peer review.

1.5 Use of Metrics to Measure and Report Progress

Onondaga County Department of Water Environment Protection, in consultation with NYSDEC and the Onondaga Lake Technical Advisory Committee (OLTAC), has developed a suite of metrics to help organize and report on the extensive AMP data set each year. These metrics relate to the lake's designated "best use" for water contact recreation, fishing, and protection of aquatic life. Table 1-6 documents the extent to which water quality conditions support the lake's designated best uses. Major reductions in loading of ammonia and phosphorus from Metro to Onondaga Lake have resulted in marked improvements in suitability of the lake for water contact recreation, aesthetic appeal, aquatic habitat, and recreational fishing. Metrics selected for Onondaga Lake address both human uses and ecosystem function:

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

Fishing on Onondaga Lake

Table 1-6. Summary of metrics, Onondaga Lake 2014.

Metrics	Measured By	Target[1]	2014 Results[2]	Comments
Improved Suitability for Water Contact Recreation				
Indicator bacteria	Percent of months in compliance with AWQS[1] for fecal colilform bacteria, April–October (disinfection period). Measured at nearshore sites, Class B segment.	100% NOTE: The best usages of Class B waters are primary and secondary contact recreation and fishing (NYCRR Part 701.7).	Percent in compliance, Lake Class B locations: Bloody Brook: 100% North Deep: 100% Eastside:100% Willow Bay: 100% Maple Bay:100% Westside Wastebeds:100%	Class B segments of Onondaga Lake met the bacteria standard for water contact recreation.
	Percent of months in compliance with AWQS[1] for fecal coliform bacteria, April–October (disinfection period). Measured at nearshore sites, Class C segment.	NOTE: The best usage classification of Class C waters is fishing; water quality shall be suitable for primary contact and secondary contact recreation, although other factors may limit the use for these purposes (NYCRR Part 701.8).	Percent in compliance, Lake Class C locations: South Deep: 100% Ninemile Creek: 100% Harbor Brook: 86% Metro: 64% Ley Creek: 100% Onondaga Creek: 55%	Three sites within Class C segments of Onondaga Lake met the bacteria standard for water contact recreation in all months. The following nearshore sites exceeded the standard in certain months: Onondaga Creek nearshore (April and June), Metro nearshore (April and October), and Harbor Brook (April) following runoff events (refer to plot in Appendix E-3 - Onondaga Lake Fecal Coliform and Metro Daily Precipitation, 2014).

Table 1-6. Summary of metrics, Onondaga Lake 2014.

Metrics	Measured By	Target[1]	2014 Results[2]	Comments
Water clarity	Percent of observations with Secchi disk transparency at least 1.2 m (4 ft.) to meet swimming safety guidance[3], June–September (recreational period). Measured at nearshore sites, Class B segment.	100%	Percent in compliance, Lake Class B locations: Bloody Brook: 95% North Deep: 100% Eastside:100% Willow Bay: 100% Maple Bay:100% Westside Wastebeds:100%	• With the exception of a single observation near the mouth of Bloody Brook, Class B segments of Onondaga Lake met the designated use for water contact recreation.
	Percent of observations with Secchi disk transparency at least 1.2 m (4 ft.) to meet swimming safety guidance[3], June–September (recreational period). Measured at nearshore sites, Class C segment.	NOTE: The best usage classification of Class C waters is fishing; water quality shall be suitable for primary contact and secondary contact recreation, although other factors may limit the use for these purposes (NYCRR Part 701.8).	Percent in compliance, Lake Class C locations: South Deep: 100% Ninemile Creek: 82% Harbor Brook: 59% Metro: 64% Ley Creek: 86% Onondaga Creek: 55%	• Class C segments in the southern end of the lake often failed to meet the clarity standard for water contact recreation, particularly following runoff events.

Table 1-6. Summary of metrics, Onondaga Lake 2014.

Metrics	Measured By	Target[1]	2014 Results[2]	Comments
Improved Aesthetic Appeal				
Water clarity	Summer average Secchi disk transparency at least 1.5 m at South Deep during the summer recreational period (June–September).	Summer average at least 1.5 m	100% (summer average 1.9 m)	By these metrics, the lake met its designated use as an aesthetic resource.
Algal blooms[3]	Reduction in average and peak algal biomass and absence of noxious algal blooms[4]. Measured by the magnitude, frequency and duration of elevated chlorophyll-*a* (Chl-*a*) during the summer recreational period (June–September). Based on laboratory measurements of Chl-*a* at South Deep.	• No more than 15% of Chl-*a* measurements above 15 µg/L • No more than 10% of observations above 30 µg/L	1 of 9 (11%) measurements exceeded 15 µg/L No measurements exceeded 30 µg/L	
Algal community structure	Low abundance of cyanobacteria (blue-green algae)	Cyanobacteria represent no more than 10% of the algal biomass	Cyanobacteria was 2.2% of the algal biomass	

Table 1-6. Summary of metrics, Onondaga Lake 2014.

Metrics	Measured By	Target[1]	2014 Results[2]	Comments
Improved Aquatic Life Protection				
Ammonia	South Deep ammonia concentrations compared to AWQS[1] (upper waters)	100% of measurements in compliance, all depths and all times	100% of measurements in compliance, all depths and all times	By these metrics, the lake met its designated use for aquatic life protection (warm water fishery)
Nitrite	South Deep nitrite concentrations[1] (upper waters)	100%	100%	
Dissolved oxygen	Minimum daily average[1] at South Deep Instantaneous minimum[1] at South Deep (upper waters)	>5 mg/L >4 mg/L	7.23 mg/L[5] 7.01 mg/L	

Table 1-6. Summary of metrics, Onondaga Lake 2014.

Metrics	Measured By	Target[1]	2014 Results[2]	Comments
Improving Sustainable Recreational Fishery				
Habitat quality	Percent of the littoral zone that is covered by macrophytes	40%	50%	Littoral zone macrophyte coverage provides high quality habitat for warm water fish community
Fish reproduction	Reproduction of target species: • bass and sunfish • yellow perch • black crappie • rock bass • walleye and northern pike	occurring occurring occurring occurring occurring	occurring occurring no evidence no evidence no evidence	Fish reproduction for several target species has not been observed; reproduction of sunfish has been limited in the last four years. Adult population of these species are stable and, in some cases, increasing.
The lack of suitable spawning habitat, not water quality, is the limiting factor for the reproduction of some fish species in the lake. Habitat restoration and enhancement are included in the Honeywell lake restoration efforts				
Fish community structure	Percent of fish species intolerant or moderately intolerant of pollution	Increasing presence of fish species in the overall community (based on all sampling methods) that are intolerant or moderately intolerant of pollution.	0% (100% of community is considered pollution tolerant)	The Onondaga Lake fish community includes mostly warmwater species. Most warmwater fish species are classified as relatively tolerant of pollution

[1] Ambient water quality standards (AWQS), criteria and guidance regulatory citations are as follows:

- *FC- fecal coliform bacteria Ambient Water Quality Criteria for Bacteria 1986 - EPA440/5-84-002, (http://water.epa.gov/type/oceb/beaches/upload/2009_04_13_beaches_1986crit.pdf)*
- *fecal coliform bacteria 6 NYCRR Part **703.4** (http://www.dec.ny.gov/regs/2485.html)*
- *ammonia and nitrite 6 NYCRR Part **703.5** (http://www.dec.ny.gov/regs/2485.html)*
- *dissolved oxygen 6 NYCRR Part **703.3** (http://www.dec.ny.gov/regs/2485.html)*

[2] 2014 Results are shaded green, yellow, or red to qualitatively represent the results as positive, mixed, or negative.

[3] Secchi depth water clarity swimming safety guidance of 4 ft. NYSDOH Title 10, Section 7-2.11

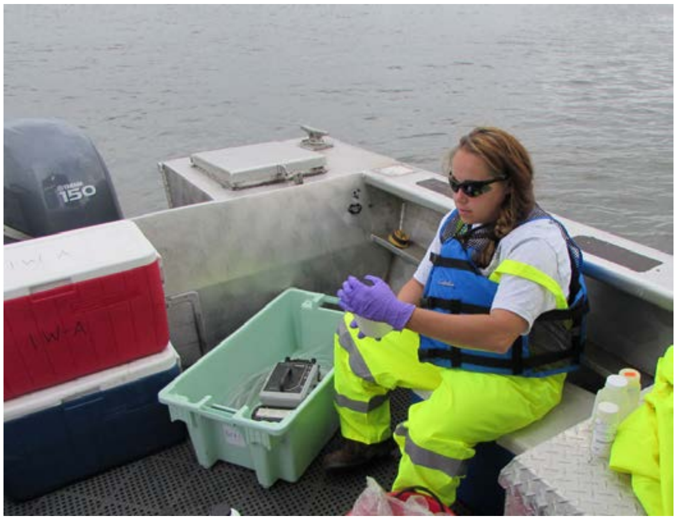
[4] Algal blooms subjectively defined as "impaired" at >15 µg/L and "noxious" at >30 µg/L

[5] daily average based on average of all measurements taken within a day (1 to 4 profiles were collected daily) from the Honeywell-UFI in-situ water quality monitoring buoy, 2 meter depth.

In addition to the annual snapshot provided in the table of metrics, a series of more detailed tables are presented to describe progress toward improvement with respect to specific water quality and biological attributes of Onondaga Lake (Appendix A). This appendix provides an overview of the monitoring program design, criteria used to evaluate progress, and a summary of temporal trends. The parameters covered are:

- total phosphorus (Appendix A-1)
- chlorophyll-*a* (Appendix A-2)
- Secchi disk transparency (Appendix A-3)
- dissolved oxygen (Appendix A-4)
- ammonia (Appendix A-5)
- nitrite (Appendix A-6)
- bacteria (Appendix A-7)
- phytoplankton (Appendix A-8)
- macrophytes (Appendix A-9)
- zooplankton (Appendix A-10)
- fish (Appendix A-11)

Metrics related to water contact recreation, aesthetic appeal, and aquatic life protection are also tracked in the tributaries to Onondaga Lake as part of the AMP. Tributaries are monitored for fecal coliform bacteria to gauge the suitability of these water bodies for contact recreation. The occurrence of sanitary floatables is documented to support assessment of aesthetic conditions in the streams affected by CSOs. A number of water quality parameters are measured in the tributaries as indicators of aquatic life protection, including dissolved oxygen, pH, and ammonia. In addition, assessments of macroinvertebrate community structure are completed periodically in the tributaries to track the quality of aquatic habitat.



OCDWEP Technician Sampling Onondaga Lake

Section 2. Onondaga Lake and Watershed

2.1 Watershed Size and Hydrology

The Onondaga Lake watershed encompasses approximately 285 square miles (740 km^2), almost entirely within Onondaga County, including six natural sub-basins: Onondaga Creek, Ninemile Creek, Ley Creek, Harbor Brook, Bloody Brook, and Sawmill Creek (refer to Figure 1-1). Tributary 5A and the East Flume direct runoff and industrial discharges into the lake. Onondaga County's Metro treatment plant discharges to Onondaga Lake. Onondaga Creek is the largest water source to the lake, followed by Ninemile Creek, Metro, Ley Creek, Harbor Brook, minor tributaries, and direct runoff (Figure 2-1). Much of the annual volume of water flowing to Onondaga Lake through the Metro treatment plant originates outside of the watershed. Water supply for the City of Syracuse is drawn from Skaneateles Lake. Lake Ontario and Otisco Lake are source waters for suburban towns and villages. Onondaga Lake discharges into the Seneca River, which flows in a northerly direction and joins the Oneida River to form the Oswego River, ultimately discharging into Lake Ontario.

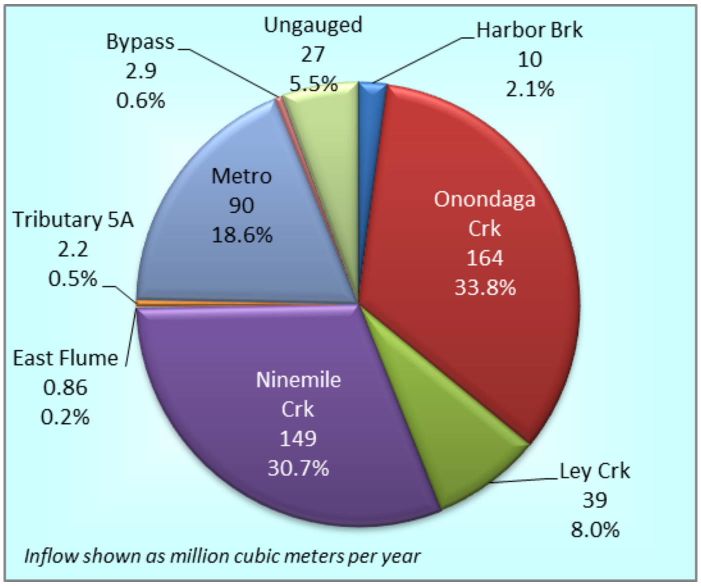
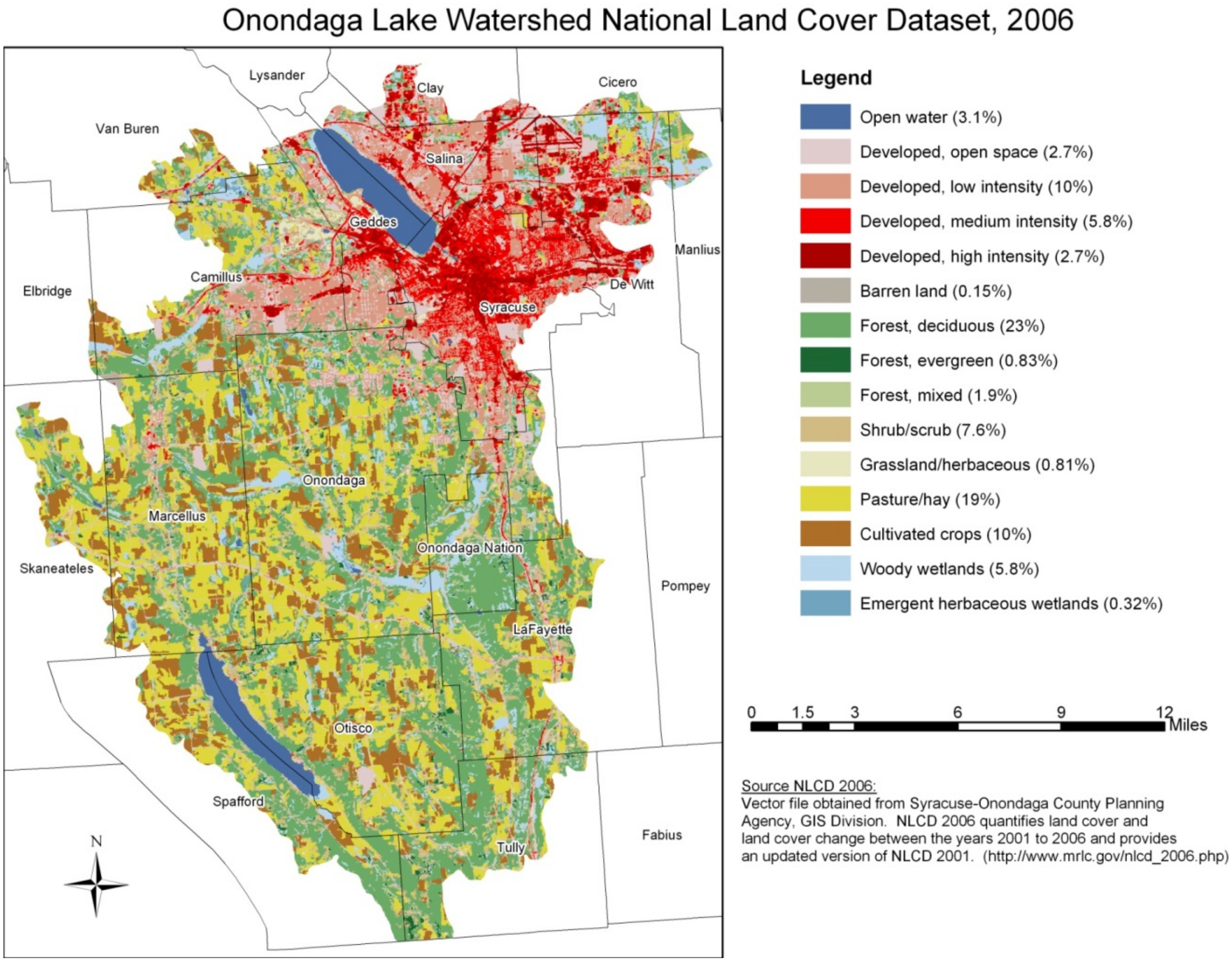


Figure 2-1. Annual average inflows (gauged and ungauged) to Onondaga Lake, 1990–2014.

The tributaries convey surface runoff and groundwater seepage from the watershed to Onondaga Lake. The volume of runoff, and consequently stream flow, varies each year depending on the amount of rainfall and snow cover. Overflows from combined sewer systems also vary in response to the intensity and timing of rainfall events and to a lesser degree, snowmelt. The Metro effluent volume exhibits less annual variation, although the effects of extreme wet or dry years can be detected due to the portion of the service area served by combined sewers. The goal of the AMP is to sample the tributaries over a range of representative flow conditions, targeting a minimum of five samples collected during high flow (*High flow* is defined as one standard deviation above the long-term monthly average flow). OCDWEP targets high flow sampling events based on real-time provisional data from the USGS flow gage at Onondaga Creek-Spencer Street.

2.2 Land Use

Compared with other lakes in the Seneca-Oneida-Oswego river basin, the watershed of Onondaga Lake is relatively urbanized, as displayed in Figure 2-2, a map of land cover updated



Source NLCD 2006:
Vector file obtained from Syracuse-Onondaga County Planning Agency, GIS Division. NLCD 2006 quantifies land cover and land cover change between the years 2001 to 2006 and provides an updated version of NLCD 2001. (http://www.mrlc.gov/nlcd_2006.php)

Figure 2-2. Land cover classification map.

in 2006. The National Land Cover Dataset classified approximately 21% of the watershed as developed (urban/suburban), 33% as forested or scrub/shrub, and 30% as cultivated lands or pasture. The remaining 9% is comprised of wetlands, lakes and barren land. Urban areas of the City of Syracuse, two towns and two villages border the lake.

2.3 Morphometry

Onondaga Lake is relatively small, with a surface area of 12 km^2. The lake's depth averages 10.9 meters (m) with a maximum of 19.5 m. Morphologic characteristics of Onondaga Lake are summarized in Table 2.1. Its bathymetry is characterized by two minor depressions, referred to as the northern and southern basins (also frequently referred to as North and South Deep), separated by a shallower region near the center of its longitudinal axis (Figure 2-3). The littoral zone, defined as the region of the lake where 1% of the incident light reaches the sediment surface, and consequently supports the growth of rooted plants, is narrow as illustrated by the proximity of the depth contours on the bathymetric map. Under current water clarity conditions, macrophyte growth extends to a water depth of approximately 6 meters; this is a more extensive littoral zone than existed in the late 1990s.

The Onondaga Lake shoreline is highly regular with few embayments. Onondaga County owns most of the shoreline, and maintains a popular park and trail system. Syracuse residents and visitors use the parklands for varied recreational activities and cultural entertainment. The lake is increasingly popular for boating; sailboats, motorboats, kayaks and canoes are familiar sights on summer days. Local and regional fishing tournaments attract anglers to the lake and shoreline each year.

Water residence time is defined as the average time water remains in the lake, and is dependent on the ratio of inflow volume to lake volume. A large watershed with a small lake will have a relatively short water residence time. Because Onondaga Lake has a relatively small volume and receives drainage from a large watershed, the water residence time is short. For Onondaga Lake, there are 62 km^2 of watershed area for each km^2 of lake surface area. Because of the relatively large watershed and abundant rainfall, the inflowing water is sufficient to replace the entire lake volume about four times each year; the average water residence time is about three months on a completely mixed basis. Lakes with smaller contributing watersheds and larger volumes have a longer water residence time. For example, Skaneateles Lake has a watershed area to lake area ratio of 4.3 and a water residence time of 18 years. Oneida Lake provides another example; this large, shallow lake has a watershed area to lake area ratio of 17 and a water residence time of one-half year.

Table 2-1. Morphologic characteristics of Onondaga Lake.

Characteristic	Metric	English
Watershed area	738 km^2	285 square miles
Lake:		
Surface area	12 km^2	4.6 square miles
Volume	131×10^6 m^3	35 billion gallons
Length	7.6 km	4.6 miles
Width	2 km	1.2 miles
Maximum depth	19.5 m	64 feet
Average depth	11 m	36 feet
Average elevation*	111 m	364 feet
Average flushing rate	~4 times per year	~4 times per year

Sources:
http://www.upstatefreshwater.org/NRT-Data/System-Description/system-description.html
http://www.dec.ny.gov/chemical/8668.html
*Elevation references to mean sea level.

Aerial view of the Metropolitan Syracuse Wastewater Treatment Plant

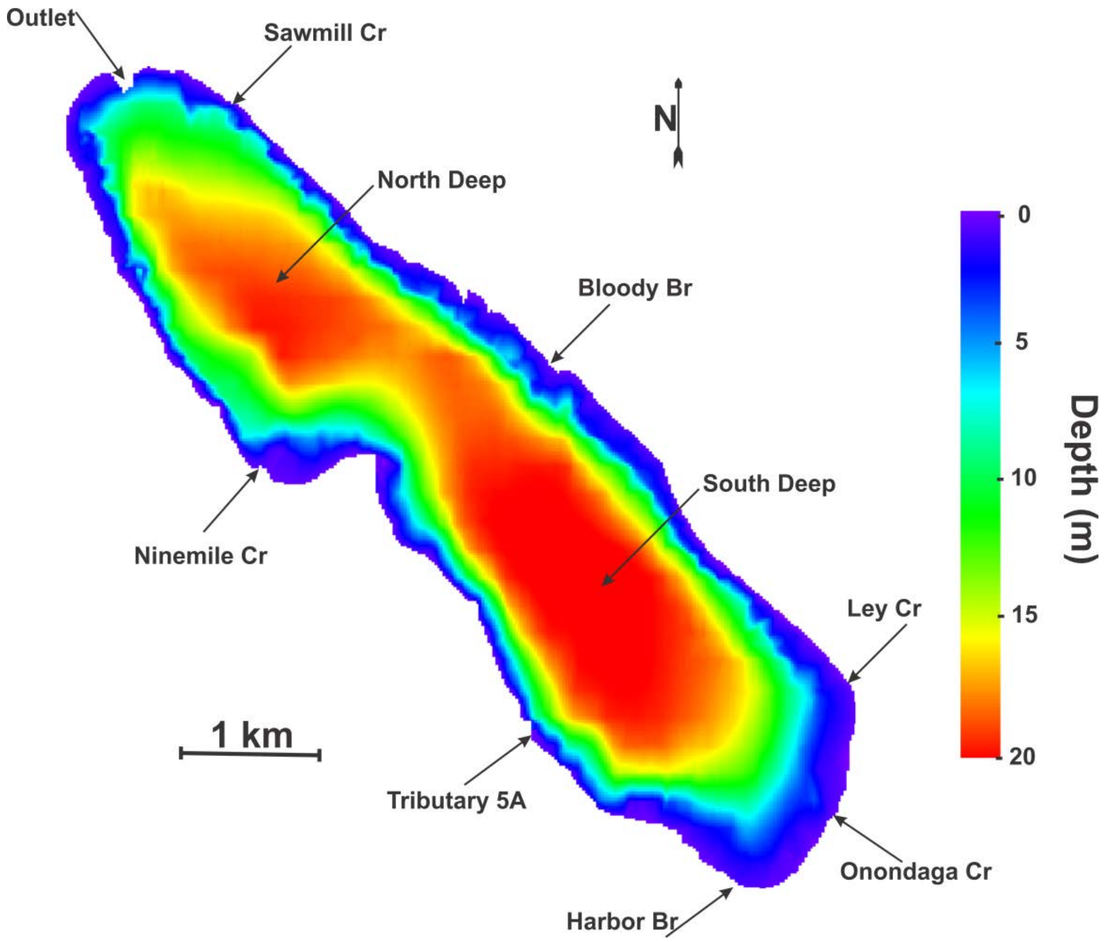


Figure 2-3. Bathymetric map of Onondaga Lake, with tributaries and primary sampling locations (South Deep, North Deep) identified.

Note: bathymetry based on data from CR Environmental Inc. 2007.

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Section 3. Onondaga County Actions and Progress with Related Initiatives

3.1 Onondaga County Projects and Milestones

By signing the ACJ in 1998, Onondaga County agreed to design and construct a series of engineering improvements to the Metro service area. The County has now completed many improvements to the Metro wastewater treatment plant and the wastewater collection system, including the combined sewers (Table 3-1). The improvements to Metro have reduced phosphorus concentrations and altered the speciation of nitrogen in the fully-treated effluent, associated with year-round nitrification treatment (Table 3-1).

Abating the CSOs is a significant challenge (Figure 3-1). The County has employed four strategies to reduce wet weather discharges from the combined sewer system to the Metro treatment plant: sewer separation, construction of regional treatment facilities, capturing floatable materials, and maximization of system storage capacity, or “gray infrastructure” (Table 3-2, Table 3-3). Since 1998, the County has closed or abated 47 of the 72 CSO locations that were active prior to the ACJ. In addition to the CSO abatement projects, Metro upgrades are planned that will achieve compliance with disinfection/dechlorination requirements and contribute to compliance with the phosphorus TMDL waste load allocation, specifically the aggregate limit for Metro discharges (001, 01A, 01B and 002).

Onondaga County’s Save the Rain (STR) Program was created in response to Fourth Stipulation of the Amended Consent Judgment (ACJ), entered into by Onondaga County, New York State and Atlantic States Legal Foundation (ASLF) on November 16, 2009. The ACJ specifically identified Green Infrastructure (GI) as an acceptable technology for combined sewer overflow control. GI is considered the County’s fifth strategy to significantly reduce or eliminate the discharge of untreated combined sewage into Onondaga Lake and its tributaries, and bring the County’s effluent discharges into compliance with the applicable water quality standards for the receiving waters.

The ACJ includes a phased schedule for Combined Sewer Overflow (CSO) compliance that uses an incremental approach in meeting the new goal of capture for treatment or elimination of no less than 95 percent by volume of CSO by 2018, within the meaning of the Environmental Protection Agency’s (EPA) National CSO Policy. To meet this goal the County initiated the “Save the Rain” program, which will implement a combination of green and gray infrastructure that focuses on the removal of stormwater from the combined sewer system through GI, CSO storage with conveyance to the Metropolitan Syracuse Wastewater Treatment Plant (Metro), and elimination of CSO discharge points. Twenty-two GI projects were completed in 2014 as part of the STR program. To date, a total of 169 GI projects have been implemented in Onondaga County through the STR program. Results from the County’s recently calibrated Storm Water Management Model (SWMM) indicate that GI projects are reducing stormwater runoff by 108 million gallons per year and providing CSO reduction of approximately 51 million gallons per year.

Table 3-1. Summary (timeline) of significant milestones, pollution abatement actions, lake water quality status, and biological status.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Status	Biological Status
1998	Amended Consent Judgment (ACJ) signed	• cap on annual ammonia and phosphorus load to the lake • begin selection and design of improvements	evaluation and implementation of nine minimum control measures	summer TP 55 µg/L in lake's upper waters	county begins design of integrated biological monitoring program
1999	--	completed upgrade of aeration system for secondary clarifiers at Metro	Maltbie Floatables Control Facility (FCF)	--	--
2000	--	--	• Franklin FCF • Harbor Brook Interim FCF	--	• Biological AMP begins • littoral zone plant coverage 11% in June
2001	--	--	• Teall FCF • Hiawatha Regional Treatment Facility (RTF)	--	--
2002	--	--	• Erie Blvd Storage System repairs completed • Kirkpatrick St. Pump Station Upgrade	--	strong Alewife year class followed by declines in large zooplankton
2003	Three Rivers Water Quality Model peer review completed	--	progress with sewer separation (refer to 2009)	compliance with AWQS for DO in lake upper waters during fall	--
2004	--	• year-round nitrification of ammonia at Metro using BAF • Stage III SPDES limit for ammonia met 8 years ahead of schedule	progress with sewer separations (refer to 2009)	compliance with AWQS: • ammonia in lake upper waters • for fecal coliform bacteria in lake Class B segments	--

Table 3-1. Summary (timeline) of significant milestones, pollution abatement actions, lake water quality status, and biological status.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Status	Biological Status
				during Metro disinfection period	
2005	--	Actiflo® system on-line to meet Metro Stage II SPDES limit for TP (0.12 mg/L as a 12-month rolling average)	progress with sewer separations (refer to 2009)	--	• no summer algal blooms • littoral zone plant coverage in June: 49%.
2006	ACJ 2nd Amendment motion filed by NYS Attorney General's Office	--	progress with sewer separations (refer to 2009)	compliance with AWQS for nitrite in the lake's upper waters	--
2007	--	• Metro meets Stage 2 SPDES limit for TP on schedule. • Onondaga Lake Water Quality Model development/calibration review (Phase 2).	progress with sewer separations (refer to 2009)	• compliance with AWQS for ammonia in the lake at all depths • Summer TP 25 µg/L in lake's upper waters	mesotrophic conditions achieved
2008	ACJ amended by Stipulation #3	--	Midland Ave. Phase I and II conveyance, storage and RTF	• Onondaga Lake delisted for ammonia. • summer TP 15 µg/L in lake's upper waters	Alewife population decline followed by resurgence of large zooplankton
2009	ACJ amended by Stipulation #4	Interim Stage II TP limit of 0.10 mg/L	• Clinton St. conveyance • Green Infrastructure (GI) program begins • 13 sewer separation projects completed 1999–2009	summer average TP of 17 µg/L in lake's upper waters	strong Alewife year class
2010	--	compliance with interim Stage II TP limit of 0.10 mg/L	• Harbor Brook Interceptor replacement initiated • 40 GI projects completed,	summer average TP of 25 µg/L in lake's upper waters	resurgence of Alewife; loss of larger zooplankton

Table 3-1. Summary (timeline) of significant milestones, pollution abatement actions, lake water quality status, and biological status.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Status	Biological Status
			eliminating 16.7 acres of impervious surfaces		
2011	NYSDEC approved AMP modifications to determine whether CSOs are causing or contributing to violations of the NYS AWQS	compliance with interim TP limit of 0.10 mg/L	• 57 GI projects completed in 2011 • Gate chamber modifications to Erie Blvd. Storage System completed • Harbor Brook Interceptor Sewer 95% complete • CSO-044 Conveyance 90% complete	summer average TP of 20 µg/L in lake's upper waters	continued high densities of Alewife and absence of larger zooplankton
2012	• Metro SPDES permit issued on March 21, 2012 • Onondaga Lake Water Quality Model completed and applied to TMDL for phosphorus • TMDL for phosphorus approved by USEPA on June 29, 2012 (in-lake TP concentration of 20 µg/L established as a target)	compliance with TP limit of 0.10 mg/L as a 12-month rolling average	• 35 GI projects completed in 2012 • CSO-044 Conveyance completed • CSO-022/045 sewer separation constructed • Construction of Harbor Brook Interceptor Sewer completed • Construction of Clinton and Harbor Brook Storage Facilities 50% complete	summer average TP of 22 µg/L in lake's upper waters	continued high densities of Alewife and absence of larger zooplankton
2013	--	compliance with TP limit of 0.10 mg/L as a 12-month rolling average	• 50 GI projects completed in	summer average TP of 25 µg/L in lake's upper	continued high densities of Alewife and

Table 3-1. Summary (timeline) of significant milestones, pollution abatement actions, lake water quality status, and biological status.

Year	Regulatory/ Management Actions	Metro Actions	CSO Abatement Actions	Water Quality Status	Biological Status
			2013 • Harbor Brook Interceptor Sewer (HBIS) replacement completed • Clinton Storage Facility - completed and placed into operation. • Lower Harbor Brook Storage Facility - completed and placed into operation.	waters	absence of larger zooplankton
2014	On June 4, 2014, the NYSDEC issued a modification to Metro's SPDES permit. The modified permit determined Metro's permit effluent total phosphorus concentration limits not exceed 0.10 mg/L as a 12-month rolling average and a monitoring requirement for the operation of the CSO 018 pilot constructed wetland.	compliance with TP limit of 0.10 mg/L as a 12-month rolling average	• 22 GI projects completed in 2014 • 95.3% of CSO volume is captured	summer average TP of 22 µg/L in lake's upper waters	continued high densities of Alewife and absence of larger zooplankton

Crew practice on Onondaga Lake

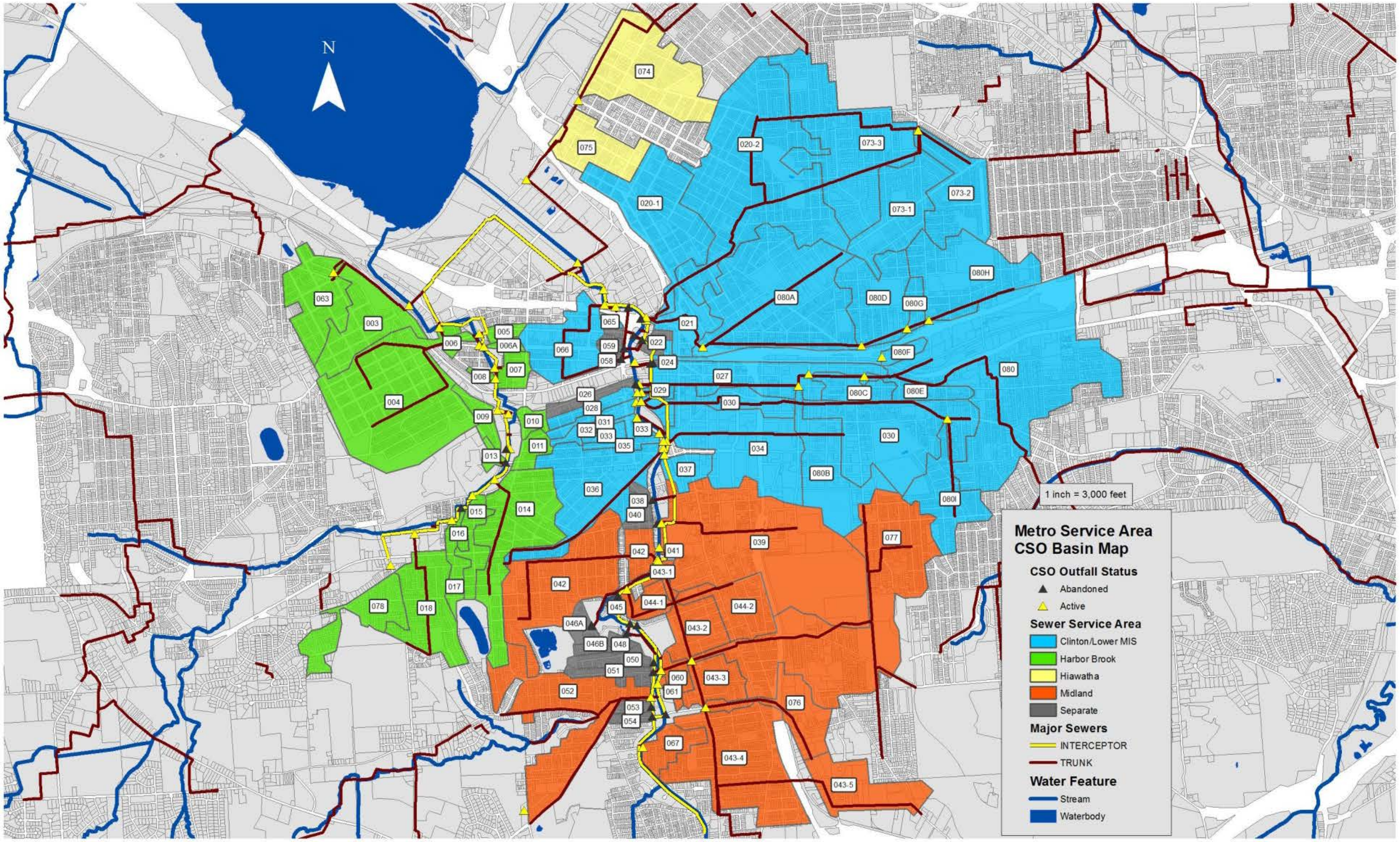


Figure 3-1. Map of CSO areas.

Table 3-2. ACJ and additional gray infrastructure milestone, schedule, and compliance status.

Projects	Milestone Description	Milestone Type	Milestone Date	Compliance Status
CSO 044 Conveyances	Plans and specs to NYSDEC for review and approval	Minor	06/01/2010	Achieved
	Commence construction	Minor	12/31/2010	Achieved
	Complete construction and commence operation	Major	12/31/2011	Achieved
Harbor Brook Interceptor Sewer Replacement	Plans and specs to NYSDEC for review and approval	Minor	08/17/2009	Achieved
	Commence construction	Minor	01/01/2010	Achieved
	Complete construction and commence operation	Major	12/31/2013	Achieved
Erie Boulevard Storage System Modifications	Plans and specs to NYSDEC for review and approval	Minor	09/01/2010	Achieved
	Complete required modifications	Major	12/31/2011	Achieved
Clinton Storage Facility	Plans and specs to NYSDEC for review and approval	Minor	02/01/2011[1]	Achieved
	Commence construction	Minor	10/01/2011[1]	Achieved
	Complete construction and commence operation	Major	12/31/2013	Achieved
Lower Harbor Brook Storage Facility	Plans and specs to NYSDEC for review and approval	Minor	04/29/2011[1]	Achieved
	Commence construction	Minor	12/31/2011[1]	Achieved
	Complete construction and commence operation	Major	12/31/2013	Achieved

[1] Date reflects ACJ Milestone extension approved by the NYSDEC on November 4, 2010

Table 3-3. Additional gray infrastructure projects and implementation schedules.

Projects	Task	Compliance Status
CSO 063 Conveyances	Plans and specifications to NYSDEC for review and approval	5/23/2013
	Construction bid opening	4/28/2014
	Notice to proceed	8/8/2014
	Complete construction	10/1/2015

Green infrastructure facility installed on a two acre parcel of land at the intersection of Amy Street, Delaware Avenue and Grand Avenue

Green infrastructure features include two bio-retention areas, a rain garden, porous gravel interior paths, and porous concrete sidewalks.

A number of significant gray infrastructure milestones were achieved in 2014, including the following major projects. See the Save the Rain website (http://www.savetherain.us) for additional details.

- Clinton Storage Facility - The 6.5 million gallon CSO storage facility was placed into operation prior to December 31, 2013. During 2014, the contractor completed additional work on electrical and instrumentation systems, automated controls, miscellaneous building work and site work. By April 17, 2014, the system was operating in automatic mode and the contractor’s one year performance period began on that date.
- Lower Harbor Brook Storage Facility (LHBSF) - The 4.9 million gallon CSO storage facility was placed into operation and capable of receiving wet weather flow on December 31, 2013. During 2014, the contractor completed work on the electrical and instrumentation systems, miscellaneous building work, and site work which included paving, tree planting, installation of two bioretention areas, and storm sewer replacement. The facility is now fully functional in the automatic mode and is operating under the contractor’s performance period which began on July 18, 2014. In addition to capturing flows from CSO 003 and 004, the facility will also accept flow from CSO 063 via a 48-inch conveyance pipeline scheduled for completion in 2015.
- CSO 063 Conveyances Project - In 2014, the County completed the bidding process and began construction on the CSO 063 Conveyances Project. This project provides for the transmission of wet weather flow from CSO 063, currently located in Emerson Street, to the LHBSF, and includes relocation of the CSO 063 outfall. In 2015 the County expects to complete installation of the pipeline, install a new outfall to Harbor Brook, and install a new regulator and grit chamber.
- CSO 061 Sewer Separation - In 2014, the County initiated the planning and design phase for the Sewer Separation of CSO Area 061 within the Midland Avenue CSO Service Area. The proposed project will separate sanitary and storm flow within the CSO 061 basin.

In 2014 the STR Program included several signature GI projects that showcase the use of GI and build general awareness in the community through impressive transformations of neighborhoods across Syracuse. Twenty-two (22) green infrastructure projects were completed in 2014, including the East Washington Street Green Corridor and the Rainwater Harvesting System at the Carrier Dome, which are reducing annual stormwater by 923,000 and 903,000 gallons, respectively. In addition, sixty-six (66) green infrastructure projects have been identified for potential implementation in 2015 and beyond. More than 3,600 tree plantings have been installed as part of the Save the Rain Street Tree Program since 2011 and more than 1,200 rain barrels have been installed.

Fishing from the pier at Onondaga Lake Park

The Comfort Tyler Park project was accomplished through the partnership of the STR Program, City of Syracuse Parks Department, and the Jim and Juli Boeheim Foundation's Courts 4 Kids Program. The project represents a comprehensive renovation of the park and includes capital improvements to the park infrastructure (paid for by the City Parks Department) and the utilization of green infrastructure to capture stormwater runoff. GI elements installed included a bioretention area at the northeast corner of the park, replacement of the existing basketball court with a porous asphalt court, and an infiltration trench and bioswale system at the south end of the park. The GI elements of the project capture approximately 600,000 gallons of stormwater annually.

The East Washington Street Green Corridor Project is a comprehensive green street application located on East Washington Street, between Almond Street and Forman Avenue, adjacent to the Syracuse University Center of Excellence. The project includes an underground infiltration trench, a PaveDrain parking lane, and bioswales along both sides of the street to capture stormwater and reduce combined sewer overflows. In addition to these beneficial green infrastructure items, the entire streetscape was retrofitted with new sidewalks and pedestrian crossings. Runoff from approximately 76,900 square feet of impervious area is captured by this green infrastructure project, reducing annual stormwater runoff by approximately 923,000 gallons. For additional information on these and other projects please visit the Save the Rain website (savetherain.us).

View of East Washington Street Green Corridor Project

County Executive Joanne Mahoney is championing a Save the Rain (STR) initiative to educate residents about storm water management. The campaign raises awareness of effective ways to improve the environment by using rain barrels, rain gardens, porous pavement, green roofs, cisterns, and vegetated swales. STR continued its approach to rebuilding neighborhoods, developing strong community relationships, and advancing signature projects to solidify its place as a national leader in stormwater management. In addition, STR continued a comprehensive public education and outreach program to engage the local community and provide continued support for program activities.

In 2014, Onondaga County continued to receive recognition and awards for its outstanding and innovative STR program. In June, Onondaga County Executive Joanne Mahoney received the Donald G. Colvin Award from Audubon New York for improvements at Onondaga Lake from the STR program. The award is the top honor given annually by the 50,000 member Audubon conservation group. The STR Public Education and Outreach Team continued to engage the general public to raise awareness of the benefits of green infrastructure and the County's efforts to implement the program. Public outreach activities in 2014 included Save the Rain Educational Videos, the Rain Barrel Art Contest, and Save the Rain Educational Signage.

Rain barrel installation

3.2 Progress with Related Initiatives

Honeywell International is proceeding with a number of projects to address industrial contamination issues, with oversight by the federal Environmental Protection Agency (EPA) and NYSDEC. Dredging and capping of Onondaga Lake sediments continued in 2014. About 2.2 million cubic yards of contaminated sediment were removed from the lake by hydraulic dredging, which was completed in 2014, a year ahead of schedule. About 450 acres of the lake bottom are being capped to provide a new habitat layer, prevent erosion, and isolate remaining contaminants. Capping is scheduled to continue into 2016. To date, 44 acres of wetlands have been restored at Geddes Brook, Harbor Brook, Nine Mile Creek, the former LCP Chemicals site, and along the western shoreline of Onondaga Lake. More than 110 species of fish, birds, and mammals have returned to restored wetlands, including mink, bald eagles, and northern pike. About 1.1 million plants, shrubs, and trees are being planted to enhance habitat for fish and wildlife in the Onondaga Lake watershed. Additional details can be found on Honeywell's project website (http://www.lakecleanup.com/about-the-cleanup/cleanup-areas/geddes-brook-wetlands/).

As part of a three-year (2011–2013) pilot test, nitrate was added to the deep waters of Onondaga Lake with the objective of limiting release of methylmercury from the profundal sediments to the hypolimnion. A liquid calcium-nitrate solution was added to the hypolimnion as a neutrally buoyant plume approximately three times per week during the summer stratification interval. Maximum hypolimnetic concentrations of methylmercury and soluble reactive phosphorus decreased 94% and 95% from 2009 levels. Based on the success of this pilot test, nitrate addition was conducted again in 2014. Detailed descriptions of Honeywell's planned remedial projects, designed to prevent the flux of contamination into the lake and restore aquatic habitat, are on the NYSDEC web site http://www.dec.ny.gov/chemical/48828.html. The Onondaga Lake Visitors Center opened on the southwest shoreline of the lake in 2012 to provide the public with access to information on the lake cleanup. Thousands of people have visited the Center to learn more about Onondaga Lake and the cleanup project. Additional information on Honeywell's remediation activities is available on their project website http://www.lakecleanup.com.

For decades, scientists at Onondaga County Department of Water Environment Protection (OCDWEP) and the State University of New York College of Environmental Science and Forestry (SUNY-ESF) have been monitoring Onondaga Lake to evaluate how biological communities are changing as pollution levels decline. In 2011 a collaborated effort began between both parties. Taken together, the findings of the two programs offer a unique window into the ecological changes taking place in this valuable community asset. Additionally, the rapid spread of non-native species including dreissenid mussels and Alewife has resulted in a collaborative effort between Onondaga County and Cornell University researchers working together to help track theses invading exotics and their impact on the water quality and biological communities of Onondaga Lake.

Onondaga Lake dredging operations

3.3 Recreational Opportunities

Water quality improvements have enabled a variety of new recreational opportunities in and around Onondaga Lake. For example, water quality conditions in the northern two-thirds of Onondaga Lake were suitable for swimming throughout the summer of 2014. Although there is no public bathing beach at Onondaga Lake, bacteria levels and water clarity consistently meet regulatory standards for swimming throughout most of the lake. As documented in the technical report "Attainment of Designated Uses in Onondaga Lake", bacteria and water clarity data indicate that a beach located at Willow Bay would have been open continuously during the summer months since 2008.

With over 1 million visitors annually, Onondaga Lake Park is the most popular park in Central New York. The park offers paved, vehicle-free trails, special events, sporting competitions, and festivals. Developed areas in Willow Bay and Cold Springs as well as seven miles of shoreline provide families with a variety of recreational opportunities. Located along the western shore of Onondaga Lake, the paved West Shore Trail includes over two miles of wind-sheltered woodlands. This trail provides acces to bicyclists, walkers, runners, and nature enthusiasts.

The Onondaga Creekwalk, an urban trail in the City of Syracuse, is currently complete from the historic Armory Square district in Downtown Syracuse to the southern shore of Onondaga Lake. The Onondaga Creekwalk measures 2.6 miles and averages 13 feet wide. It will eventually connect to the progressing Loop the Lake Trail, as well as to the Erie Canalway Trail, scheduled to connect Canal communities from Albany to Buffalo along the 524-mile New York State Canal System. The Syracuse section of the Canalway Trail will connect 15 miles of trails in Onondaga County.

The "Onondaga Lake Lounge", a 1,350-square-foot wooden deck that will be built at the end of the Onondaga Creekwalk near Destiny USA, will have tiered seating to offer views of the lake and Onondaga Creek. Construction is expected to begin in 2015.

The Lakeview Amphitheater Facility, an outdoor event complex located on the western shore of Onondaga Lake, hosted its first concert during the 2015 New York State Fair. The facility includes an amphitheater with both covered and lawn seats, a vendor area, recreational trails, and amenities.

Sport fishing at Onondaga Lake has become increasing popular over the past 15 years and continues to expand. In addition to non-competitive angling, a modest tournament fishery has developed in recent years. Local bass organizations compete during several weekends throughout the summer, and several large-scale fishing tournaments have been held on Onondaga Lake including the Bassmasters Memorial in 2007 and the BASS Junior World Championship in 2008.

Fish from Onondaga Lake on display at the 2014 Clean Water Fair
September 6, 2014 at Metro

Section 4. Tributary Water Quality: 2014 Results and Long-Term Trends

4.1 Tributary Monitoring Program

The primary objectives of the tributary monitoring program are to assess compliance with ambient water quality standards in the tributary streams and to estimate loading of materials to the lake, including the volume and loading of materials from combined sewer overflows. In addition, tributary monitoring data are used to support long-term trend analysis. To support these objectives seven tributaries to the lake are monitored, as are the Metro effluent and the Onondaga Lake outlet. The tributary monitoring program targets sample collection over a range of streamflow conditions, including a minimum number of high flow events as defined by statistical analysis of long-term flow records.

The post construction monitoring program (PCCM) includes monitoring of representative CSO outfalls and receiving streams (Onondaga Creek and Harbor Brook) to support assessment of the effectiveness of green and gray infrastructure and CSO controls. Storm event monitoring is an important component of the PCCM efforts. Changes to the tributary sampling program for 2014 included the following:

- Discontinued measurements of total alkalinity, sodium, potassium, manganese, iron, sulfate, and silica-dissolved.
- Limited fecal coliform sampling at all AMP tributary sampling locations to 5 samples per month during the April to October disinfection period, as specified in the Metro SPDES permit requirements.
- Discontinued BOD-5 measurements.
- Discontinued sampling at Onondaga Creek-Spencer Street and Harbor Brook-Bellevue Ave.
- Reduced sampling frequency at Bloody Brook and Tributary 5A to quarterly. Bloody Brook is sampled five times per month for fecal coliform bacteria.
- Added visual observations of floatables in Onondaga Creek, Harbor Brook, and Ley Creek during tributary sampling events.

Additional information on the tributary monitoring program can be found in the Five-Year (2014–2018) AMP Work Plan. Results for key parameters and tributary sampling locations are presented in this section. Long-term time series covering 2004–2014 are provided for all AMP parameters and tributary sampling locations in Appendix D-1. Based on discussions with NYSDEC in May 2015 regarding the PCCM program, samples will be collected from CSO facilities (RTF and Storage) to characterize CSO water quality data in-lieu of individual representative CSO outfall sampling.

4.2 Meteorological Drivers and Streamflow

Meteorological conditions are subject to substantial seasonal variations in this region. These conditions typically vary day-to-day, and noteworthy differences are commonly observed between years. Air temperature is the primary determinant of stream temperatures, which can affect the fate and transport of these inflows in the lake. However, precipitation, as the primary driver of stream flow, is the single most important meteorological attribute affecting material loading from the tributaries. Annual precipitation totaled 40.5 inches in 2014, 4% higher than the 30-year historic (1984–2013) average of 38.8 inches and nearly equivalent to the 40.4 inches received in 2013. Monthly precipitation totals were higher than the long-term averages in February, March, April, May, July, and October (Figure 4-1). Precipitation was particularly high during the months of April, July, and October. The months of January, June, September, November, and December were dryer than the long-term average. September was a particularly dry month, with just 1.6 inches of rain compared to the long-term average of 3.7 inches. Snowfall for the 2013–2014 winter season totaled 132 inches, higher than the 1951–2013 average of 119 inches.

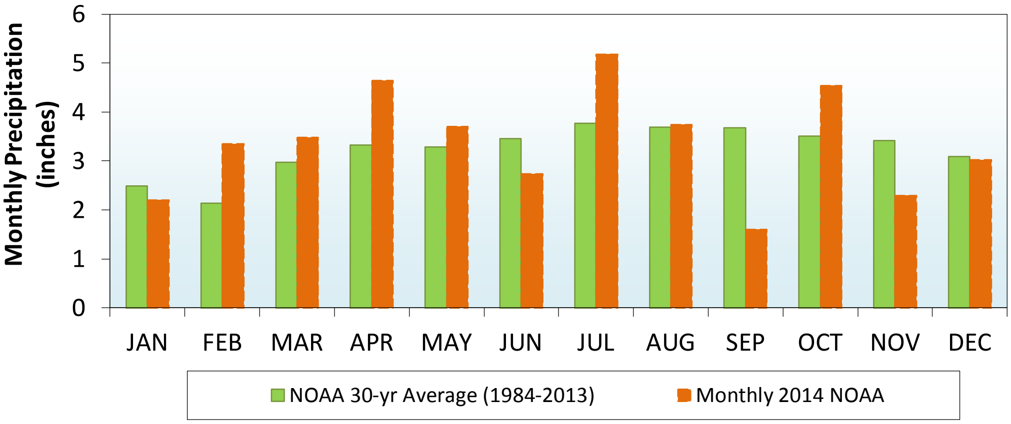


Figure 4-1. Monthly precipitation in 2014 compared to the long-term (1984–2013) average.

Substantial year-to-year variations in precipitation are reflected in the wide range of annual average flows carried by Onondaga Creek during the 1971–2014 interval (Figure 4-2). Above average precipitation during most of 2014 resulted in an annual average flow for Onondaga Creek that was 13% higher than the average for the 43-year record (Figure 4-2). Annual average streamflow in Onondaga Creek has exceeded the long-term average in three of the last four years. Plotting the long-term annual average flows in a cumulative probability format shows that the likelihood of exceeding the 2014 average flow is less than 30% (Figure 4-3).

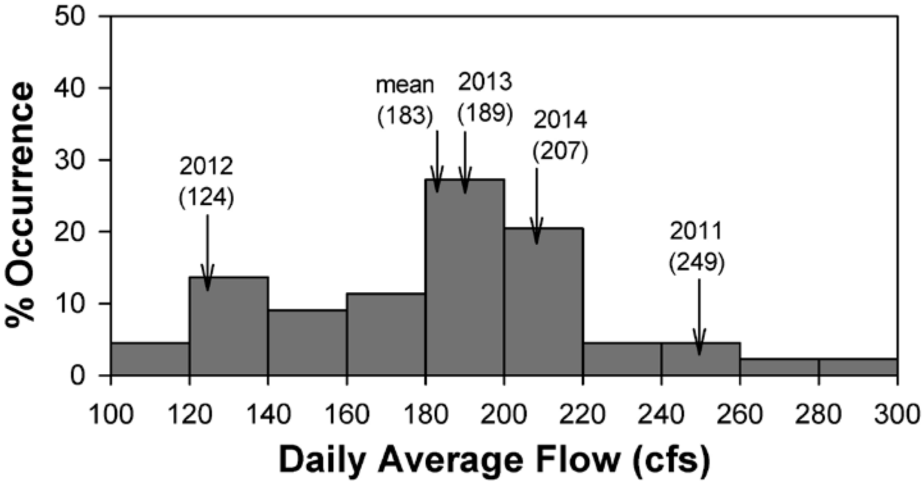


Figure 4-2. Distribution of the annual average of daily average flows for Onondaga Creek at Spencer Street, 1971–2014.

*Note**:** Annual average values for 2011-2014 and the entire 43-year record are identified.*

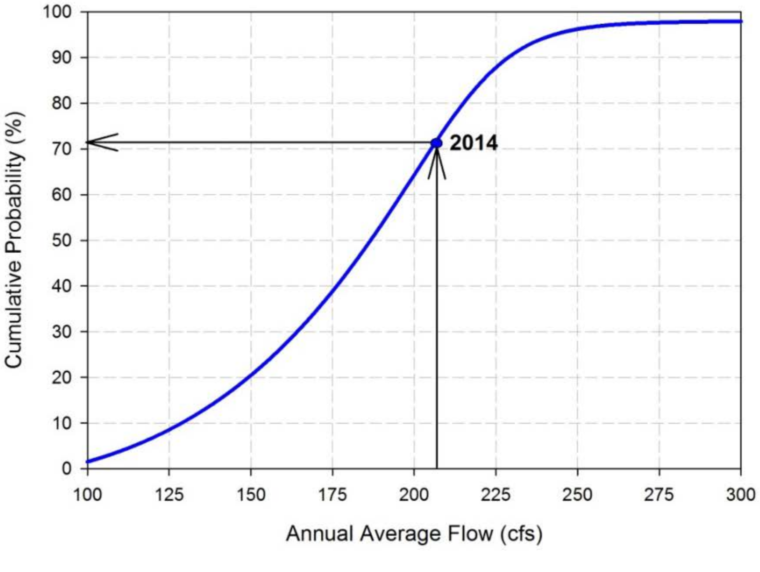


Figure 4-3. Cumulative probability plot of annual average flows for Onondaga Creek at Spencer Street, 1971–2014.

Temporally detailed streamflow patterns for the major tributaries in 2014 depict major runoff events in late March, mid-April, mid-May, mid-December, and late December (Figure 4-4). Following a dry interval that began in mid-April, the late May to early July period was characterized by a series of significant runoff events and elevated flows in the tributaries. The wettest day of the year was July 28, when 2.16 inches of rain was recorded at Hancock International Airport. However, this event did not cause particularly high stream flows because of seasonally high levels of evapotranspiration and dry antecedent conditions. The flows and material loadings received during late spring and early summer are considered particularly important in influencing summer water quality in receiving lakes. Accordingly, the elevated flows of April and May 2014 would be expected to have significant impacts on lake water quality during the summer months. Major runoff events also occurred in mid-October and December. Relative to runoff events that occur during spring and summer, these events have a diminished impact on lake water quality during the following summer season.

Concentrations, and thereby loading rates, of many constituents of water quality interest are known to depend importantly on the magnitude of stream flow. In recognition of this, the AMP targets a broad range of flow conditions to support robust loading rate estimates; specifically, a minimum of five sampling events are targeted during high flow conditions (defined as stream flow at the Onondaga Creek-Spencer St. gauge of at least one standard deviation above the long-term monthly average). In 2014 this goal was exceeded by a wide margin at Onondaga Creek, Ninemile Creek, Ley Creek, and Harbor Brook (Figure 4-4).

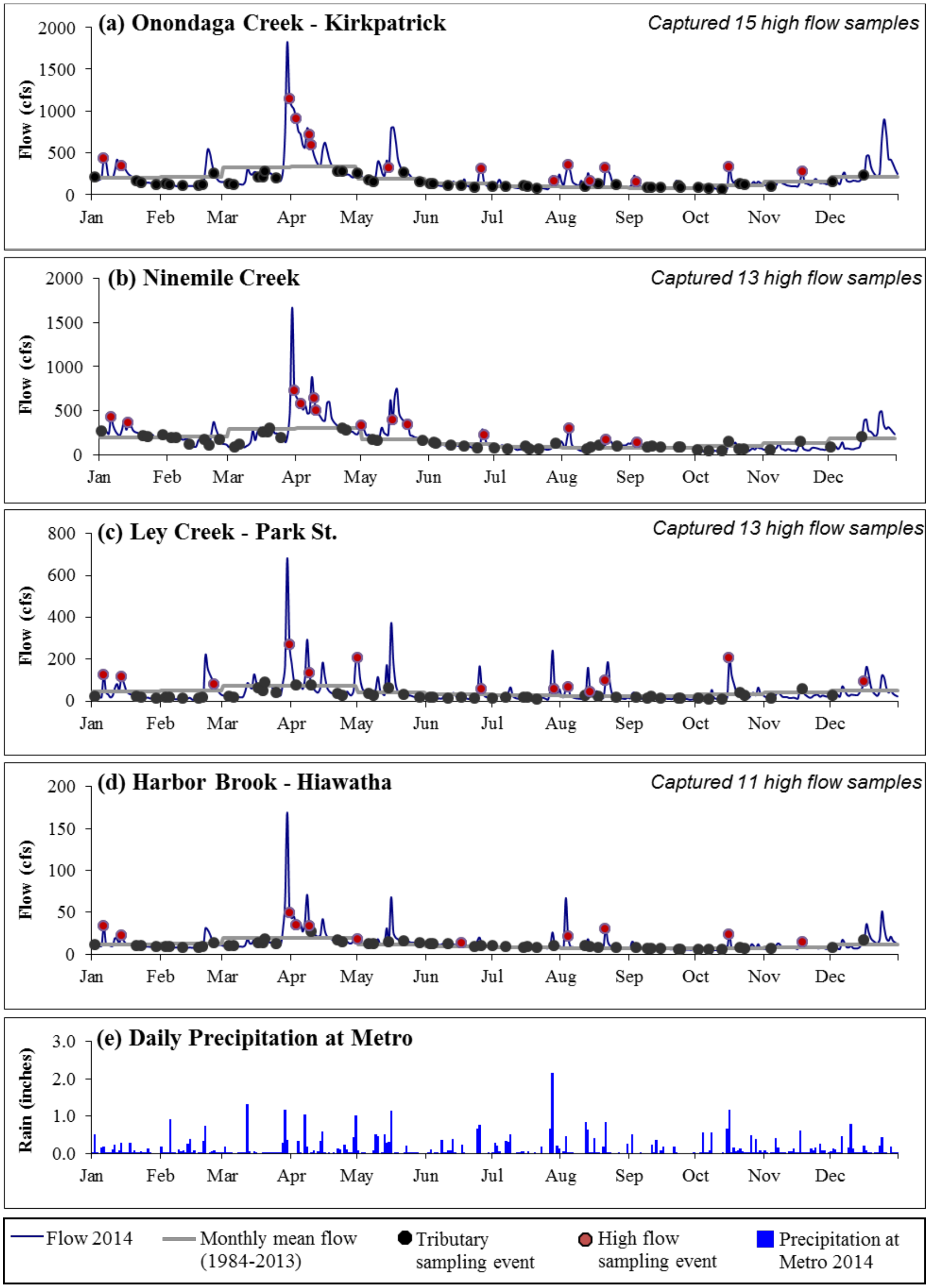


Figure 4-4. Hydrographs showing tributary flows in 2014 compared with the 30-year average (1984–2013) USGS average flow for (a) Onondaga Creek, (b) Ninemile Creek, (c) Ley Creek, (d) Harbor Brook, and (e) daily precipitation at Metro.

Note: points indicate days of sampling.

4.3 Loading Estimates

4.3.1 Methodology

Dr. William Walker developed customized software for WEP staff to calculate annual loads using the program AUTOFLUX, method 5. This software is designed to support load estimates from detailed (e.g., continuous) flow measurements and less frequent (often biweekly) analyses of tributary water quality samples. Concentrations from the tributary monitoring program are stratified by flow regime and by season using a multiple regression technique. High-frequency measurements collected during storm events are incorporated into the calculations. Conditions during unmonitored periods are estimated using a residual interpolation method that includes a flow derivative term. This term was included to account for the potential effect of differences in the flow and concentration relationship depending on whether samples were collected during periods of increasing or decreasing flows. This software was used to compute all of the loading estimates presented in this report. Annual loading estimates for selected parameters are presented for 2014 (Table 4-1), mostly in units of metric tons (mt). Forms of phosphorus and nitrogen are measured frequently in the Metro effluent. Tributary loading calculations were supported by at least 21 observations within the year, except for East Flume Manhole 015 (n=4). Fecal coliform samples were collected more frequently (5 samples per month) to allow for determination of compliance with the AWQS.

4.3.2 Results for Key Constituents

The largest total phosphorus (TP) loads to Onondaga Lake were delivered by the two largest tributaries, Onondaga and Ninemile Creeks, and the Metro effluent (Table 4-1, Table 4-2). Onondaga Creek was the predominant source of total phosphorus, contributing 46% of the total load. The Metro Bypass (002) load was estimated to be the fifth highest input of total phosphorus, following Ley Creek. Metro's contribution was substantially greater before the Actiflo® upgrade in 2005. Total phosphorus loads in 2014 were 5% higher than in 2013, consistent with slightly higher precipitation and stream flow in 2014. From 2013 to 2014 the total phosphorus loads from Onondaga Creek and Metro (001+002) increased 4% and 22%, respectively, while the load from Ninemile Creek decreased by 18%. Reduced total phosphorus loading from Ninemile Creek may be associated with the completion of in-stream remediation activities conducted by Honeywell. Onondaga Creek, Ninemile Creek, and the Metro effluent were also the largest contributors of total dissolved phosphorus (TDP) loads in 2014. The total dissolved phosphorus fraction is a better representation of bioavailable forms than is total phosphorus, as a large portion of particulate phosphorus is typically unavailable to support algal growth. In an effort to reduce phosphorus levels in stormwater runoff, New York State restricted the use of phosphorus fertilizer on lawns and non-agricultural turf beginning January 1, 2012.

Table 4-1. Annual loading estimates for selected water quality constituents, 2014.

Notes: mt = metric tons. n represents the number of water quality samples included in the annual load calculation.

Parameters[1]	**TP**		**TDP**		**TN**[7]		**NH_3-N**		**TSS**		**FC**[2]	
units	**mt**	**n**	**mt**	**n**	**mt**	**n**[3]	**mt**	**n**	**mt**	**n**	**10^{10} cfu**	**n**
Metro:												
Treated Effluent (001)[5]	5.6	358	1.6	246	1,156	360	25.8	360	507	362	33,778	165
Bypass (002)[6]	1.9	61	0.5	2	20	61	10.6	61	85	62	104,918	49
Watershed:												
East Flume[4] Manhole 015	0.1	4	0.1	4	5	4	0.2	4	6	4	40	4
Harbor Brook-Velasko[4]	0.3	26	0.1	26	19	27	0.4	27	250	27	27,313	62
Harbor Brook-Hiawatha[4]	0.5	27	0.2	27	22	27	0.7	27	200	27	20,245	63
Ley Creek[4]	3.2	24	0.8	24	41	23	8.6	23	731	24	89,712	53
Ninemile Creek[4]	11.5	26	2.7	26	263	26	31.1	26	4,658	26	196,637	61
Onondaga Creek-Dorwin[4]	15.3	27	2.0	27	237	27	7.6	27	10,676	27	70,075	62
Onondaga Creek-Kirkpatrick[4]	19.9	27	3.0	27	289	27	13.9	27	17,678	27	244,275	62
Tributary 5A[4]	0.3	21	0.1	21	5.7	21	0.5	21	35	21	586	52
Total	43	--	9.0	--	1,801	--	91	--	23,900	--	690,191	--

Notes:

[1] Parameters are: TP (total phosphorus), TDP (total dissolved phosphorus), TN (total nitrogen), NH_3-N (ammonia-nitrogen), TSS (total suspended solids), and FC (Fecal coliform bacteria). Because TDP was not measured on the Bypass, soluble reactive phosphorus (SRP) loads are reported rather than TDP loads.

[2] FC- fecal coliform bacteria loads have a very high standard error due to the episodic nature of the FC inputs.

[3] Not measured directly, counts reflect NH_3-N counts.

[4] Tributary loading results are calculated using 2014 measurements and concentration-flow relationships for the 2005-2014, processed through AutoFlux Method 5.

[5] Metro Effluent Outfall 001 loads for TP, TSS, and NH_3-N are calculated using daily observations. FC are collected biweekly as part of the long-term tributary program and daily from April 1 to October 15 (per SPDES permit during disinfection season).

[6] Metro Bypass Outfall 002 loads are calculated using periodic grab samples when Outfall 002 is active (secondary bypass events when the capacity of Metro is exceeded).

[7] TN loads were calculated by summing the annual NH_3-N, NO_3-N, NO_2-N, and ORG-N loads

The Metro effluent was the leading source of total nitrogen (TN) and the second largest source of ammonia nitrogen (NH_3-N) to the lake in 2014 (Table 4-1, Table 4-2). The largest source of ammonia in 2014 was Ninemile Creek (34%), followed by the treated Metro effluent (28%). The total suspended solids (TSS) load was dominated by inputs from Onondaga Creek (74%) and Ninemile Creek (20%), which combined to account for 94.5% of the total load to Onondaga Lake. The high TSS load in Onondaga Creek is at least in part attributable to inputs from the mud boils in upstream portions of its watershed. The TSS contribution from Ninemile Creek in 2014 (20%) was much lower than in 2013 (45%). This is attributable to the completion of in-stream remediation activities conducted as part of the Honeywell cleanup.

Loading estimates for total suspended solids and fecal coliform bacteria in Harbor Brook were higher at the upstream sampling location (Velasko Rd.) than at the downstream site (Hiawatha Blvd.). Decreased loading over this stream reach was caused by higher flows reported at the Velasko gage compared to the Hiawatha gage, as measured concentrations were consistently higher at Hiawatha. Note that flow measurements at the Hiawatha gage are uncertain (rated by the USGS as “fair” with estimated daily flows rated as “poor”), and similar flow rates at the upstream and downstream sites are expected because the gages are very close to each other (~ 4 km apart). Estimated loads were higher at the downstream site (Kirkpatrick St.) than the upstream site (Dorwin Ave.) for these selected constituents. The difference was greatest for fecal coliform bacteria loading, which was 3.5-fold higher at the downstream location.

The primary sources of fecal coliform bacteria were Onondaga Creek (35%) and Ninemile Creek (29%). The Metro bypass (002) and Ley Creek made noteworthy contributions as well (Table 4-2). The combined loading from these four sources accounted for 92% of the total fecal coliform load to Onondaga Lake. Loading contributions of gauged inputs for selected constituents in 2014 are presented here in both tabular (Table 4-2) and graphical (Figure 4-5) formats. Loading estimates for additional constituents are provided in Appendix D-2 and relative standard errors of these estimates can be found in Appendix D-7. Total annual loads (tributaries and Metro) to Onondaga Lake for the 1995–2014 interval are presented in Appendix D-3.

Table 4-2. Percent annual loading contribution by gauged inflow in 2014.

Parameter	TP	TDP	TN	NH_3-N	TSS	FC	Water
Metro:							
Treated Effluent (001)	13.1%	18.0%	64.2%	28.2%	2.1%	4.9%	18.7%
Bypass (002)	4.3%	5.2%	1.1%	11.6%	0.4%	15.2%	0.3%
Harbor Brook	1.2%	2.3%	1.2%	0.8%	0.8%	2.9%	2.4%
Ley Creek	7.5%	9.3%	2.3%	9.4%	3.1%	13.0%	7.9%
Ninemile Creek	26.8%	30.1%	14.6%	34.0%	19.5%	28.5%	32.4%
Onondaga Creek	46.2%	33.0%	16.1%	15.2%	74.0%	35.4%	37.5%
Tributary 5A	0.7%	1.3%	0.3%	0.5%	0.1%	0.1%	0.8%

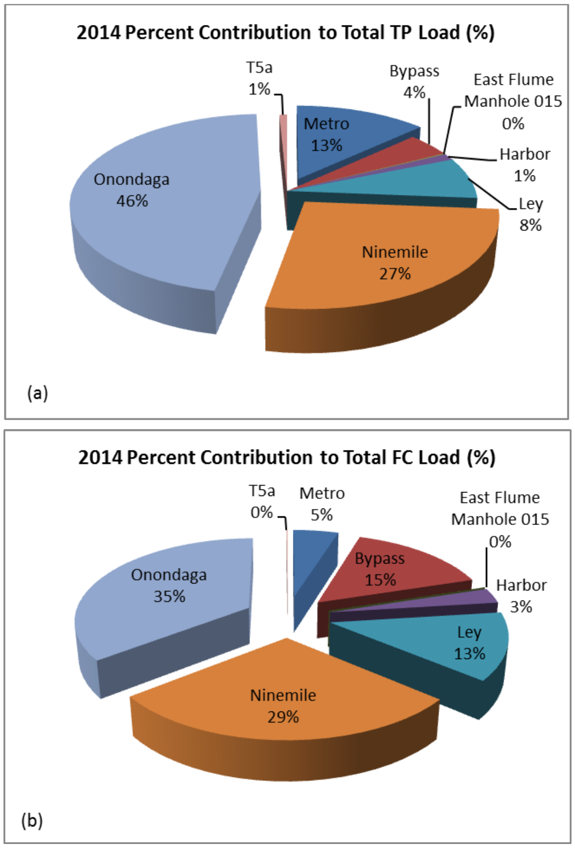


Figure 4-5. Percent contributions to 2014 total load to Onondaga Lake for (a) total phosphorus and (b) fecal coliform bacteria.

The relative potency of the various inflows can be represented by comparisons of annual flow-weighted average concentrations (total annual loads (mass) ÷ total flow (volume)) calculated for each input. Flow-weighted concentrations for 2014 are presented in Table 4-3 for selected constituents. Flow-weighted total phosphorus concentrations ranged from 45 µg/L in Harbor Brook to 129 µg/L in East Flume Manhole 015, but were much higher for the partially treated Metro bypass (1,118 µg/L). Concentrations of total dissolved phosphorus were lowest in Ninemile Creek, Onondaga Creek, Harbor Brook, and the fully-treated Metro effluent and highest in the bypass. The Metro effluent, Metro bypass, and East Flume were enriched in total nitrogen relative to the other inputs. Concentrations of TSS were highest in Onondaga Creek and the bypass and lowest in the fully treated Metro effluent. The bypass had the highest fecal coliform concentrations, followed by Ley Creek and Harbor Brook. The complete list of constituent flow-weighted average concentrations and relative standard errors is provided in tabular format (Appendix D-4).

Table 4-3. Flow-weighted average concentrations for selected constituents in Onondaga Lake tributaries, 2014.

Parameters[1]	**TP**		**TDP**		**TN**[7]		**NH_3-N**		**TSS**		**FC**[2]	
units	**µg/L**	**n**	**µg/L**	**n**	**mg/L**	**n**[3]	**mg/L**	**n**	**mg/L**	**n**	**10^{10} cfu**	**n**
Metro:												
Treated Effluent (001)[5]	61	358	17	246	12.50	360	0.28	360	5.5	362	365	165
Bypass (002)[6]	1,118	61	281	2	11.70	61	6.32	61	51	62	62,724	49
East Flume[4] Manhole 015	129	4	146	4	11.21	4	0.42	4	13	4	86	4
Harbor Brook-Velasko[4]	33	26	13	26	1.90	27	0.04	27	26	27	2,815	62
Harbor Brook-Hiawatha[4]	45	27	18	27	1.86	27	0.06	27	17	27	1,735	63
Ley Creek[4]	83	24	22	24	1.06	23	0.22	23	19	24	2,311	53
Ninemile Creek[4]	72	26	17	26	1.64	26	0.19	26	29	26	1,230	61
Onondaga Creek-Dorwin[4]	108	27	14	27	1.70	27	0.05	27	75	27	495	62
Onondaga Creek-Kirkpatrick[4]	108	27	16	27	1.56	27	0.08	27	96	27	1,320	62
Tributary 5A[4]	85	21	31	21	1.50	21	0.13	21	9.3	21	155	52
All Inflows[8]	87	-	18	-	3.65	-	0.19	-	48	-	1,398	-

Notes:

[1] Parameters are TP (total phosphorus), TDP (total dissolved P), TN (total nitrogen), NH_3-N (ammonia), TSS (total suspended solids), and FC (fecal coliforms). Because TDP was not measured on the Bypass, SRP loads are reported rather than TDP loads.

[2] FC loads have a very high standard error due to the episodic nature of the FC inputs.

[3] Not measured directly, sample counts reflect NH_3-N counts.

[4] Tributary flow-weighted concentrations are calculated using 2014 observations (n = number of samples for 2014) processed through AutoFlux Method 5 and reported here for the sampling locations closest to Onondaga Lake.

[5] Metro Effluent Outfall 001 loads for TP, TSS, and NH_3-N are calculated using daily observations; FC are collected biweekly as part of the long-term tributary program and daily during the Metro disinfection period of April 1 –October 15.

[6] Metro Bypass Outfall 002 loads are calculated using periodic grab samples when the capacity of Metro is exceeded.

[7] All TN flow-weighted concentrations were calculated by dividing the total TN load (see Table 4-1) by the total flow volume for each site.

[8] Flow-weighted average concentrations for the sum of all inflows (Metro+tributaries).

4.3.3 Phosphorus Loading and Bioavailability

Estimates of total phosphorus loads for the tributaries have generally been greater in higher runoff years (Figure 4-6). Annual rainfall for the 1990–2014 period explained 45% of the year-to-year variation in total phosphorus loading according to linear least-squares regression (*p*<0.01). Two- to three-fold differences in total phosphorus loads from the watershed can be expected due to natural variations in rainfall. Clearly, variations in runoff need to be considered when evaluating year-to-year dynamics in lake water quality.

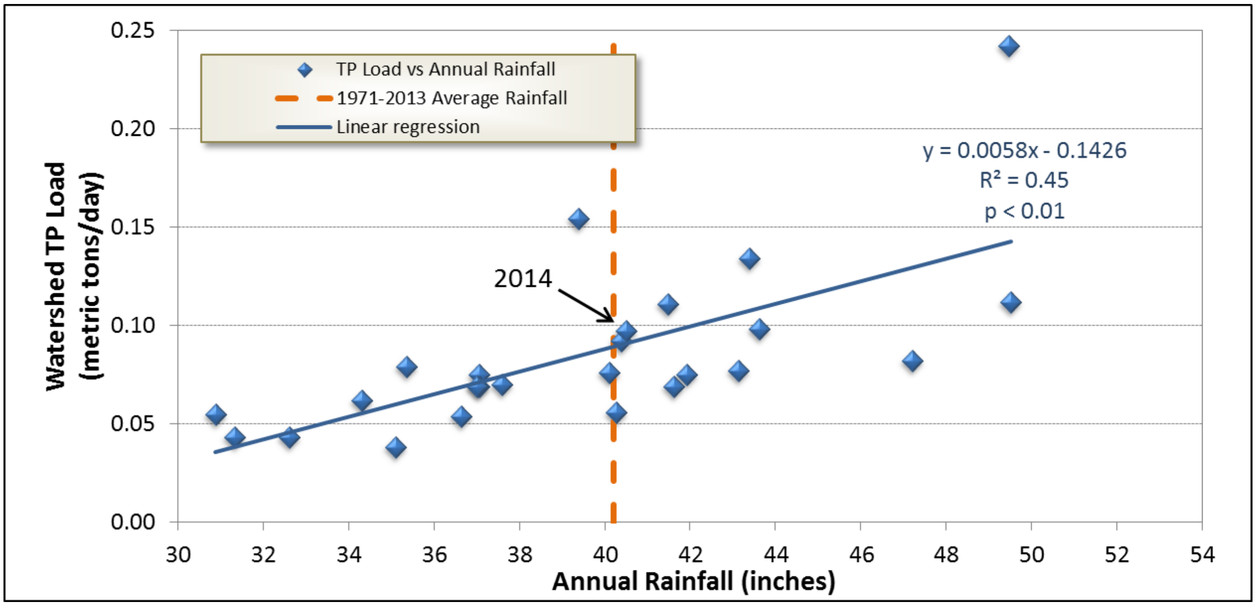


Figure 4-6. Daily average total phosphorus (TP) loading from the watershed versus annual precipitation for the 1990–2014 period.

Note: precipitation data from: http://www.nws.noaa.gov/climate/xmacis.php?wfo=bgm

The timing of phosphorus loads within a year is a potentially important factor relative to algal growth during the critical summer months, particularly in the context of the rapid flushing rate of Onondaga Lake (~ 4 times per year). Although a portion of the phosphorus load received in the fall to winter interval can contribute through various recycle pathways (e.g., sediment diagenesis), it is largely flushed through the lake, or particulate forms are deposited, by the following spring. Accordingly, late spring and summer loads are expected to be the most important for this lake. Monthly loads of total phosphorus (TP) and total dissolved phosphorus (TDP) are presented for 2014 (Figure 4-7). Compared to recent years (Appendix D-5), watershed loading of total phosphorus in 2014 was relatively high during the March–May interval and rather low during September–November. The relatively high loading of total dissolved phosphorus during March–May was available to support algal growth during spring and early summer. Monthly total phosphorus loads are presented for the years 2011–2014 for comparison (Appendix D-5). There has been a recurring seasonal pattern driven by the seasonality of runoff, with the lowest loads generally prevailing in the summer and the highest in winter and spring. Substantial interannual differences in loading have occurred because of the dependency on the timing of runoff.

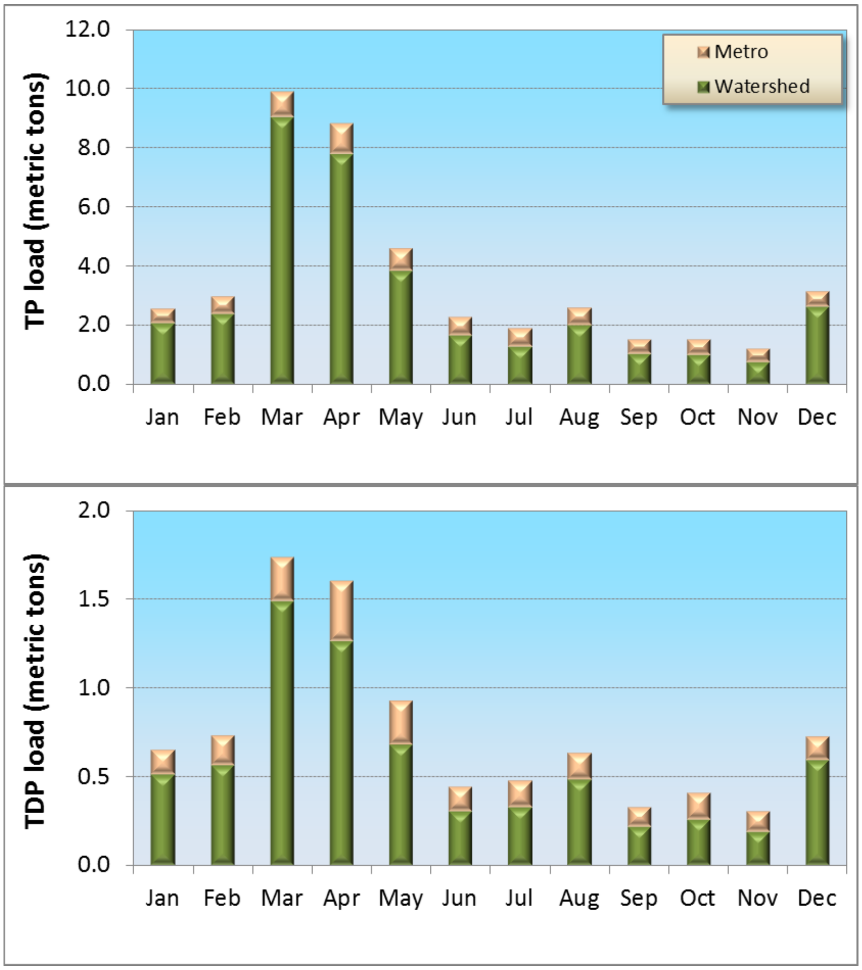


Figure 4-7. Monthly phosphorus loading to Onondaga Lake from Metro and watershed sources in 2014: (a) total phosphorus (TP) and (b) total dissolved phosphorus (TDP).

Increasingly, lake management programs acknowledge that only a portion of the total phosphorus loading to a lake is available to support algal growth. It is important to note that only dissolved forms of phosphorus can be utilized by algae. Much of the total phosphorus loading from the primary tributaries and Metro is in the form of particulate phosphorus (PP). Only a fraction of this PP is converted to dissolved forms that are available to support algal growth. At least two other processes further limit the potential for external total phosphorus loads to support algal growth: (1) settling of PP before it can be transformed and (2) the plunging of dense inputs that are colder or more saline than the upper waters of the lake. Experiments conducted with the Metro effluent in 2009 established the limited bioavailability of this phosphorus load (Effler et al. 2012). Only about 30% of the total phosphorus load from Metro is in a dissolved form, while the remaining 70% is in particulate form. Bioavailability assays established that only 1% of the particle bound phosphorus was available to support algae growth. Moreover, the PP from Metro had an unusually high settling rate and a portion plunged below layers where algae grow. Further reductions in PP would not contribute importantly to achievement of water quality goals. In contrast, the bioavailability of PP from the primary tributaries ranged from 22% to 52% (Effler et al. 2002).

Bioavailability considerations highlight the importance of assessing loading rates for the major forms of phosphorus. The changes in loading from Metro and the tributaries from the 1990–1998 interval (before the ACJ) to after implementation of Actiflo® (2007–2014) are presented here for total phosphorus (Table 4-4), total dissolved phosphorus (Table 4-5), and soluble reactive phosphorus (Table 4-6). Loading of total phosphorus was reduced by 87% for the fully treated Metro effluent (Table 4-4). The 76% decrease in the total phosphorus load from the bypass is also noteworthy. The changes for the tributaries over this period have been relatively modest, including 46% and 21% decreases for Ley Creek and Onondaga Creek, respectively. In recent years (post-Actiflo®), Metro (effluent plus bypass) has represented about 25% of the total phosphorus load, the third largest source, after Onondaga and Ninemile Creeks.

Loading rates of total dissolved phosphorus (TDP) and soluble reactive phosphorus (SRP) are particularly important, as these forms of phosphorus are generally available to support algal growth. The contributions of Metro versus those of the tributaries to annual TDP loading for the 2007–2014 interval (post-Actiflo® upgrade) are presented in Table 4-5. Metro's average contribution to TDP loading over this interval was 29%, approximately equivalent to loadings from Ninemile Creek (29%) and Onondaga Creek (28%). The Metro bypass was the fifth largest contributor at 6%. Flow-weighted total dissolved phosphorus concentrations for the three smallest tributaries considered (Harbor Brook, Tributary 5A, and East Flume-Manhole 015) were higher than for the Metro effluent (0.024 mg/L). The Actiflo® upgrade resulted in a 98% reduction in SRP loading from the treated Metro effluent (Table 4-6). The SRP fraction is particularly noteworthy because it is immediately available to support algal growth. Loading of SRP from the Metro bypass declined by 81% during this period. Metro's combined SRP load represents about 15% of the contemporary total, less than one-half of the inputs from Onondaga Creek (35%) or Ninemile Creek (32%).

Table 4-4. A comparison of total phosphorus (TP) loading and flow-weighted concentrations for pre-ACJ (1990–1998) and post-Actiflo® (2007–2014) periods.

Note: (mt = metric tons; concentrations flow-weighted)

Site	1990-1998 (pre ACJ)				2007- 2014 (post-Actiflo®)			
	Flow (%)	TP (mt P/yr)	TP (% load)	TP (mg P/L)	Flow (%)	TP (mt P/yr)	TP (% load)	TP (mg P/L)
Metro:								
fully treated	21%	52	57%	0.559	19%	7.0	19%	0.082
Bypass	0.94%	8.5	7.5%	1.832	0.37%	2.0	5.2%	1.189
East Flume Manhole 015	0.23%	0.19	0.18%	0.203	0.18%	0.10	0.27%	0.134
Harbor Brook	2.1%	0.71	0.71%	0.070	2.4%	0.82	2.1%	0.073
Ley Creek	8.7%	5.7	5.8%	0.139	8.3%	3.1	8.0%	0.082
Ninemile Creek	32%	10.2	10%	0.065	33%	10.6	26%	0.068
Onondaga Creek	34%	20.1	19%	0.119	37%	15.9	39%	0.092
Tributary 5A	0.72%	0.17	0.19%	0.054	0.26%	0.12	0.31%	0.103
Total		**97.4**				**39.8**		

Table 4-5. A comparison of total dissolved phosphorus (TDP) loading and flow-weighted concentrations for pre-ACJ (1990–1998) and post-Actiflo® (2007–2014) periods.

Note: (mt = metric tons; concentrations flow-weighted)

Site	1990-1998 (pre ACJ)				2007- 2014 (post-Actiflo®)			
	Flow (%)	TDP (mt P/yr)	TDP (% load)	TDP (mg P/L)	Flow (%)	TDP (mt P/yr)	TDP (% load)	TDP (mg P/L)
Metro:								
fully treated	21%	-	-	-	19%	2.0	23%	0.024
Bypass	0.94%	-	-	-	0.37%	0.57	6.0%	0.332
East Flume Manhole 015	0.23%	-	-	-	0.18%	0.07	0.83%	0.098
Harbor Brook	2.1%	-	-	-	2.4%	0.36	3.8%	0.032
Ley Creek	8.7%	-	-	-	8.3%	0.87	9.5%	0.023
Ninemile Creek	32%	-	-	-	33%	2.8	29%	0.018
Onondaga Creek	34%	-	-	-	37%	2.6	28%	0.015
Tributary 5A	0.72%	-	-	-	0.26%	0.05	0.51%	0.040
Total						**9.3**		

Table 4-6. A comparison of soluble reactive phosphorus (SRP) loading and flow-weighted concentrations for pre-ACJ (1990–1998) and post-Actiflo® (2007–2014) periods.

Note: (mt = metric tons; concentrations flow-weighted)

Site	1990-1998 (pre ACJ)				2007- 2014 (post-Actiflo®)			
	Flow (%)	SRP (mt P/yr)	SRP (% load)	SRP (mg P/L)	Flow (%)	SRP (mt P/yr)	SRP (% load)	SRP (mg P/L)
Metro:								
fully treated	21%	12.0	59%	0.130	19%	0.26	5.5%	0.003
Bypass	0.94%	2.5	9.7%	0.500	0.37%	0.47	9.3%	0.268
East Flume Manhole 015	0.23%	0.07	0.29%	0.092	0.18%	0.05	1.2%	0.081
Harbor Brook	2.1%	0.25	1.1%	0.024	2.4%	0.31	6.4%	0.028
Ley Creek	8.7%	1.4	6.1%	0.033	8.3%	0.50	10%	0.013
Ninemile Creek	32%	1.7	7.9%	0.011	33%	1.6	32%	0.010
Onondaga Creek	34%	3.3	16%	0.021	37%	1.7	35%	0.010
Tributary 5A	0.72%	0.03	0.17%	0.010	0.26%	0.04	0.72%	0.030
Total		**21.2**				**5.0**		

4.4 Metro Performance

The ammonia concentration of the Metro effluent decreased dramatically with the implementation of the BAF treatment upgrade in 2004 (Figure 4-8). Upgraded treatment resulted in a 98% decrease in ammonia loading to the lake from Metro (Figure 4-8). Efficient, year-round nitrification of ammonia reduced Metro's contribution to the total annual load (Metro + tributaries) from 91% to 46% (Figure 4-9). The seasonal regulatory limits for ammonia concentrations in the Metro effluent are presently 1.2 mg/L for the June 1 to October 31 interval and 2.4 mg/L for November 1 to May 31. Monthly average concentrations continued to meet these limits by a wide margin in 2014; 2013 conditions are included for reference (Figure 4-10). Seasonality in the performance of the nitrification treatment is observed, with the lowest ammonia concentrations reported in summer. This seasonality is consistent with the timing of the limits, as well as the known dependence of nitrification treatment performance on temperature.

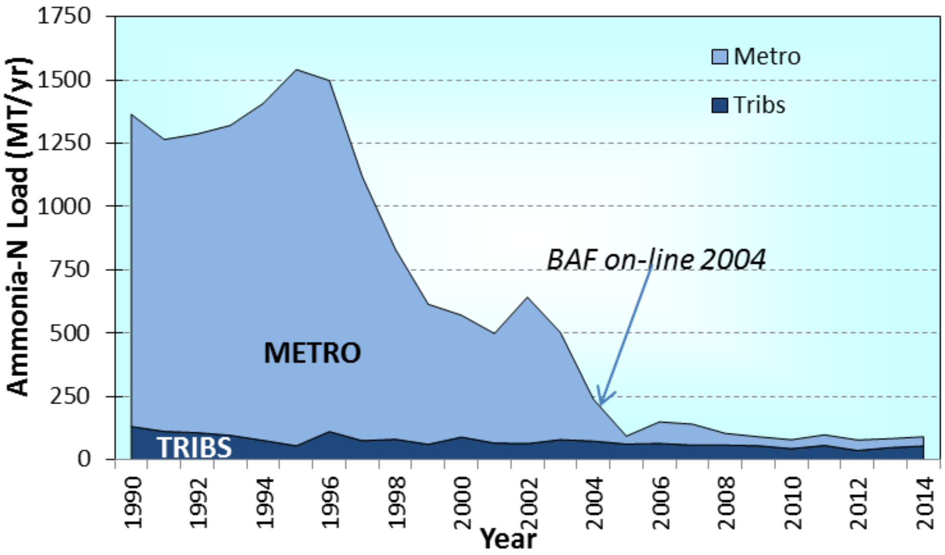


Figure 4-8. Time plot of the annual daily average Metro (outfalls 001+002) and tributary ammonia-N loading (metric tons per year) to Onondaga Lake, 1990–2014.

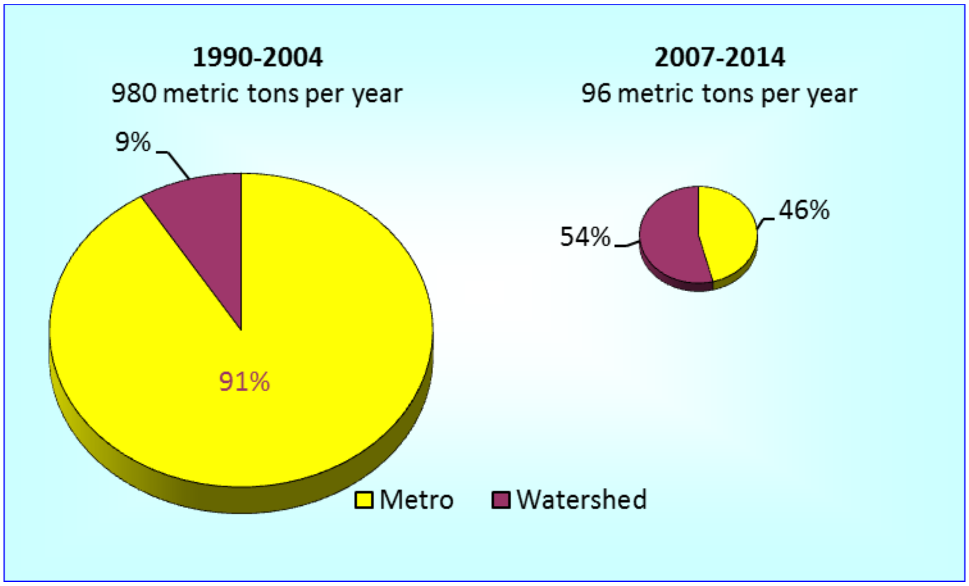


Figure 4-9. Contributions of Metro (outfalls 001+002) and the watershed to the total annual input of ammonia-N to Onondaga Lake, average for 1990–2004 compared to the average for 2007–2014.

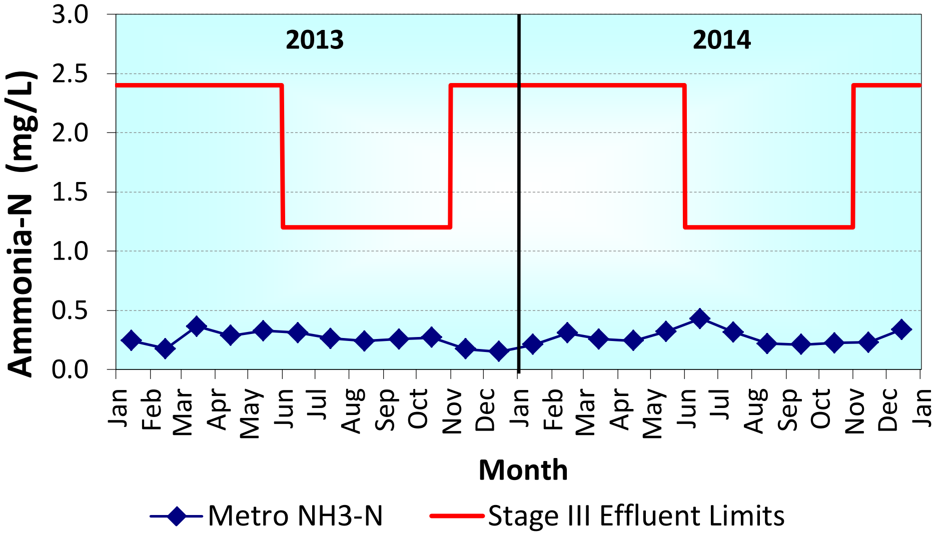


Figure 4-10. Metro effluent monthly average ammonia-N concentrations compared to permit limits for 2013 and 2014.

The total phosphorus concentration of Metro's effluent and associated loading (Figure 4-11) decreased dramatically with the implementation of the Actiflo® treatment upgrade. Moreover, Metro's contribution to the total annual phosphorus load has decreased from 61% over the 1990 to 2004 interval to 23% during 2007–2014 (Figure 4-12). Total phosphorus concentrations for the 2006–2014 interval are presented as a 12-month rolling average concentration, calculated monthly, consistent with the format of the regulatory limit (Figure 4-13). Accordingly, each monthly value on the plot corresponds to the average total phosphorus concentration of that month combined with the 11 preceding months. Initially, the limit was 0.12 mg/L (or 120 µg/L), starting in the spring of 2007. As part of the November 2009 Fourth Stipulation Amending the ACJ, the interim Stage II total phosphorus effluent limit became 0.10 mg/L (Figure 4-13). These limits have been successfully met with the Actiflo® treatment upgrade. The rolling average total phosphorus concentration in the Metro effluent has remained below 0.10 mg/L since mid-2008 and below 0.07 mg/L since May 2013 (Figure 4-13). During 2014 the average total phosphorus concentration in the Metro effluent was 0.062 mg/L.

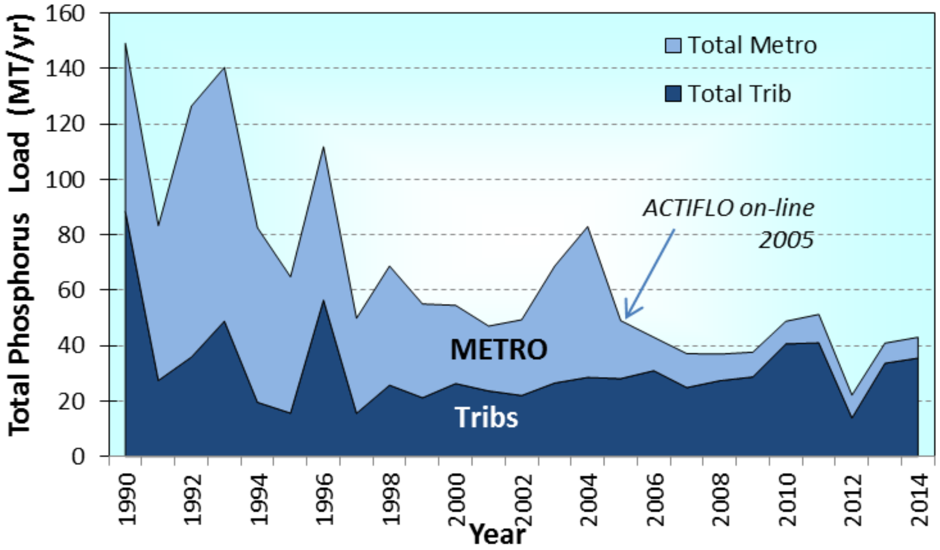


Figure 4-11. Time plot of the annual daily average Metro (outfalls 001+002) total phosphorus (TP) loading (metric tons per year) to Onondaga Lake, 1990–2014.

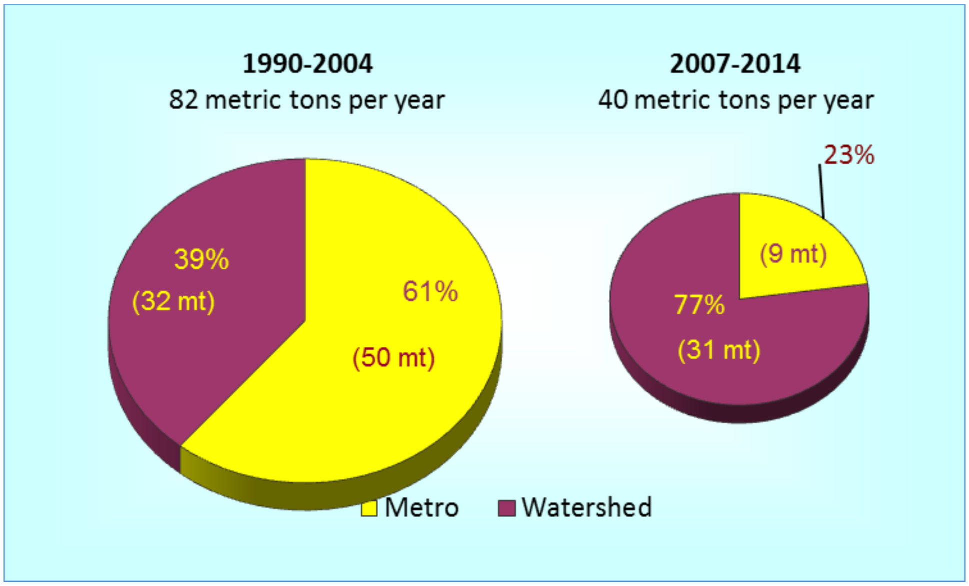


Figure 4-12. Contributions of Metro (outfalls 001+002) and the watershed to the annual input of total phosphorus to Onondaga Lake, average for 1990–2004 compared to the average of 2007–2014.

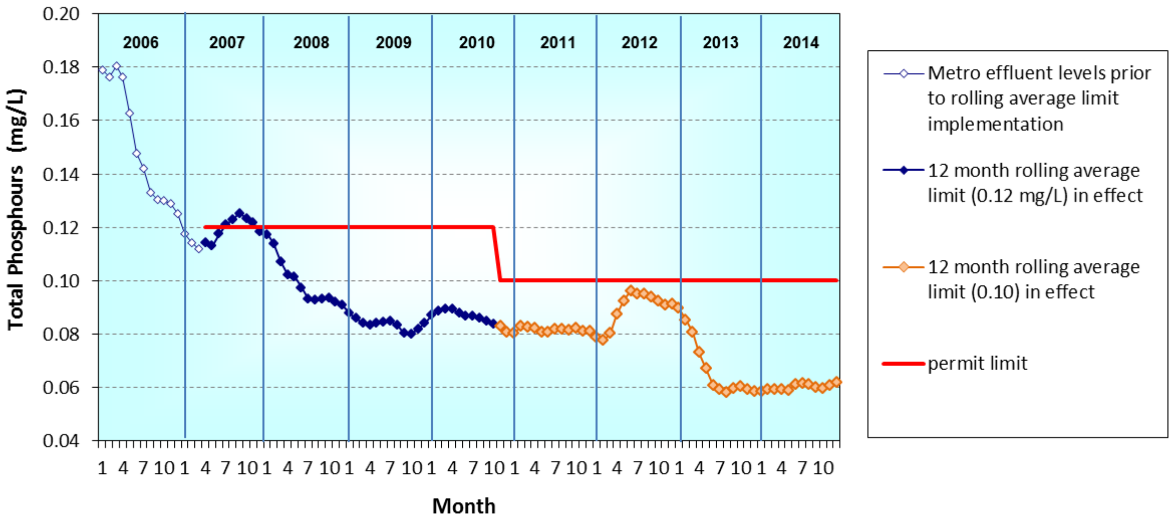


Figure 4-13. Metro effluent total phosphorus concentrations compared to permit limits for the 2006–2014 interval.

Note: Concentrations are monthly rolling average values for 12-month intervals. Interim limits were in place through June 30, 2012. The final limit of 0.10 mg/L as a 12-month rolling average has been in place since June 30, 2012.

The major reductions in ammonia and total phosphorus loading from treatment upgrades at Metro (BAF and Actiflo®, respectively) were identified and graphically supported (Figure 4-8 for ammonia, Figure 4-11 for total phosphorus). The BAF upgrade resulted in a 98% decrease in ammonia loading to the lake from Metro. Implementation of the Actiflo® upgrade achieved an 85% decrease in total phosphorus loading from Metro compared to the early 1990s. Loading of total nitrogen from Metro has not changed substantially from the BAF upgrade, but a highly desirable shift in the contribution of the various forms has been achieved. Implementation of the BAF treatment reduced the Metro loading of ammonia and nitrite, forms of nitrogen that raise water quality concerns, but increased the input of nitrate, which is not a water quality concern for Onondaga Lake. Moreover, the increased nitrate loading from Metro is having beneficial effects on the lake by diminishing the cycling of phosphorus and mercury (Matthews et al. 2013).

Metro performance relative to the requirements of the most recent modification to the SPDES permit, dated June 4, 2014, is provided in Appendix C-4. There were no violations of permit limits reported for Outfall 001 in 2014 for the following parameters: flow, $CBOD_5$, suspended solids, fecal coliform bacteria, pH, settleable solids, ammonia-N, total phosphorus, and total mercury. The SPDES permit limits for total cyanide and total phenol were exceeded three times and four times during 2014, respectively. The Metro bypass exceeded permit limits for settleable solids, chlorine residual, and fecal coliform on single occasions in 2014.

A schematic of the Metro treatment process, including the various outfalls, is available on page 32 of the Metro SPDES permit (Appendix C-7). Flow exits Metro through four outfalls, depending on the level of wastewater treatment:

- headworks bypass – Outfall 01B
- secondary bypass – Outfall 002
- tertiary bypass – Outfall 01A
- fully treated – Outfall 001

Metro provided full treatment to an average flow of 66.8 million gallons per day (mgd) in 2014, which was discharged to the lake through Outfall 001. On an annual basis, discharge from Outfall 001 summed to more than 24.3 billion gallons. During particularly high runoff intervals, inflows to Metro can exceed the capacity of the facility to provide full treatment of wastewater. Portions of this inflow receive partial treatment, usually primary treatment and disinfection, and are discharged via Outfall 002 (secondary bypass; Appendix C-1). There were 86 secondary bypasses in 2014, which had a combined duration of 448 hours and a total volume of 442 million gallons. Less frequently, the inflow receives secondary treatment and disinfection prior to discharge via Outfall 01A (tertiary bypass; Appendix C-2). In 2014 there were 17 tertiary bypasses that contributed a total of 19 million gallons over a period of 60 hours. These inputs are of concern because concentrations of various constituents are higher compared to the fully treated effluent, as described above. Rarely, under particularly extreme runoff conditions, a small portion of the inflow to the facility receives no treatment and is discharged via Outfall 01B (plant headworks are bypassed; Appendix C-3). There were 15 headworks bypasses in 2014, which had a combined duration of 40 hours and a total volume of 33 million gallons. All of the headworks bypasses during 2014 were associated with reduced plant capacity due to the Grit Improvement Project. The extent to which bypasses occur depends critically on runoff, and therefore precipitation, both of which are subject to substantial variability. Metro's annual discharge volumes for 2010–2014 are summarized in Table 4-7.

Table 4-7. Annual Metro discharge volumes for the fully treated effluent and bypasses, 2010–2014.

Year	Fully Treated Outfall 001 (million gallons)	Tertiary Bypass Outfall 01A (million gallons)	Secondary Bypass Outfall 002 (million gallons)	Headworks Bypass Outfall 01B (million gallons)
2010	22,000	22	374	43
2011	24,300	41	751	5
2012	20,200	12	214	0
2013	24,300	26	446	71
2014	24,400	19	442	33

Saline groundwater from dewatering of the Clinton and Lower Harbor Brook Storage facilities during construction was conveyed to Metro from June 2012 to May 2013, resulting in elevated ionic content in the Metro effluent. Specific conductance and other measures of the ionic content (e.g., chloride, TDS) of the Metro effluent decreased abruptly when dewatering ceased in May of 2013. Whole effluent toxicity testing (WET) of the Metro effluent in the third and fourth quarters of 2012 and in the first quarter of 2013 indicated the effluent was both acutely and chronically toxic. Toxicity was likely the result of temporarily elevated salinity levels from dewatering activities. The specific conductance values measured during this period were in the range that has been associated with toxic effects to aquatic biota (Corsi et al. 2010, Kimmel and Argent 2009). A year of monthly WET testing of the Metro effluent was initiated in September 2013, as requested by NYSDEC. Monthly WET testing conducted on the most sensitive species (*Ceriodaphnia dubia*) during the September 2013–August 2014 interval indicated a reduced level of toxicity in the Metro effluent. Acute toxicity was indicated in the November 2013 sample and chronic toxicity was reported in the February 2014 sample. Based on these results, the frequency of WET testing of the Metro effluent has been reduced to quarterly.

4.5 Prohibited Combined and Sanitary Sewer Overflows

The occurrence and volumes of prohibited combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) within the Onondaga County service area are tracked by OCDWEP each year. As per the Metro SPDES permit CSO best management practices (BMP) requirements, dry weather overflows from the combined sewer system are prohibited. In accordance with 6NYCRR Part 750-2.8(b) and 40CFR 122.41, bypass of the collection and treatment system without treatment (i.e., SSOs) are prohibited except as noted in the Metro SPDES Permit. Detailed documentation of the prohibited CSO and SSO events that occurred during 2014 is presented in Appendix C-5 and Appendix C-6, respectively. Annual summaries of prohibited CSOs and SSOs within the Onondaga Lake watershed for the 2010–2014 period are presented in Table 4-8. The increase in SSO volume during 2014 was largely attributable to a single rain on snow event in late March that caused a failure at the West Side Pumping Station located on the western shore of Onondaga Lake in the Town of Geddes.

Table 4-8. Number and volume of prohibited combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) within the Onondaga Lake watershed during 2010–2014.

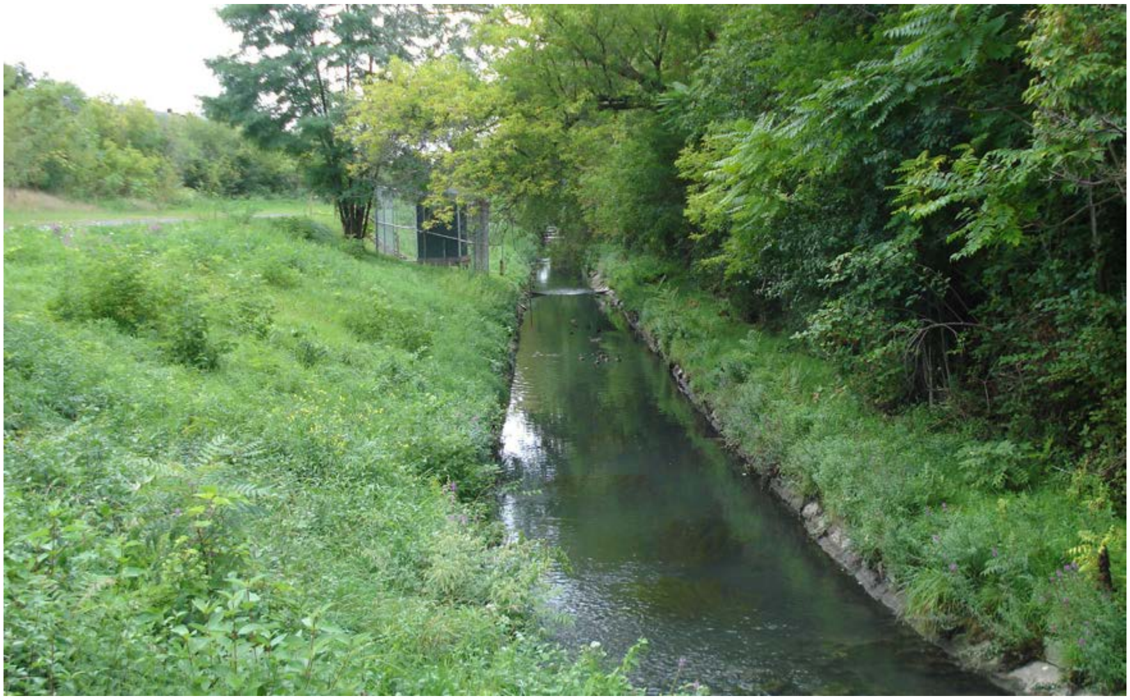
Year	CSO		SSO	
	Number	Volume (gallons)	Number	Volume (gallons)
2010	7	98,000	37	23,614,535
2011	4	2,700	66	12,390,818
2012	7	20,450	40	69,940
2013	5	800	35	31,105
2014	1	1,000	31	1,694,150

4.6 Compliance with Ambient Water Quality Standards

Several segments of Onondaga Lake's tributary streams are included on the 2014 NYSDEC compendium of impaired waters. NYSDEC places waterbodies on this list when there is evidence that water quality conditions do not meet applicable standards, and/or the water bodies do not support their designated use. Results of Onondaga County's AMP are among the primary data sets used to evaluate compliance with standards and use attainment. The 2014 tributary data indicate that the major tributaries were generally in compliance with ambient water quality standards (AWQS) for most parameters addressed (Table 4-9). The primary exceptions in meeting AWQS in the tributaries were total dissolved solids (TDS) and fecal coliform bacteria (FC). The AWQS for TDS (500 mg/L) was contravened at all of the tributary monitoring sites, and often by a wide margin. Contravention of this standard is primarily associated with the natural hydrogeology of the watershed and not with anthropogenic effects. Achieving compliance with this water quality standard is not a goal of the remediation program.

Compliance with the AWQS for fecal coliform bacteria is specified by NYSDEC as the geometric mean of a minimum of five observations per month being less than or equal to 200 colony forming units (cfu) per 100 milliliters (mL). In April 2010 Onondaga County increased the frequency of bacterial sampling at each tributary sampling location to support monthly assessments of compliance with this AWQS. The abundance of fecal coliform bacteria in the tributaries during wet weather is affected by stormwater runoff and functioning of the combined sewer system. CSO remedial measures and improved stormwater management measures are underway. Among the objectives of the AMP is the tracking of changes in the input of bacteria to Onondaga Lake during wet weather. WEP also tracks bacterial abundance during non-storm periods; these observations provide a means of identifying potential illicit connections of sanitary waste to the stormwater collection system, or portions of the sewerage infrastructure in need of repair. Compliance with the AWQS for fecal coliform bacteria was achieved for less than 50% of the monthly means at Bloody Brook (33%), Harbor Brook at Hiawatha (30%), Ley Creek (0%), Ninemile Creek (44%), Onondaga Creek at Kirkpatrick (22%), and Onondaga Creek at Dorwin (44%). Fecal coliform conditions were somewhat better at Harbor Brook at Velasko Rd., where 78% of the monthly means were in compliance with the AWQS.

pH values exceeded the upper limit of the acceptable range (6.5–8.5) on single occasions at Sawmill Creek, Onondaga Creek at Kirkpatrick, and Harbor Brook at Hiawatha. The other exceptions to 100% compliance pertained to dissolved mercury, which was monitored on a quarterly basis. Compliance with the AWQS for dissolved mercury was documented for three of the four samples collected at Harbor Brook at Hiawatha, Harbor Brook at Velasko, Ley Creek, and Sawmill Creek and for one of the four samples collected at Tributary 5A. A single free cyanide sample was collected from Ley Creek at Park St. on 11/4/14. The free cyanide concentration was 0.003 mg/L, less than the AWQS of 0.0052 mg/L.



Harbor Brook

Table 4-9. Summary of tributary and outflow compliance (percent of observations in compliance) with ambient water quality standards (AWQS), 2014.

Note: occurrences of less than 100% compliance are highlighted in red text; dissolved oxygen, ammonia, nitrite, and fecal coliform are specified in the ACJ; the number of observations is shown in parentheses; NS is not sampled.

	Field Data		**Solids**	**Nitrogen**		**Metals[1]**				**Bacteria**
Site	**Dissolved Oxygen (4 mg/L)**	**pH**	**TDS**	**Ammonia**	**Nitrite**	**Dissolved Cadmium**	**Dissolved Copper**	**Dissolved Lead**	**Dissolved[2] Mercury**	**Fecal[3] Coliform**
Bloody Brook at Onon. L. Parkway	100% (58)	100% (59)	**5% (21)**	100% (21)	100% (21)	NS (0)	NS (0)	NS (0)	100% (4)	**33% (59)**
Harbor Brook at Hiawatha Bvd.	100% (63)	**98% (64)**	**0% (28)**	100% (27)	100% (28)	NS (0)	NS (0)	NS (0)	**75% (4)**	**30% (63)**
Harbor Brook at Bellevue Ave.	100% (52)	100% (52)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	**86% (50)**
Harbor Brook at Velasko Rd.	100% (64)	100% (64)	**0% (27)**	100% (27)	100% (27)	NS (0)	NS (0)	NS (0)	**75% (4)**	**78% (62)**
Ley Creek at Park St.[4]	100% (52)	100% (53)	**4% (24)**	100% (23)	100% (24)	NS (0)	NS (0)	NS (0)	**75% (4)**	**0% (53)**
Ninemile Creek at Lakeland	100% (62)	100% (62)	**0% (26)**	100% (26)	100% (26)	NS (0)	NS (0)	NS (0)	100% (4)	**44% (61)**
Onondaga Creek at Kirkpatrick St.	100% (63)	**98% (64)**	**4% (27)**	100% (27)	100% (27)	100% (4)	100% (4)	100% (4)	100% (4)	**22% (62)**
Onondaga Creek at Dorwin Ave.	100% (63)	100% (63)	**30% (27)**	100% (27)	100% (27)	100% (4)	100% (4)	100% (4)	100% (4)	**44% (62)**
Sawmill Creek at Onon. L. Rec. Area	100% (57)	**98% (58)**	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	**75% (4)**	**67% (57)**
Trib. 5A at State Fair Blvd.	100% (53)	100% (53)	**0% (22)**	100% (21)	100% (22)	100% (3)	100% (4)	100% (4)	**25% (4)**	**88% (52)**
Onondaga Lake Outlet (2ft)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)	NS (0)
Onondaga Lake Outlet (12ft)	100% (24)	100% (25)	**0% (26)**	100% (25)	100% (26)	NS (0)	NS (0)	NS (0)	100% (4)	NS (0)

[1] AWQS for metals apply to the total dissolved form

[2] Dissolved mercury standard applies to health fish consumption standard (H(FC))

[3] Fecal coliform compliance is assessed monthly, based on the geometric mean of at least 5 samples

Time series of fecal coliform concentrations in Onondaga Creek, Harbor Brook, and Ley Creek during 2014 are presented for both wet and dry weather conditions (Figure 4-14). Wet weather samples are those collected following at least 0.1 inches of rain in the preceding 48 hours; all other samples are considered to be representative of dry weather conditions. Both upstream and downstream values are shown for Onondaga Creek (Dorwin Ave., Kirkpatrick St.) and Harbor Brook (Velasko Rd., Hiawatha Blvd.). Only downstream samples are available for Ley Creek (Park St.). Fecal coliform levels were generally higher at downstream sampling sites and during wet weather. However, fecal coliform concentrations at the upstream sampling locations of Onondaga Creek (Dorwin Ave., Figure 4-14a) and Harbor Brook (Velasko Rd., Figure 4-14c) routinely exceeded the AWQS of 200 counts/100 mL during wet weather and during dry weather in the summer months. A distinct seasonality in fecal coliform concentrations was apparent at all sampling locations, with higher values observed during the warmer summer months of June–September. This temporal pattern, which suggests that fecal coliform abundance is strongly dependent on ambient temperatures, was also observed in an analysis of historic data (see Section 4.3.5 of the 2012 AMP Report). This seasonality was least apparent at the Kirkpatrick St. site on Onondaga Creek and at Ley Creek (Figure 4-14b).

Fecal coliform time series data for Onondaga Creek (Figure 4-15), Harbor Brook (Figure 4-16), and Ley Creek (Figure 4-17) are presented for the 1998–2014 interval. The frequency of bacterial sampling increased to five samples per month starting in April 2010 to support assessments of compliance with the AWQS for fecal coliform bacteria. These figures include a reference line at 200 cfu/100 mL, which is the NYS AWQS for fecal coliform bacteria. Because this standard strictly applies to a monthly geometric mean based on a minimum of five samples, it is only included for numerical perspective. Although the upstream concentrations of fecal coliform are generally lower than the downstream concentrations, the upstream concentrations are frequently above 200 cfu/100 mL, indicating compliance likely is affected by issues upstream of urban sources. The long-term record continues to show higher fecal coliform concentrations during the summer months.

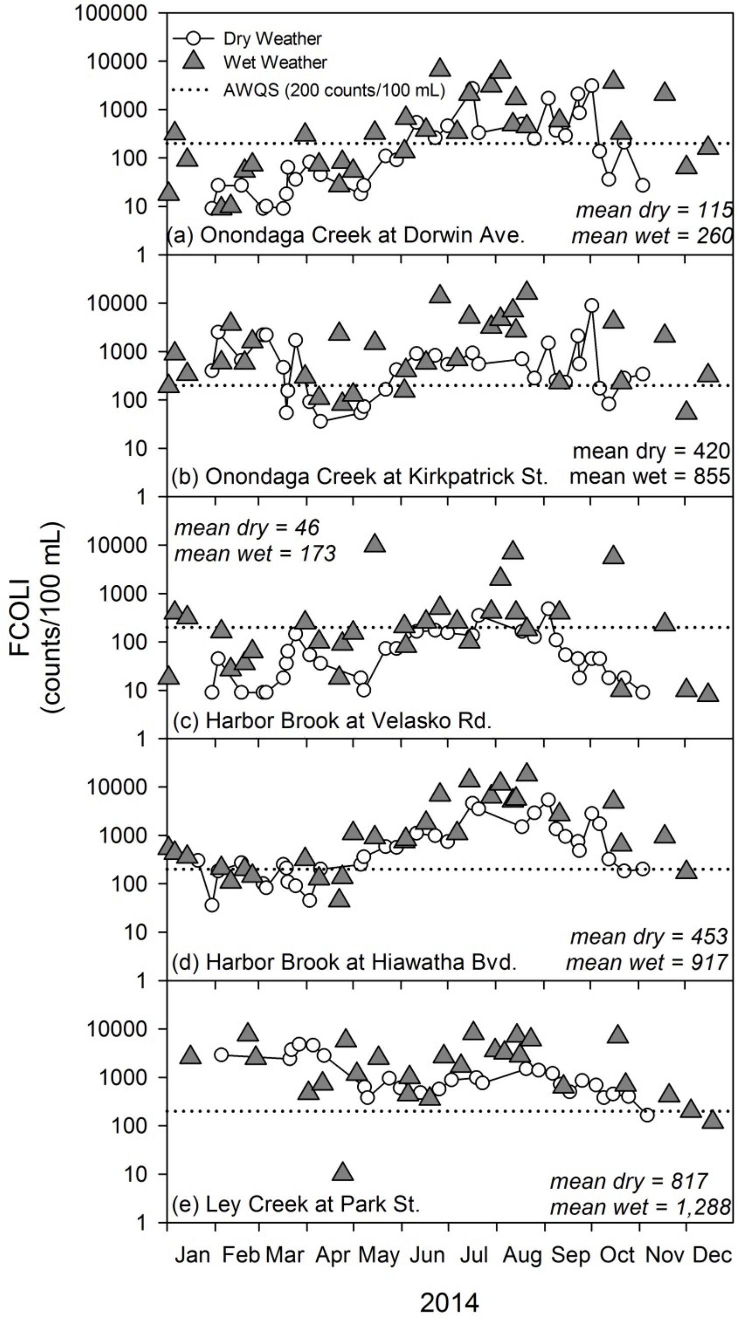


Figure 4-14. Time series of fecal coliform concentrations during wet weather and dry weather during 2014: (a) Onondaga Creek at Dorwin Ave., (b) Onondaga Creek at Kirkpatrick St., (c) Harbor Brook at Velasko Rd., (d) Harbor Brook at Hiawatha Blvd., and (e) Ley Creek at Park St.

Note: value of the AWQS for fecal coliform shown for reference (200 counts/100 mL).

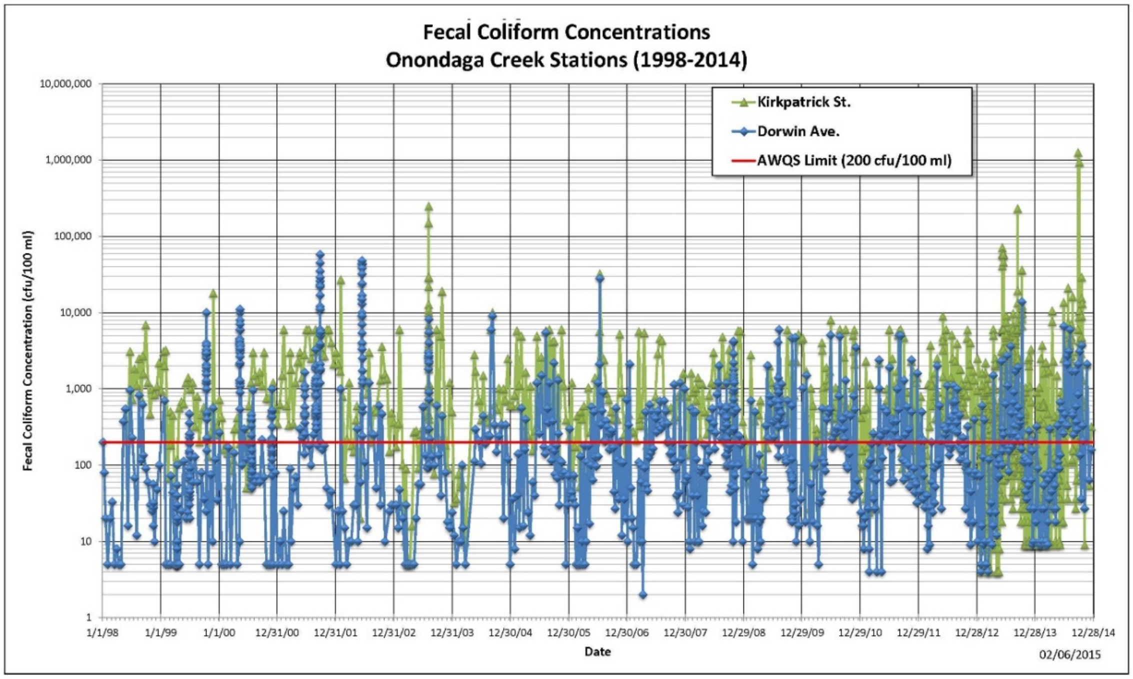


Figure 4-15. Fecal coliform concentrations measured at Onondaga Creek stations, 1998–2014.

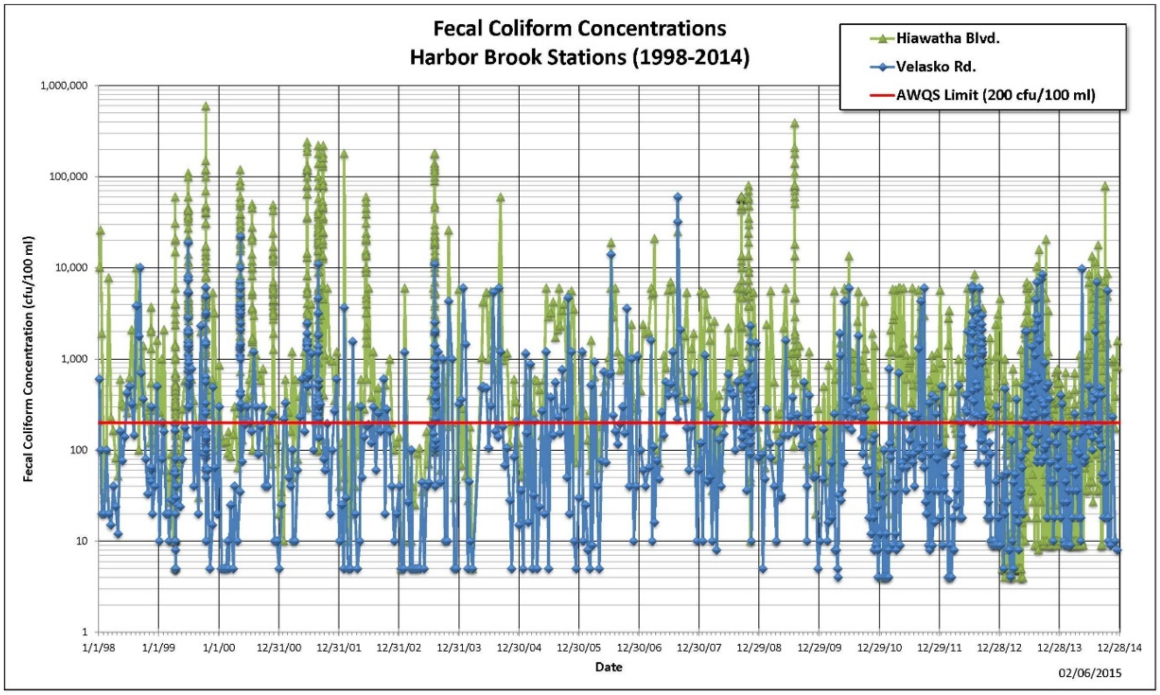


Figure 4-16. Fecal coliform concentrations measured at Harbor Brook stations, 1998–2014.

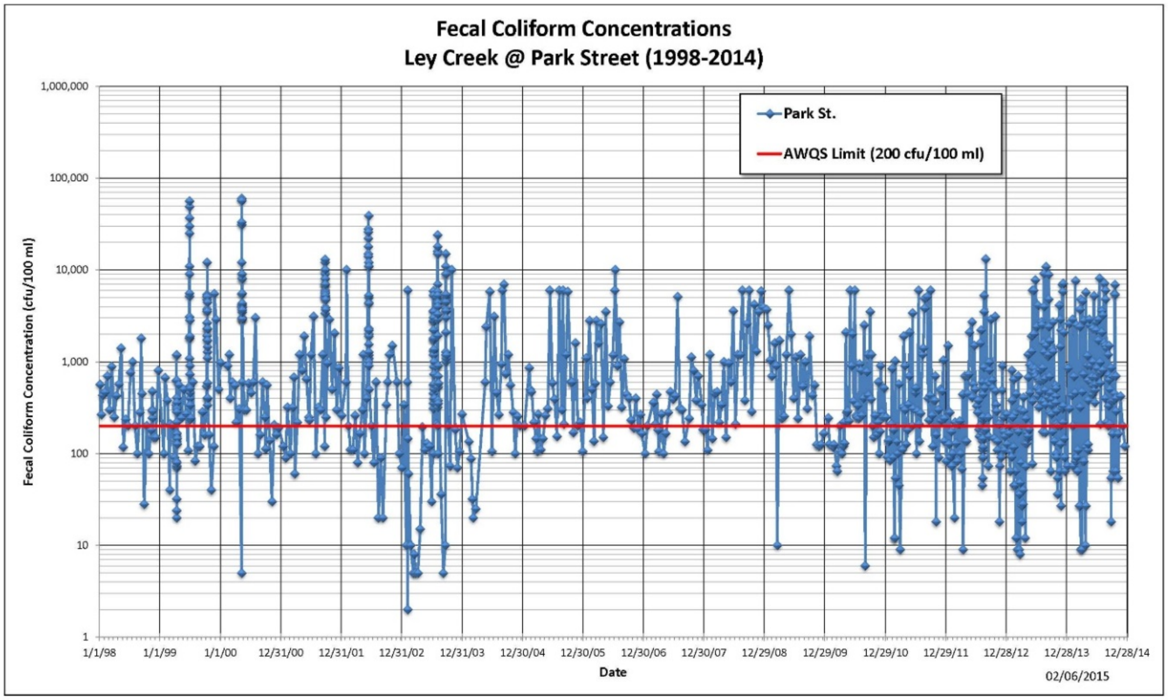


Figure 4-17. Fecal coliform concentrations measured at Ley Creek, 1998–2014.

4.7 Long-Term Trends

Loading trends for Metro and the tributaries over the 1991–2014 interval are presented graphically for selected constituents (Figure 4-18). Annual loads for additional constituents are presented in tabular format in Appendix D-3. Long-term decreases in loading of total phosphorus and total dissolved phosphorus have been driven mostly by reductions in the Metro contribution. Year-to-year variations in phosphorus loading from the watershed are regulated to a large extent by differences in the timing and magnitude of runoff. For example, the particularly low runoff conditions of 2012 are reflected in major reductions in constituent loading from the tributaries. Long-term decreases in ammonia loading and increases in nitrate loading are associated with implementation of efficient, year-round nitrification treatment at Metro. Variations in ammonia and nitrate loading from the tributaries have been modest in comparison. Noteworthy reductions in loading of fecal coliform bacteria have occurred since the 1990s, led by decreasing inputs from the Metro bypass.

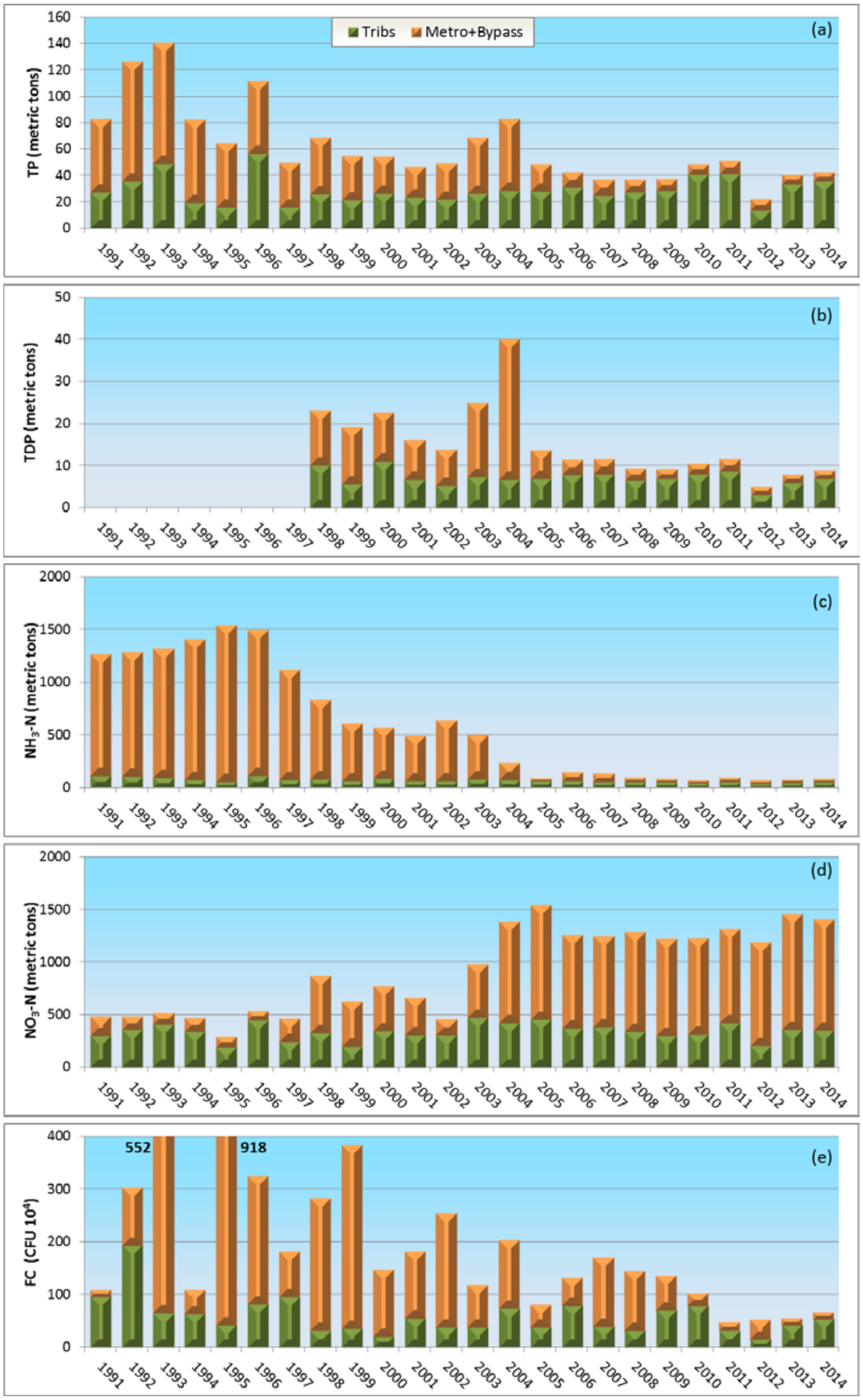


Figure 4-18. Annual loading of selected constituents to Onondaga Lake from Metro and watershed sources, 1991–2014: (a) total phosphorus (TP), (b) total dissolved phosphorus (TDP), (c) ammonia-N (NH_3-N), (d) nitrate (NO_3-N), and (e) fecal coliform (FC) bacteria

Seasonal Kendall tests were conducted for the 10-year period 2005–2014 to identify statistically significant (p<0.1) trends in tributary concentrations (Table 4-10). Statistically significant decreases were evident for various constituents related to the Metro treatment upgrades, including decreases in phosphorus, nitrite, organic carbon, BOD_5, and fecal coliform bacteria. However, this 10-year analysis doesn't capture the effects of major upgrades to ammonia and phosphorus treatment that occurred in 2004 and 2005, respectively. Increased concentrations in the treated Metro effluent were indicated for total dissolved solids, calcium, and chloride. Fecal coliform bacteria decreased in the treated Metro effluent, in the bypass, and at the downstream site on Onondaga Creek (Kirkpatrick St.). Significant decreases in concentrations of ammonia, nitrate, and nitrite are indicated since 2005 for Ley Creek (Table 4-10). In contrast, concentrations of organic nitrogen and total Kjeldahl nitrogen have increased in Onondaga Creek, Ninemile Creek, and at the upstream sampling location on Harbor Brook. A cause for these changes in concentrations of nitrogen species is not apparent at this time. Total phosphorus concentrations increased at the upstream site on Onondaga Creek (Dorwin Ave.) and at Ninemile Creek. Both total phosphorus and soluble reactive phosphorus concentrations decreased at the downstream site on Harbor Brook (Hiawatha Blvd.). Increased total suspended solids concentrations were observed for the upstream site on Onondaga Creek. Increased suspended solids levels in Onondaga Creek have been linked to the resurgence of mud boil activity in the Tully Valley, which likely also contributed to increased total phosphorus concentrations.

Tributary loading trends were analyzed and tested using a linear regression analysis of annual load in metric tons (mt) versus time (Table 4-11). Annual loading trend slopes with p-values less than 0.1 were considered statistically significant. Treatment upgrades at Metro have resulted in decreasing loading trends for most constituents. However, the magnitude of the reductions has decreased as the number of pre-upgrade years included in the analysis has diminished. For example, the absence of a decreasing trend for ammonia at Metro is caused by the analysis beginning in 2005, which was after the ammonia treatment upgrades. Reductions in ammonia loading were indicated for Harbor Brook at Velasko, Ley Creek, and Ninemile Creek. Harbor Brook has experienced significant loading reductions for total suspended solids and measured forms of nitrogen, phosphorus, and carbon. Loading of the ionic constituents, calcium, sodium, and chloride has decreased in Ninemile Creek over the 2005–2014 interval.

Table 4-10. Ten-year (2005–2014) trends in tributary concentrations, from application of two-tailed Seasonal Kendall tests adjusted for serial correlation.

Variable		Metro		Onondaga Creek		Harbor Brook		Ley Creek	Ninemile Creek
		Treated Effluent	Bypass	Dorwin	Kirkpatrick	Velasko	Hiawatha	Park	Route 48
Nitrogen	Ammonia (NH_3-N)	○	○	○	○	○	○	-2.6%	○
	Nitrite (NO_2-N)	-6.4%	○	○	○	○	○	-2.1%○	○
	Nitrate (NO_3-N)	○	○	○	○	○	○	-4.4%	○
	Organic Nitrogen	○	○	8.3%	7.1%	5.3%	○	○	7.4%
	Total Kjeldahl Nitrogen (TKN)	○	○	7.7%	5.7%	3.1%	○	○	2.6%
Phosphorus	Total Phosphorus (TP)	-9.0%	○	6.4%	○	○	-7.0%	○	2.4%
	Soluble Reactive Phosphorus (SRP)	-10.9%	○	○	5.4%	○	-10.6%	○	○
Solids	Total Suspended Solids (TSS)	○	○	7.8%	○	○	○	○	○
	Total Dissolved Solids (TDS)	2.7%	○	○	○	○	1.0%	○	-1.8%
	Volatile Suspended Solids (VSS)	○	○	○	○	○	○	○	○
Carbon	Total Inorganic Carbon (TIC)	-2.1%	○	○	-0.8%	-1.1%	○	○	-1.1%
	Total Organic Carbon (TOC)	-2.5%	○	○	○	○	-2.0%	○	○
	Total Organic Carbon, filtered (TOC_F)	-2.6%	○	○	○	○	-1.4%	○	1.3%
Other	Alkalinity	○	○	○	○	○	0.6%	○	○
	BOD_5*	-3.0%	○	○	○	○	○	○	○
	Calcium (Ca)	2%	○	○	○	○	1.0%	○	○
	Chloride (Cl)	4.2%	○	○	○	○	1.6%	○	-2.8%
	Specific Conductance	○	○	○	○	○	1.3%	○	○
	Dissolved Oxygen (DO)	○	○	○	○	○	0.6%	1.1%	○

Table 4-10. Ten-year (2005–2014) trends in tributary concentrations, from application of two-tailed Seasonal Kendall tests adjusted for serial correlation.

Variable	**Metro**		**Onondaga Creek**		**Harbor Brook**		**Ley Creek**	**Ninemile Creek**
	Treated Effluent	**Bypass**	**Dorwin**	**Kirkpatrick**	**Velasko**	**Hiawatha**	**Park**	**Route 48**
Fecal Coliform Bacteria	**-6.3%**	**-21.5%**	○	**-7.4%**	○	○	○	○
pH	**0.6%**○	○	○	○	○	○	○	○
Silica (SiO_2) dissolved	○	○	**1.4%**	**1.2%**	**0.5%**	**1.3%**	**1.5%**	○
Sulfate (SO_4)	○	○	○	○	○	**0.8%**	○	○
Temperature (°C)	○	○	○	○	**-1.9%**	○	○	○

Notes:
Significance level, two-tailed, seasonal Kendall test accounting for serial correlation ($p < 0.1$).
Blue value (%) indicates decreasing trend, percent per year
Red value (%) indicates increasing trend, percent per year
○ indicates no trend
- dash indicates parameter is not measured at this location.

Table 4-11. Ten-year (2005–2014) trends in tributary loading, from linear regression of annual load versus time.

Variable		Metro		Onondaga Creek		Harbor Brook		Ley Creek	Ninemile Creek
		Treated Effluent	Bypass	Dorwin	Kirkpatrick	Velasko	Hiawatha	Park	Route 48
Nitrogen	Ammonia (NH_3-N)	○	○	○	○	-8.7%	○	-4.1%	-3.5%
	Nitrite (NO_2-N)	-12.1%	○	○	○	○	○	○	○
	Nitrate (NO_3-N)	○	○	○	○	-4.8%	-4.7%	-6.2%	○
	Total Kjeldahl Nitrogen (TKN)	○	○	○	○	○	○	○	○
Phosphorus	Total Phosphorus (TP)	-12.3%	○	○	○	○	-7.7%	○	○
	Soluble Reactive Phosphorus (SRP)	-27.6%	○	○	○	○	-10.8%	○	○
Solids	Total Suspended Solids (TSS)	-2.5%	○	○	○	○	-11.1%	○	○
Carbon	Total Inorganic Carbon (TIC)	-3.7%	○	○	○	-4.2%	○	○	-3.1%
	Total Organic Carbon (TOC)	-3.3%	○	○	○	-5.1%	-6.1%	○	○
	Total Organic Carbon, filtered (TOC_F)	-2.9%	○	○	○	○	-5.1%	○	○
Other	Alkalinity	○	○	○	○	○	○	○	○
	BOD_5*	-7.1%	○	○	○	○	○	○	○
	Calcium (Ca)	○	○	○	○	-3.3%	○	○	-2.8%
	Chloride (Cl)	○	○	○	-4.7%	○	○	○	-3.6%
	Fecal Coliform Bacteria	-18.7%	○	○	○	○	○	○	○
	Sodium (Na)	○	○	○	-5.3%	○	○	○	-3.1%
	Silica (SiO_2)	○	○	○	○	○	○	○	○

Notes:
Significance level, least squares linear regression of annual loads ($p < 0.1$).
Blue value (%) indicates decreasing trend, percent per year
Red value (%) indicates increasing trend, percent per year
○ indicates no trend
- dash indicates parameter is not measured at this location.
*BOD_5 (Biochemical Oxygen Demand (5-day)) trend analysis results are accurate only for Metro & bypass because of the preponderance of data less than the MRL (PQL) in other inputs.

4.8 Post Construction Compliance Monitoring Program (PCCM)

4.8.1 Overview of the PCCM Program

The ACJ, as amended by the Fourth Stipulation in 2009, required the County to capture 95 percent of the annual CSO volume and to submit a plan with a schedule for implementation for proposed modifications to the tributary component of the County's established AMP. These modifications include additional wet weather monitoring within the CSO-affected stream reaches to evaluate compliance with the AWQS for bacteria and floatables following improvements to the infrastructure for wastewater and stormwater collection. The monitoring program, which includes water quantity and quality monitoring of CSOs and receiving streams (Onondaga Creek and Harbor Brook), is referred to as the post construction compliance monitoring program (PCCM).

A limited PCCM program has been conducted since 2011 to assess the effectiveness of the gray and green infrastructure projects designed to mitigate the impacts of CSOs. The primary objective of the PCCM, in the context of the recently constructed gray project milestones, is to demonstrate that the abated CSOs which include the captured (up to the 1-year, 2- hour storm) and separated CSOs are not causing or contributing to violations of water quality standards in the receiving water. In addition, the PCCM program supports assessment of whether Onondaga Creek and Harbor Brook are meeting the NYS AWQS's and their designated uses. The PCCM includes a monitoring plan through 2018, for assessing compliance with AWQS associated with specific individual CSO controls. The 2014 AMP annual work plan was implemented September 17, 2014, following conditional NYSDEC approval of the five-year AMP work plan on September 16, 2014. No PCCM sampling events, with the exception of the SPDES permit required PCCM quarterly sampling for the CSO 022 and 045 sewer separation projects, were conducted in 2014 during the non-disinfection period from October 16, 2014, through March 30, 2015.

4.8.2 Sewer Separation Projects

Consistent with the requirements of SPDES Permit Number NY 002 7081, the PCCM for two of the sewer separation projects, initiated in 2013 continued in 2014. A goal of the PCCM is to verify that CSO outfalls 022 and 045 are not causing or contributing to violations of water quality standards in the receiving waters. This monitoring program was specifically designed to verify the separation of sanitary and storm flow performed under two sewer separation projects completed in 2012 to improve the water quality of Onondaga Creek and to reduce system-wide overflows from the combined sewer outfalls, as required by the ACJ. These outfalls included CSO 022, located in the vicinity of Wallace and West Genesee streets, and CSO 045 located in the vicinity of West Castle and Hudson streets. During significant wet weather events, CSOs 022 and 045 would overflow to Onondaga Creek. The sewers within the regulator manholes were sealed in 2012 in order to eliminate sanitary connections to the outfalls for CSO 022 and 045, and these outfalls became the storm sewer outfalls to Onondaga Creek. The goal of post construction monitoring is to ensure that there are no remaining sanitary connections to the storm system or storm connections to the sanitary system. As required by the Metro SPDES permit, these outfalls will be monitored for a period of no less than three years, with a minimum of four samples per site per year during storm events to confirm the effectiveness of the sewer separation. Dry weather observations (no less than four per year) were recorded and documented as well. During the 2014 weekly inspection program, observations of the regulators and these CSO outfalls indicated no dry weather discharges. In 2014, the NYSDEC requested that sites upstream of each of the CSO outfalls be added, and subsequently the following upstream bridge sampling sites were added as follows:

- Onondaga Creek at Rich Street bridge (upstream of former CSO 045 outfall); and
- Onondaga Creek at Water Street bridge (upstream of former CSO 022 outfall)

Table 4-12 and Table 4-13 summarize the results of the 2013 and 2014 quarterly sampling events conducted at CSO Outfalls 022 and 045 and the receiving water sampling sites. The 2014 sampling results for CSO 022 and 045 are rather ambiguous, likely as a result of extreme spatial and temporal variability in water quality metrics during wet weather events and the myriad sources of bacteria and turbidity. Fecal coliform and TSS/turbidity levels were higher at CSO Outfall 022 than downstream during the February, July, and November sampling events. This pattern was reversed during the April event. Fecal coliform and TSS/turbidity levels were also higher at CSO Outfall 022 compared to the upstream site during the July and November events. The particularly high fecal coliform concentration measured at CSO Outfall 022 during the July event (98,200 CFU/100mL), was accompanied by low dissolved oxygen (3.43 mg/L). However, both fecal coliform and TSS/turbidity remained largely unchanged from the upstream to downstream sites during the July and November events. These results suggest that during the July and November events intervening inputs had negligible impacts on these metrics of water quality.

Table 4-12. Summary of post-sewer separation water quality data for CSO 022.

Event #	Date	Total Rainfall[1], Inches	Location (CSO Outfall)	Location (In-Stream)	Fecal Coliform, CFU/100mL	Floatables (Absent/Present w/Description)	TSS, mg/L	Turbidity, NTU	DO, mg/L
1	04/12/13	0.87"	Upstream of CSO Outfall 022	-	-	-	-	-	-
			CSO Outfall 022		990	NC[2]	NC	NC	NC
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	5000	NC	NC	NC	NC
2	06/13/13	1.04"	Upstream of CSO Outfall 022	-	-	-	-	-	-
			CSO Outfall 022		18000	Absent	35	51.2	9.39
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	57000	NC	66	66.8	9.02
3	09/10/13	0.38"	Upstream of CSO Outfall 022	-	-	-	-	-	-
			CSO Outfall 022		3900	Absent	5	8.81	9.06
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	V[3]	Absent	99	71.6	7.78
4	10/07/13	0.91"	Upstream of CSO Outfall 022	-	-	-	-	-	-
			CSO Outfall 022		5200	Absent	<5	7.11	9.23
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	36000	Absent	80	72.2	9.59
5	02/21/14	0.78"	Upstream of CSO Outfall 022	-	-	-	-	-	-
			CSO Outfall 022		1530	Absent	440	240	14.47
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	350	Present (Food/Beverage Packaging)	82	81	14.36
6	04/15/14	0.60"	Upstream of CSO Outfall 022	-	-	-	-	-	-
			CSO Outfall 022		1230	Absent	53	58.8	12.64
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	10500	Present (Street Litter)	90	99.6	10.27
7	07/23/14	0.42"	Upstream of CSO Outfall 022	Onondaga Creek @ Water Street	430	Absent	11	10.4	9.48

Table 4-12. Summary of post-sewer separation water quality data for CSO 022.

Event #	Date	Total Rainfall[1], Inches	Location (CSO Outfall)	Location (In-Stream)	Fecal Coliform, CFU/100mL	Floatables (Absent/Present w/Description)	TSS, mg/L	Turbidity, NTU	DO, mg/L
			CSO Outfall 022		98200	Absent	39	30.2	3.43
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	400	Absent	6	7.75	8.33
8	11/06/14	0.41"	Upstream of CSO Outfall 022	Onondaga Creek @ Water Street	260	Absent	5	6.95	12.63
			CSO Outfall 022		1080	Absent	82	54	10.53
			Downstream of CSO Outfall 022	Onondaga Creek @ West Genesee St.	340	Absent	9	9.55	10.53

Footnotes:

[1] Rainfall as recorded at the Metro Weather station.

[2] NC: Not collected.

[3] V: Reported result "flagged" due to variance from quality control or assurance criteria and was rejected.

Fecal coliform levels were higher at CSO Outfall 045 than downstream during the February, July and November events, but were lower during April. TSS/turbidity was not elevated at CSO Outfall 045 compared to the upstream or downstream sampling sites. Similar to the observations from CSO 022, the fecal coliform concentration at CSO Outfall 045 was particularly high during the July event (210000 CFU/100mL) and the dissolved oxygen concentration was slightly depressed (7.48 mg/L). Again, the absence of increases in either fecal coliform or TSS/turbidity levels from upstream of CSO Outfall 045 to downstream suggests that intervening inputs had negligible impacts on these metrics of water quality during the July and November events. Street litter was noted at both CSO outfall locations during the February and April events, but not during the July and November events. There was no evidence of sewage or related floatables at either location during any of the sampling events. There were no visual observations of floatables or evidence of sewage in the samples collected at either of these two CSO outfalls.

The monitoring period ends in 2015, and upon inspection and confirmation by NYSDEC that these outfalls have been permanently sealed or eliminated, CSO outfalls 022 and 045 may then be removed from the County's SPDES permit (NY 0027081).

Table 4-13. Summary of post-sewer separation water quality data for CSO 045.

Event #	Date	Total Rainfall, Inches	Location (CSO Outfall)	Location (In-Stream)	Fecal Coliform, CFU/100mL	Floatables (Absent/Present w/Description)	TSS, mg/L	Turbidity, NTU	DO, mg/L
1	04/12/13	0.87"	Upstream of CSO Outfall 045	-	-	-	-	-	-
			CSO Outfall 045		570	NC	NC	NC	NC
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	16400	NC	NC	NC	NC
2	06/13/13	1.04"	Upstream of CSO Outfall 045	-	-	-	-		-
			CSO Outfall 045		5000	Absent	17	20.2	9.63
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	>6000	Absent	66	71.8	10.28
3	09/10/13	0.38"	Upstream of CSO Outfall 045	-	-	-	-	-	-
			CSO Outfall 045		1910	Absent	11	17.6	9.12
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	7545	Absent	63	67.6	9.57
4	10/07/13	0.91"	Upstream of CSO Outfall 045	-	-	-	-	-	-
			CSO Outfall 045		2800	Absent	7	9.09	8.73
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	10000	Absent	74	68.4	8.9
5	02/21/14	0.78"	Upstream of CSO Outfall 045	-	-	-	-	-	-
			CSO Outfall 045		3600	Absent	<10	15	14.41
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	636	Present (Food/Beverage Packaging)	79	84	14.15
6	04/15/14	0.60"	Upstream of CSO Outfall 045	-	-	-	-	-	-
			CSO Outfall 045		801	Absent	31	42.8	11.51
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	7570	Present (Street Litter)	126	158	10.32

Table 4-13. Summary of post-sewer separation water quality data for CSO 045.

Event #	Date	Total Rainfall, Inches	Location (CSO Outfall)	Location (In-Stream)	Fecal Coliform, CFU/100mL	Floatables (Absent/Present w/Description)	TSS, mg/L	Turbidity, NTU	DO, mg/L
7	07/23/14	0.42"	Upstream of CSO Outfall 045	Onondaga Creek @ Rich Street	21000	Absent	74	39.7	9.17
			CSO Outfall 045		210000	Absent	74	29.1	7.48
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	7290	Absent	33	23.1	9.35
8	11/06/14	0.41"	Upstream of CSO Outfall 045	Onondaga Creek @ Rich Street	240	Absent	5	7.61	12.12
			CSO Outfall 045		2100	Absent	24	21.5	8.77
			Downstream of CSO Outfall 045	Onondaga Creek @ South Avenue	210	Absent	6	7.31	11.91

4.8.3 Storage Facility Performance

The Clinton CSO Storage Facility (CSF), located in the Clinton/Lower MIS service area, and the Lower Harbor Brook Storage Facility (LHBSF) accepted wet weather flow starting December 31, 2013. Both storage facilities capture and store combined sewage generated during wet weather for up to the 1-year, 2-hour design storm. In 2014, these storage facilities stored (for treatment at Metro) an estimated 113 MG of combined sewage that would previously have been discharged to Onondaga Creek and Harbor Brook. This reduction in CSO discharge volume is expected to result in substantial water quality improvements in these tributaries.

4.8.4 Stormwater Management Model (SWMM)

The purpose of the CSO discharge monitoring effort is to increase the veracity of the Stormwater Management Model (SWMM) used for planning, design, and determination of compliance with the volume capture requirements. Onondaga County implemented a comprehensive expansion of, and updates to, the SWMM in 2012. SWMM is the USEPA software package specifically identified in Paragraph 14.I of the ACJ for determination of compliance with CSO volume reduction requirements.

The County is updating the SWMM on a yearly basis using the monitoring data to verify, reconcile, and re-calibrate (as necessary) SWMM values and output. With a newly calibrated model better representing the actual system conditions than the 2013 conditions model, the annual combined sewage volume capture is estimated to be 480 MG. This capture volume represents a combined contribution from various green and gray projects completed since 2009. In accordance with the ACJ Fourth Stipulation, Paragraph 14I, Determination of Compliance, the County installed flow meters at 13 representative CSOs and continued to receive data in 2014 from the installed flow metering devices. The typical year model results show that the annual capture percentage for the 2014 system conditions exceeds the 95 percent final capture milestone mandated for 2018. Per the ACJ, the County is required to maintain these meters through December 31, 2018.

Enjoying the View at Onondaga Lake Park

4.9 Preliminary Assessment of Changes in Urban Runoff Characteristics Following Implementation of Green and Gray Infrastructure

In the 2013 AMP Report a manual hydrograph separation technique was employed to quantify flows and fecal coliform loading to Onondaga Creek during brief periods of increased stream flow. These abrupt increases in flow, which are recurring downstream of urban Syracuse but absent upstream, have been attributed to urban stormwater, including CSO inputs. Based on the recent completion of major green and gray infrastructure projects, including the Clinton and Harbor Brook storage facilities in 2013, it is reasonable to expect reductions in CSO volumes and magnitudes of the urban flow peaks during precipitation events. This exploratory analysis, which is an extension of the analysis presented in the 2013 AMP Report, examines high frequency (15 minute) USGS flow data from Onondaga Creek and Harbor Brook to look for evidence of decreases in urban storm flow peaks associated with runoff capture from green and gray infrastructure projects. Visual and quantitative comparisons of the flow records at upstream and downstream locations allow for detailed hydrograph analysis and determination of base flow and surface runoff contributions. This analysis technique, known as hydrograph separation, was used to delineate the urban runoff component of the hydrograph for both streams (red area; Figure 4-19).

The objectives of this exploratory analysis were to: (1) identify and characterize urban runoff signatures over the 1995–2014 interval for Onondaga Creek and Harbor Brook using hydrograph separation techniques, (2) quantify the relationships between urban runoff event characteristics and precipitation drivers, and (3) assess if changes in runoff event characteristics have occurred over time as a result of green and gray infrastructure projects. Here we present selected highlights of this analysis. The full report, including additional figures, tables, and analyses, can be found in Appendix D-6.

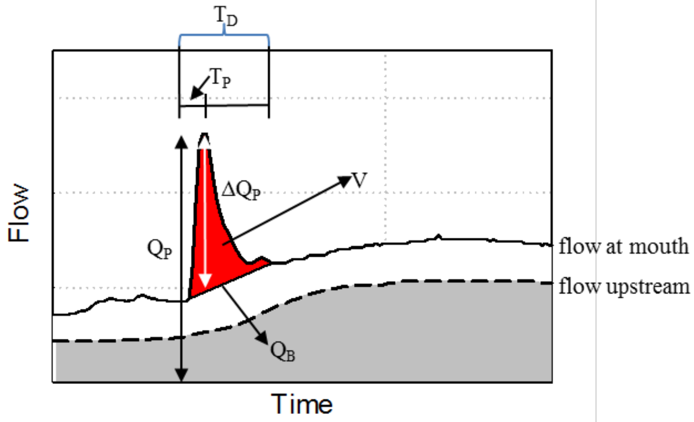


Figure 4-19. Schematic of a generalized urban runoff event common to Onondaga Creek with flow at the mouth and upstream and event characteristics identified. Q_P = peak flow, ΔQ_P = peak flow relative to base flow (white arrow), Q_B = base flow, V = event volume (red area), T_D = time of duration, and T_P = time to peak.

4.9.1 General Character of Urban Runoff Events in Onondaga Creek

Urban runoff events were defined as all abrupt, short-term increases in flow at the downstream gage that were not observed at the upstream gage (see Figure 4-19). These events have been attributed to CSO inputs and other sources of urban stormwater. Over the 1995–2014 interval 1,352 urban runoff events were identified for Onondaga Creek, an average of nearly 68 events per year. For all identified events, the average peak flow was 9.54 m^3/s with a range of 0.96 m^3/s to 104.31 m^3/s. Urban runoff event volumes varied widely from event to event, ranging from small events with < 1 million gallons (MG) of runoff to large events which delivered > 100 MG of runoff. The average runoff volume delivered was 7.06 MG and the range between the lower and upper quartiles (25-75% occurrence) was nearly 18.0 MG. Urban runoff events were very short-lived; the average event duration was 4.3 h (± 1.9 h) and the average time to peak was just 1.6 h (± 1.0 h). Ninety percent of the events lasted less than 6.8 h with times to the flow peak less than 3.0 h. Selected examples of the different types of urban runoff signatures observed in Onondaga Creek are presented (Figure 4-20). These examples highlight the complexity of stream flow response during precipitation events and demonstrate the short-lived nature of these events that require the use of high-frequency flow data.

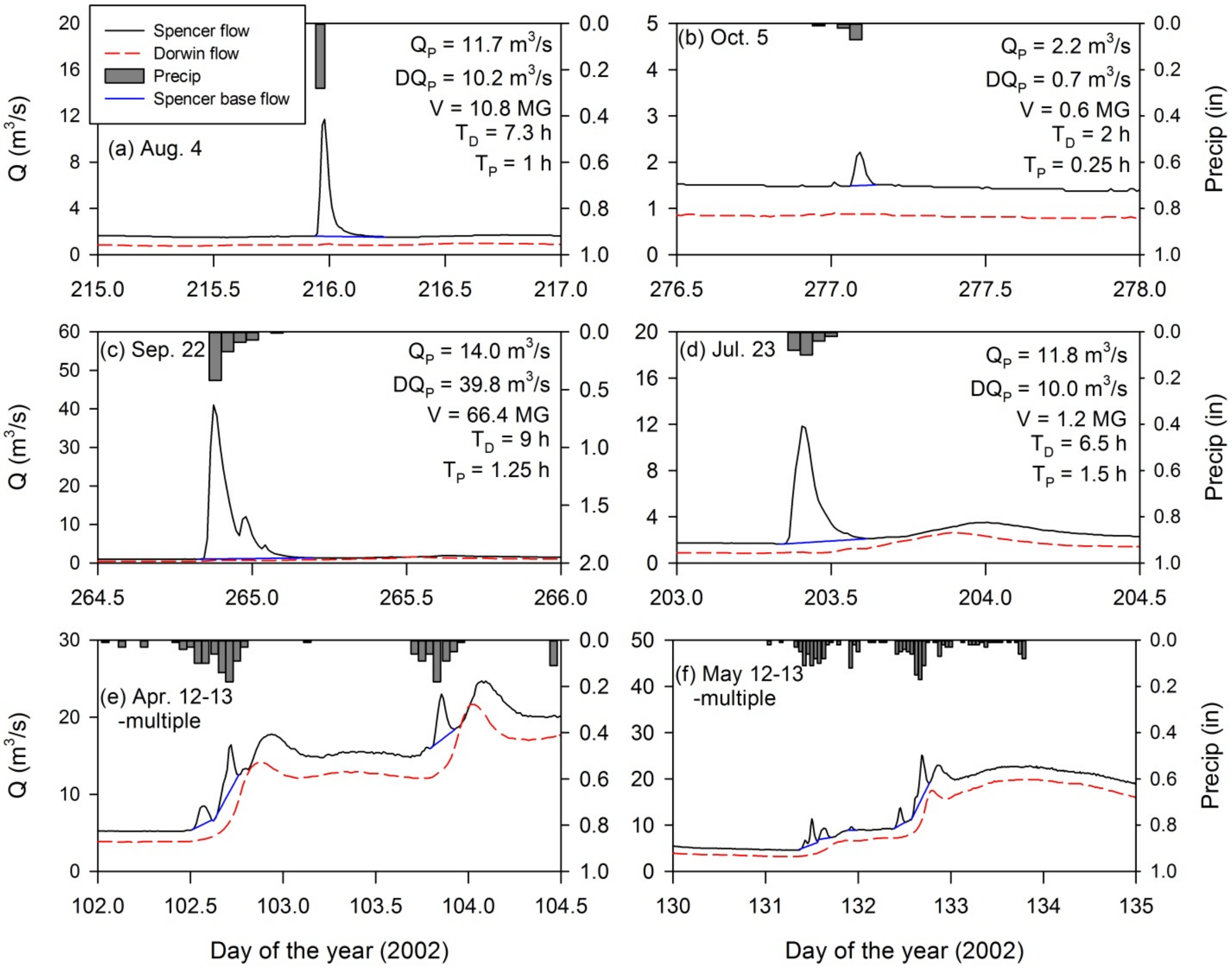


Figure 4-20. Time series of Onondaga Creek flow and hourly precipitation for selected events in 2002: (a) August 4, (b) October 5, (c) September 22, (d) July 23, (e) April 12-13, and (f) May 12-13.

4.9.1.1 Annual Statistics

The study interval was segmented into three time periods corresponding to progress with CSO abatement efforts: (1) Pre-remediation, from 1995–2008; (2) Transitional, from 2009–2013; and (3) Post-remediation, 2014 only. Annual counts, means, and standard deviations for the identified urban runoff events for Onondaga Creek are presented in Table 3 of the complete report. Urban runoff characteristics were highly variable within the Pre-remediation period, both within and amongst years. The Pre-remediation interval (all monitored events) ranked the highest for mean flow peak (9.70 m^3/s), mean delta flow peak (4.91 m^3/s), mean event volume (7.28 MG), mean duration (4.35 h), and mean time to peak (1.61 h). The Transitional period ranked second highest for all characteristics. In 2014 (Post-remediation) the mean flow peak was 9.10 m^3/s, 6.2% less than the Pre-remediation average. Mean delta peak flow was 4.25 m^3/s in 2014 which represented a 13.4% decrease from the 1995-2008 interval. Mean event volume in 2014 was 14.3% less than the Pre-remediation interval (6.24 MG). Both mean event duration and mean time to peak in 2014 were somewhat less than the Pre-remediation interval (3.93 and 1.47 h, respectively). These changes represented decreases of 9.6 and 8.9%, respectively.

In 2014, 40.5 inches of precipitation were recorded at Hancock International Airport, which ranked as the 7th wettest year during the 20-year study interval. Annual precipitation in 2014 represented a 6.1% increase compared to the Pre-remediation average (38.17 in) and a 0.3% increase compared to the Transitional average (40.37 in). The annual total urban runoff volume during the Pre-remediation period averaged 504 MG/yr (range: 306 MG to 770 MG). During the Transitional period, total annual urban runoff volume averaged 422 MG (range: 244 MG to 502 MG), which was 16% lower than the Pre-remediation interval. In 2014, there was an estimated 399 MG of total urban runoff volume. This represented a 21% decrease from the Pre-remediation period and 5.5% decrease from the Transitional period. The annual statistics and interval averages all indicate improvement in urban runoff event conditions in 2014 compared to Pre-remediation years. However, these results must be considered in the context of the large variability in the Pre-remediation interval and the Post-remediation period being represented by a single year. Additional years of Post-remediation data will be required to support more definitive conclusions regarding reductions in urban runoff.

The influence of total annual precipitation on urban runoff event characteristics was evaluated in the form of regression plots (Figure 4-21). The best-fit line and R^2-value from the linear least squares regression for the Pre-remediation interval are presented on each plot. The annual number of events, annual mean flow peak, and annual total urban runoff volume were all found to be positively correlated with annual precipitation (Figure 4-21). The annual statistics from the Transitional and Post-remediation intervals are presented on the same plots as green squares and a red star, respectively. In all cases the 2014 results fall below the best-fit line from the Pre-remediation data, suggesting improved urban runoff conditions from CSO capture.

However, these apparent improvements in 2014 are not statistically significant and are based on just a single year of Post-remediation data.

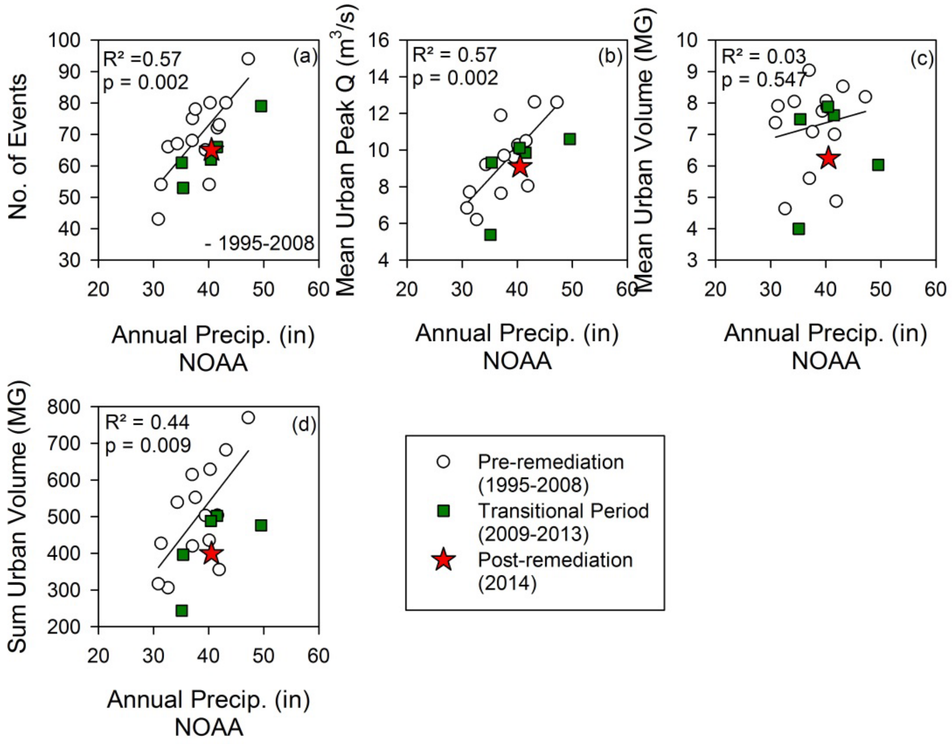


Figure 4-21. Regression scatterplots for total annual precipitation versus: (a) number of urban runoff events, (b) mean urban runoff peak flow, (c) mean urban runoff event volume, and (d) total annual urban runoff volume. Annual means are presented for three periods: 1995–2008 (white circles), 2009–2013 (green squares), and 2014 (red star). Best-fit line and R^2 values are provided for the 1995–2008 period.

4.9.1.2 Comparison of Hydrologic Parameters at Different Levels of Precipitation

All identified events were grouped into 7 categories based on the total precipitation from 6 hours prior to the end of the event. This precipitation statistic was used because of the relatively short duration of the urban runoff signatures (e.g., mean duration for all events was 4.3 hours). For each level of precipitation, data from the Pre-remediation period are shown as box-whiskers and the mean for 2014 is shown as a red star (Figure 4-22).

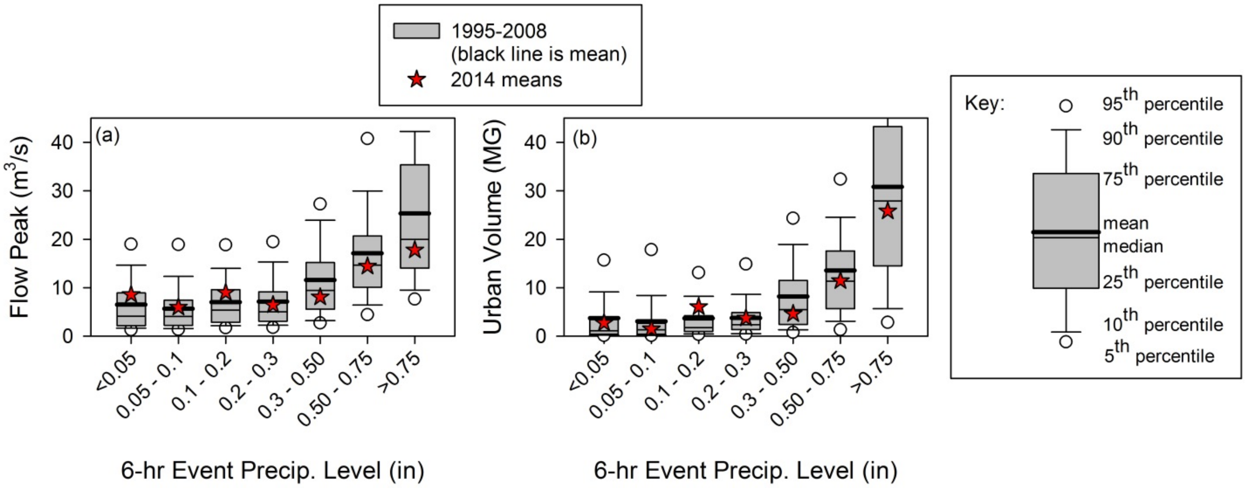


Figure 4-22. Box-whisker plots for all events grouped by 6-hour total precipitation levels for all individual events from 1995-2008 for: (a) flow peak and (b) urban runoff volume. Mean 2014 conditions as red stars for the same levels of precipitation. Box-whisker key presented for reference.

Mean event peak flows in the Pre-remediation period were similar for runoff events with less than 0.3 inch of precipitation, ranging from 5.6 to 7.4 m^3/s (Figure 4-22a). However, the range of flow peaks in these groups was rather large (~ 20 m^3/s). The mean flow peak increased substantially in the next three precipitation groups, from 11.4 m^3/s in the 0.3-0.5 inch group to 16.9 m^3/s inch the 0.5-0.75 inch group to a maximum of 25.7 m^3/s for events greater than 0.75 inches. In general, as precipitation increased so did the variability and range of observed events (e.g., the range in event peak flows was > 50 m^3/s in the largest precipitation group). The shift to lower peaks in 2014 indicates a reduction in urban runoff.

In the four smallest precipitation groups in the Pre-remediation interval, mean event volumes were generally small (2.9 to 4.0 MG) but with large variability (ranges from < 0.1 to > 50 MG per event). As with the flow peak results, mean event volumes increased in the three largest precipitation groups: from 8.0 MG in the 0.3-0.5 inch group to 13.5 MG in the 0.5-0.75 inch group to 31.9 MG in the > 0.75 inch group. Variability in event volume also increased with increased precipitation levels. Mean event runoff volumes in 2014 were lower than the Pre-remediation averages for all precipitation levels with the exception of the 0.1–0.2 inch group (Figure 4-22c). At precipitation levels < 0.1 inches, mean event volume reduction 2014 ranged between 32 and 50%. For precipitation events in the four largest groups (those events > 0.2 inches), the mean event volume reduction in 2014 was 5%, 42%, 15%, and 19%, respectively. The lower mean event volumes per unit precipitation in 2014 suggest that the green and gray projects are indeed capturing urban runoff.

These results suggest that the green and gray infrastructure improvements over the 2009-2013 interval have resulted in capture of urban runoff in Onondaga Creek. However, these results should be viewed as preliminary given the large variability in the Pre-remediation interval and the single year of Post-remediation data. Updates to this urban runoff analysis are recommended as additional years of Post-remediation data become available.

4.9.2 Review of Urban Runoff Events in Harbor Brook

The classic urban peak commonly observed in Onondaga Creek was rarely seen in Harbor Brook. This difference in character between the two streams is likely a result of the large difference in urban area between the two watersheds (10 times greater urban area for Onondaga Creek) and the short travel time between the upstream and downstream gages on Harbor Brook. The Harbor Brook flow record was incomplete for the study interval. For this analysis only the years 2002 and 2014 were considered because these years were relatively complete in terms of flow data and had similar total annual precipitation. Peak flows at the mouth of Harbor Brook were lower in 2014 than in 2002. The difference in flow peaks between the upstream and downstream gages ($Q_{P/M} - Q_{P/U}$) was used as an indicator of urban runoff. Median $Q_{P/M} - Q_{P/U}$ values decreased 82% from 2002 to 2014 when all runoff events are considered and 92% for larger events. This analysis suggests substantial reductions in urban runoff from 2002 to 2014. However, this conclusion is based on limited data and should be considered preliminary. This analysis should be updated as additional post-remediation data become available.

Aerial view of the Harbor Brook Wetland Pilot Treatment System at CSO 018.

4.10 Microbial Trackdown Study: Phase 2

Phase 2 of the Microbial Trackdown Study was conducted from June 2012 through July 2014, and included regular and trackdown sampling events in an effort to: (A) monitor spatial trends in bacteria levels in tributaries to Onondaga Lake, (B) monitor problematic point sources identified during Phase 1, (C) monitor newly discovered point sources, and (D) trackdown and remediate problematic bacterial discharges. All activities were performed during dry weather conditions, defined as a maximum of 0.08 inches (2 mm) of precipitation during the preceding 48 hours preceding a sampling event. In addition, spatial and temporal trends in bacteria levels were identified that helped to: (1) explain patterns of stream water quality related to land use, (2) detect relationships between measured parameters, (3) identify and prioritize point source (PS) trackdown work, (4) measure the effects of remedial activities on bacteria levels, and (5) assess changes in bacteria levels since Phase 1.

Results from this study helped to elucidate spatial and temporal trends in bacteria and water quality, identify areas of concern, and make physical improvements to the system, most notably:

- In-stream bacteria levels were significantly different between rural and urban locations, with urban locations consistently having higher bacteria levels.

- Routine and temporal sampling events identified several drivers that explained patterns in bacteria levels.

- Five new point sources were identified in Onondaga Creek since Phase 1, illustrating the dynamic nature of an aging infrastructure.

- Two urban tributaries to Onondaga Creek, City Line Brook and Hopper Brook (N), had high levels of bacteria at several locations during the 2013 trackdown event. By comparison, City Line Brook had lower bacteria levels than Hopper Brook (N); however, due to persistently higher flows, this tributary has a higher bacterial load to Onondaga Creek.

- Site specific bacteria levels in Onondaga Creek varied between Phase 1 and Phase 2, with two upstream locations showing significant increases in bacteria levels and three downstream locations showing significant decreases in bacteria levels between study phases. In 2012, OEI conducted an extensive ecological study of the Upper Onondaga Creek Watershed (OEI 2013). Water quality impacts at several sites were found to be associated with agricultural and residential practices. Decreases in bacteria at several locations downstream were attributed to physical improvements to the system made during and shortly after the completion of Phase 1.

- Through the collective efforts of Phase 1 and Phase 2, a total of 12 physical improvements to the system have been made in Harbor Brook, Onondaga Creek, and Ley Creek, and followup work is currently being conducted on several other point sources. With the exception of one point source in Harbor Brook, subsequent sampling events showed that the corrective work was successful.

Strategies are being developed to perform targeted sampling and analysis of each point source in an effort to isolate the source (i.e., animal vs. human) and location (cross-connection, illicit discharge, etc.) of the discharge. Results from this study effectively documented the effects of dry-weather inputs on bacteria levels and water quality in Harbor Brook, Onondaga Creek, and Ley Creek. The results are presented in *Identification of the Primary Sources of Bacteria Loading in Selected Tributaries of Onondaga Lake: Phase 2 Microbial Trackdown Stud*y, Final Draft Report, August 2014 (to be finalized in 2015).

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Section 5. Onondaga Lake Water Quality: 2014 Results and Trends

5.1 Onondaga Lake Sampling Program

Trained Water Environment Protection (WEP) technicians collect samples from various locations and depths within Onondaga Lake to characterize water quality and biological conditions. Most sampling occurs between April and November when the lake is free of ice. The ambient monitoring program (AMP) encompasses multiple parameters (Table 1-2) with a focus on evaluating compliance with ambient water quality standards (AWQS) and assessment of trends toward attainment of designated uses. Results for key parameters and lake sampling locations are presented in this section. Long-term time series covering 2004–2014 are provided for all AMP parameters and lake sampling locations in Appendix E-1.

WEP also tracks physical factors, such as the development and extent of ice cover. During the winter of 2013–2014, ice cover extended for 107 days in the north basin and 95 days lake wide. This was the most extensive ice cover documented during the 1987–2014 record. Ice cover was nearly as extensive in the winter of 2014–2015, when ice cover persisted 95 days in the north basin and 89 days over the entire surface of the lake.

The main sampling station in the lake, referred to as South Deep, is located near the deepest point in the southern basin. South Deep has been the long-term reference monitoring location on Onondaga Lake since the County initiated monitoring in 1970. In addition to the routine biweekly sampling at South Deep, WEP technicians collect samples for a reduced number of parameters from the deepest point of the lake's northern basin (North Deep) four times each year to confirm that water quality conditions measured at the South Deep station adequately characterize open water conditions. Results from North Deep and South Deep remained generally comparable in 2014 (Appendix E-2). The AMP also includes sampling of a network of ten near-shore locations for parameters related to suitability for water contact recreation. These parameters include Secchi disk transparency, turbidity, and fecal coliform bacteria. Changes to the in-lake sampling program for 2014 included the following:

- Discontinued sampling of calium, sodium, potassium, magnesium, manganese, iron, and sulfate.
- Reduced depths sampled for nitrogen species (TKN, NH_3-N, Org-N, F-TKN, TN) from seven (0, 3, 6, 9, 12, 15, 18 meters) to two (3, 15 meters).

5.2 Trophic State

The trophic state of a lake refers to its level of primary production (production of organic matter through photosynthesis). This is a fundamental feature of the ecology of lakes that also has important water quality implications. Highly productive lakes are termed eutrophic, while lakes with low levels of productivity are termed oligotrophic. Those with intermediate levels of productivity are described as mesotrophic. Excessive productivity can result in conditions that impair a waterbody for a particular use, such as water supply or recreation.

Primary production in Onondaga Lake, like most lakes in the Northeast, is limited by the availability of the nutrient phosphorus. Addition of phosphorus to lakes causes increased primary production, described as eutrophication. This is generally accompanied by higher concentrations of algae and often cyanobacteria (blue-green algae), which can have deleterious effects on water quality. Certain cyanobacteria can produce harmful toxins.

Decay of settled algae contributes to the depletion of dissolved oxygen in the lower stratified layers. Where this decay is substantial, oxygen can be depleted to levels that make these layers uninhabitable for fish and other oxygen-requiring biota. The complete absence of dissolved oxygen (anoxia) enables the release of a number of undesirable substances from the sediments, including, soluble phosphorus, methylmercury, and various oxygen-demanding constituents, such as hydrogen sulfide and methane.

Much effort has been directed at decreasing primary production in Onondaga Lake through reductions in phosphorus loading. The progress of this program has been tracked by monitoring multiple measures of the lake's trophic state. This has included measurements of the three common trophic state parameters, total phosphorus (TP), chlorophyll-*a* (Chl-*a*), and Secchi disk (SD) transparency, as well as related chemical metrics of the deep waters, and the composition and abundance of the algal community (see Section 6). Each of these parameters has shortcomings, but together they represent a robust representation of trophic state conditions. The three most often monitored parameters are all related to the amount of phytoplankton (microscopic algae) present in the water column. Much of the phosphorus and all of the chlorophyll-*a* (the dominant pigment of algae) is associated with phytoplankton. The Secchi disk measurement is more indirectly related to trophic state and controlled primarily by the concentration of particles in the water. The common case of dominance of the overall particle population by phytoplankton makes Secchi disk a valuable trophic state metric. These metrics of trophic state can all be influenced by both bottom-up (e.g., phosphorus supply) and top-down (food web) effects. Top-down effects associated with large zooplankton that effectively feed on (graze) phytoplankton can confound relationships between phosphorus loading and common metrics of trophic state.

5.2.1 Phosphorus

Total phosphorus (TP) concentrations in the upper waters of the lake remained near 20 µg/L during most of the 2014 monitoring period (Figure 5-1). The highest TP concentrations were measured in mid-April (45.0 µg/L), early July (29.5 µg/L), and early August (28.0 µg/L). The peak concentration in mid-April followed an extended period of elevated stream flow and the early August peak was preceded by a significant summer storm. Only the high total phosphorus concentration on July 8 coincided with a peak in algal biomass (Figure 5-3a). Total phosphorus concentrations in the upper waters of the lake averaged 22 µg/L during the summer (June–September) of 2014, slightly lower than the summer average of 25 µg/L in 2013. Total dissolved phosphorus (TDP) concentrations averaged 5.6 µg/L and accounted for 14% to 39% (average of 25%) of TP. Soluble reactive phosphorus (SRP) levels were consistently low, with a maximum concentration of 4 µg/L. Long-term trends in TP concentrations in the upper waters of the lake depict major decreases since the early 1990s (Figure 5-2). Since 2007, summer total phosphorus concentrations in the upper waters of Onondaga Lake have been close to the guidance value of 20 µg/L. The summer average TP concentration was below the guidance value in 2008 and 2009. With the advanced treatment system at Metro producing consistently low effluent total phosphorus, the year-to-year variability in lake phosphorus levels largely reflects changes in precipitation patterns and the resultant watershed loading as well as changes in the food web structure (see Section 5.8.4). At times, a substantial portion of the total phosphorus in Onondaga Lake may be associated with inorganic particles rather than phytoplankton. Total phosphorus is a flawed metric of trophic state during these periods, which are usually associated with major runoff events and a large influx of inorganic particles to the lake. Summer average concentrations of both TDP and SRP have been consistently low since 2007.

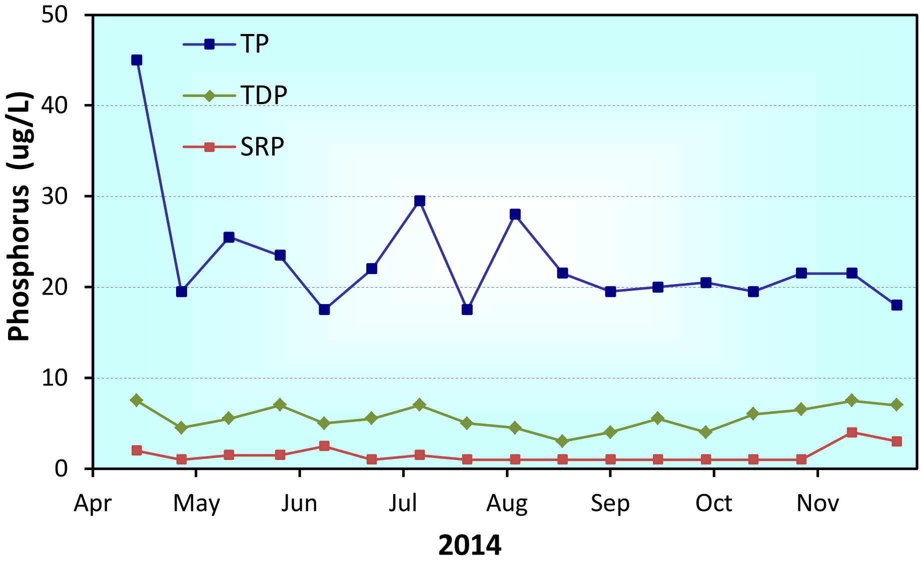


Figure 5-1. Time series of total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP) concentrations in the upper waters (0-3 meters) of Onondaga Lake during 2014.

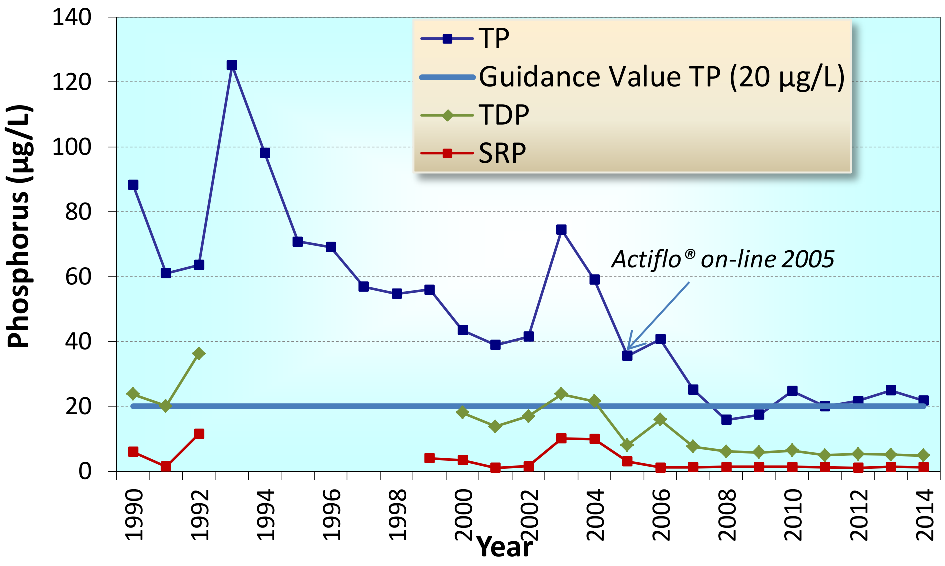


Figure 5-2. Summer (June to September) average total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP) concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2014.

Note: TDP and SRP data not collected during 1993-1998.

5.2.2 Chlorophyll-a

Chlorophyll-*a* (Chl-*a*) concentrations in the upper waters of the lake in 2014 ranged from 3.7 µg/L in late October to a peak of 17.6 µg/L in early July (Figure 5-3a). The increase in chlorophyll-*a* from mid-April to mid-May was accompanied by a reduction in silica concentrations (Figure 5-3b). Diatoms are a group of phytoplankton that use silica to form their cell walls, known as frustules, and this pattern of silica depletion is indicative of the spring diatom bloom, a recurring feature in Onondaga Lake. The summer average Chl-*a* concentration in 2014 was 8.5 µg/L, lower than the 2013 average of 9.1 µg/L (Figure 5-4). The average and peak concentrations of this indicator of algal biomass have declined substantially, particularly since the Actiflo® upgrade at Metro (Figure 5-4). Summer data (June–September) are used to track suitability of the lake for recreational uses. NYSDEC (2009) lists three levels of chlorophyll-*a* that serve as recreation use assessment criteria. Chlorophyll-*a* concentrations greater than 15 µg/L, 12 µg/L, and 8 µg/L correspond to impaired, stressed, and threatened conditions, respectively. Summer average chlorophyll-*a* concentrations in Onondaga Lake, which commonly exceeded 15 µg/L during 1990–2004, have remained less than 12 µg/L since 2007 (Figure 5-4).

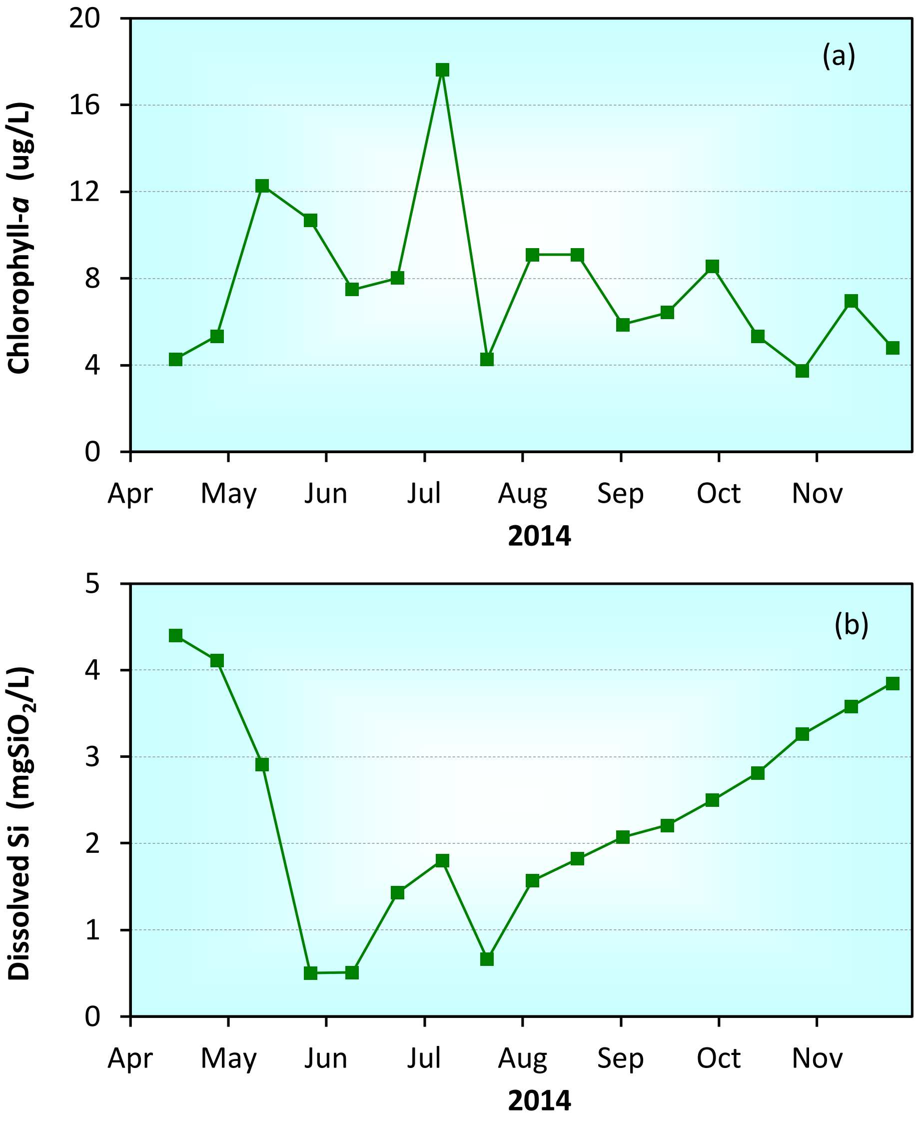


Figure 5-3. Seasonal time plot of average upper water (0-3 meters) concentrations in Onondaga Lake, 2014: (a) chlorophyll-*a*, and (b) silica.

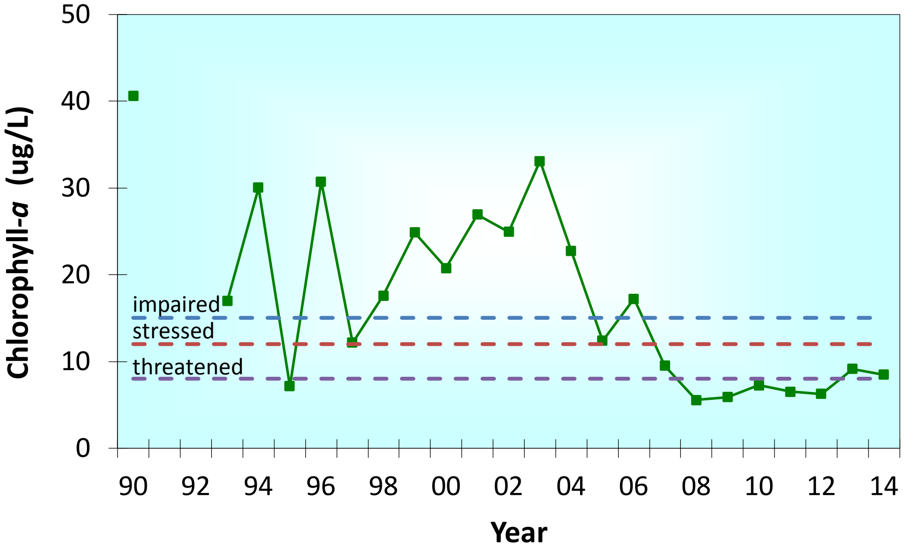
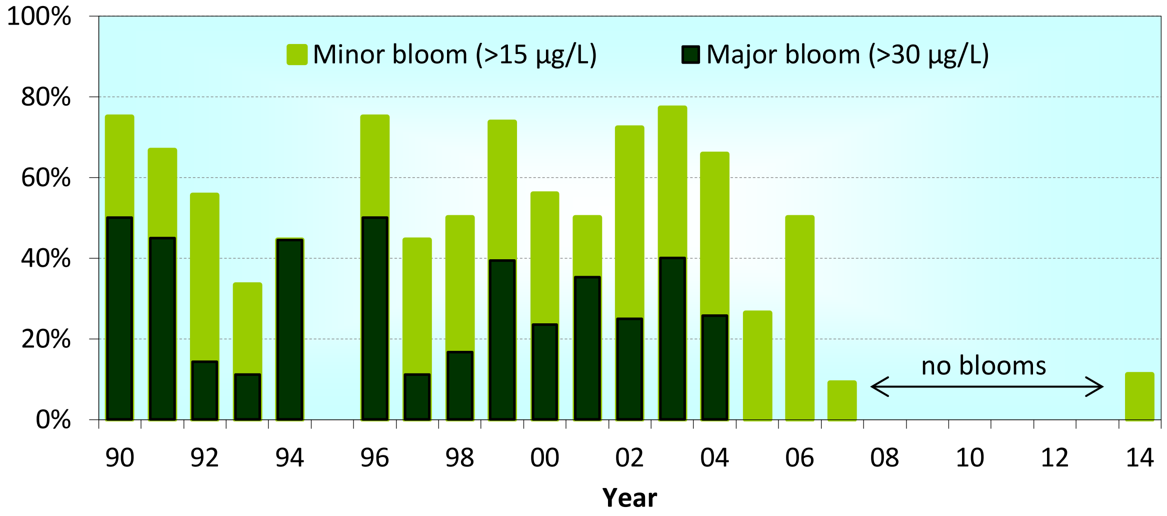


Figure 5-4. Summer average (June–September) chlorophyll-*a* concentrations in the upper waters of Onondaga Lake (South Deep), 1990–2014.

The EPA and NYSDEC are developing nutrient criteria for lakes to protect aquatic life, water supply and recreational uses, as well as deriving numerical limits on response variables such as chlorophyll-*a*. Algal blooms are generally esthetically undesirable, accompanied by a turbid green appearance in Onondaga Lake. In the absence of state or federal criteria, the AMP has used subjective thresholds of 15 µg/L and 30 µg/L to represent minor blooms (impaired conditions) and major blooms (noxious conditions), respectively. According to the criteria adopted here, and based on biweekly laboratory measurements, there was one minor algal bloom in Onondaga Lake during the summer recreational period (June–September) of 2014, when the chlorophyll-*a* concentration was 17.6 µg/L (Figure 5-5). Detailed vertical patterns of chlorophyll-*a* are depicted in Figure 5-13d as a color contour plot. It is important to note that the results of the in-situ chlorophyll-*a* analysis are not as accurate as results from the certified extractive analysis procedure performed in the laboratory. The in-situ high frequency measurements are not intended to replace the standard procedure, but are intended to complement the more accurate, but less frequent laboratory results. The laboratory results are best suited for tracking and reporting long-term patterns in the occurrence of summer algal blooms because they are more accurate and there is a long-term record of these measurements. Although the paired laboratory and *in-situ* chlorophyll-*a* measurements from 2014 were significantly correlated (p = 0.05), the relationship was rather weak (R^2 = 0.23). Accordingly, with the exception of Figure 5-13d, laboratory results are used exclusively in this report.



No blooms were observed during summer in 1995, 2008, 2009, 2010 - 2013

Figure 5-5. Percent occurrence of summer (June to September) algal blooms in Onondaga Lake evaluated annually for the 1990–2014 period, based on chlorophyll-*a* measurements.

The total phosphorus concentration in spring has been a good predictor of the occurrence of severe summertime algal blooms (Figure 5-6), which have not been observed when the total phosphorus concentration is less than 50 µg/L. The Metro total phosphorus load has been a good predictor of the summer average chlorophyll-*a* concentration of the upper waters, with decreases in chlorophyll-*a* observed as the total phosphorus load has been reduced (Figure 5-7). This analysis uses total phosphorus loads from the full water year (October 2013–September 2014) to account for loading that may influence algal growth during summer.

Diatoms – A Major Group of Algae in Onondaga Lake

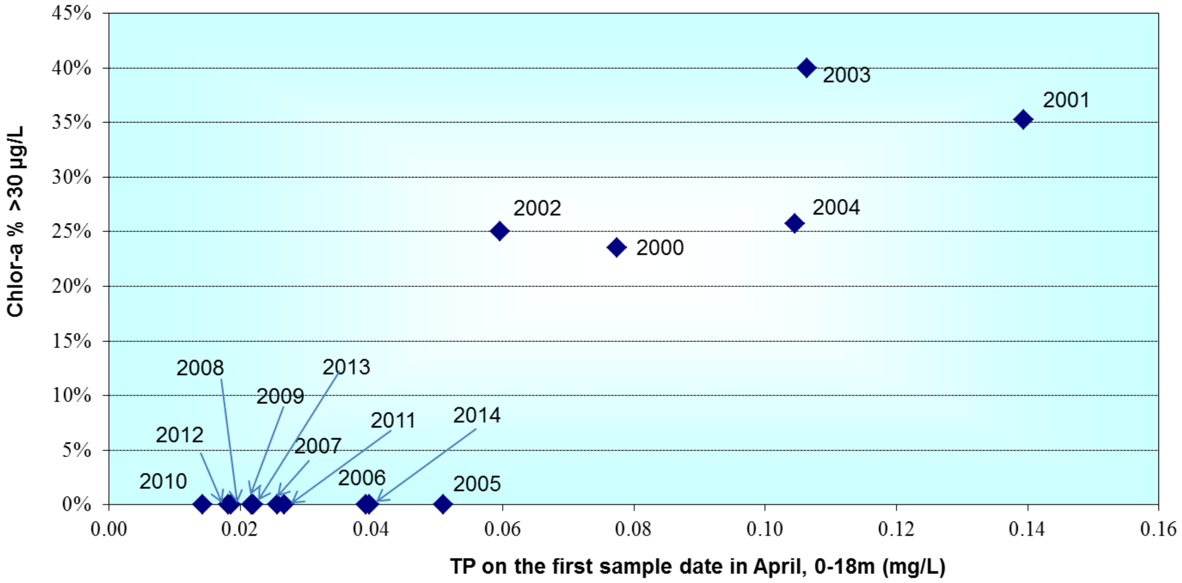


Figure 5-6. Relationship between the frequency of major summertime algal blooms at South Deep and the total phosphorus concentration in spring, 2000–2014.

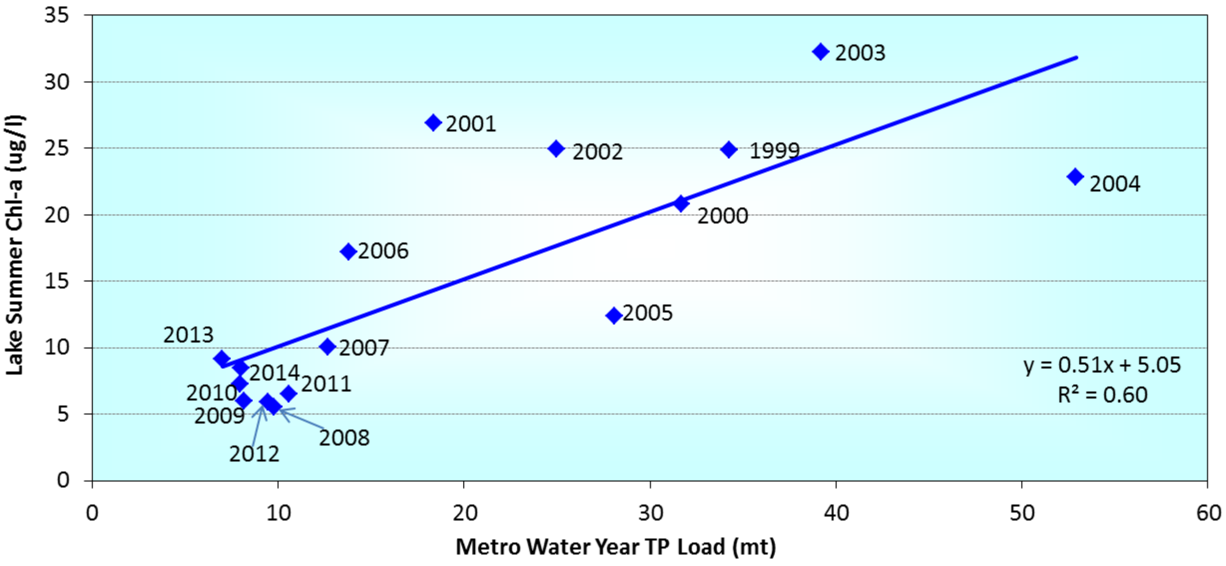


Figure 5-7. Relationship between summer (June–September) average chlorophyll-*a* concentrations in the upper waters at South Deep and total phosphorus loading from Metro over the full water year (October–September) for 1999–2014.

5.2.3 Secchi Disk Transparency

A Secchi disk is a 25 centimeter diameter disk with alternating black and white quadrants. The depth at which it can no longer be seen in the water is known as the Secchi disk transparency. Greater depth indicates clearer waters with lower concentrations of particles, often in the form of phytoplankton. Secchi disk transparency greater than 1.2 meters (4 feet) is required to meet swimming safety guidance at designated beaches. There is no New York State standard or guidance value for Secchi disk transparency for off-shore waters. Most lake monitoring programs in the state make Secchi disk measurements at a mid-lake station overlying the deepest water, comparable to the Onondaga Lake South Deep station. A summer average Secchi disk transparency of at least 1.5 meters at South Deep has been established for Onondaga Lake as a target for improved aesthetic appeal (Table 1-5). The Citizens Statewide Lake Assessment Program (CSLAP), a joint effort of NYSDEC and the NYS Federation of Lake Associations, considers summer average Secchi disk transparency greater than 2 meters as indicative of mesotrophic conditions (Kishbaugh 2009). The average water clarity of Onondaga Lake during the summer of 2014 was 1.9 meters and ranged from 1.2 to 2.9 meters (Figure 5-8). Summer average water clarity in 2014 was slightly higher than during 2013 (Figure 5-9a) and there were no measurements less than 1.2 meters (Figure 5-9b).

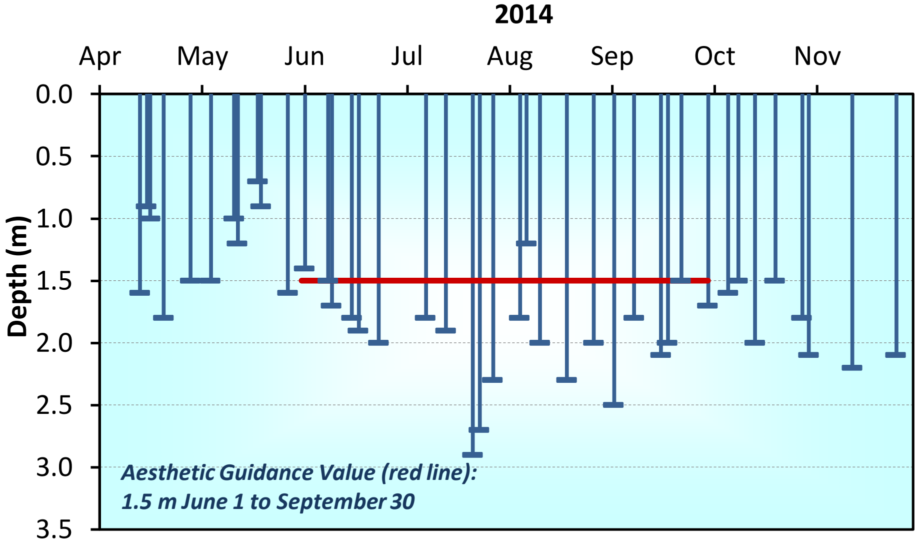


Figure 5-8. Secchi disk transparency, Onondaga Lake South Deep, 2014.

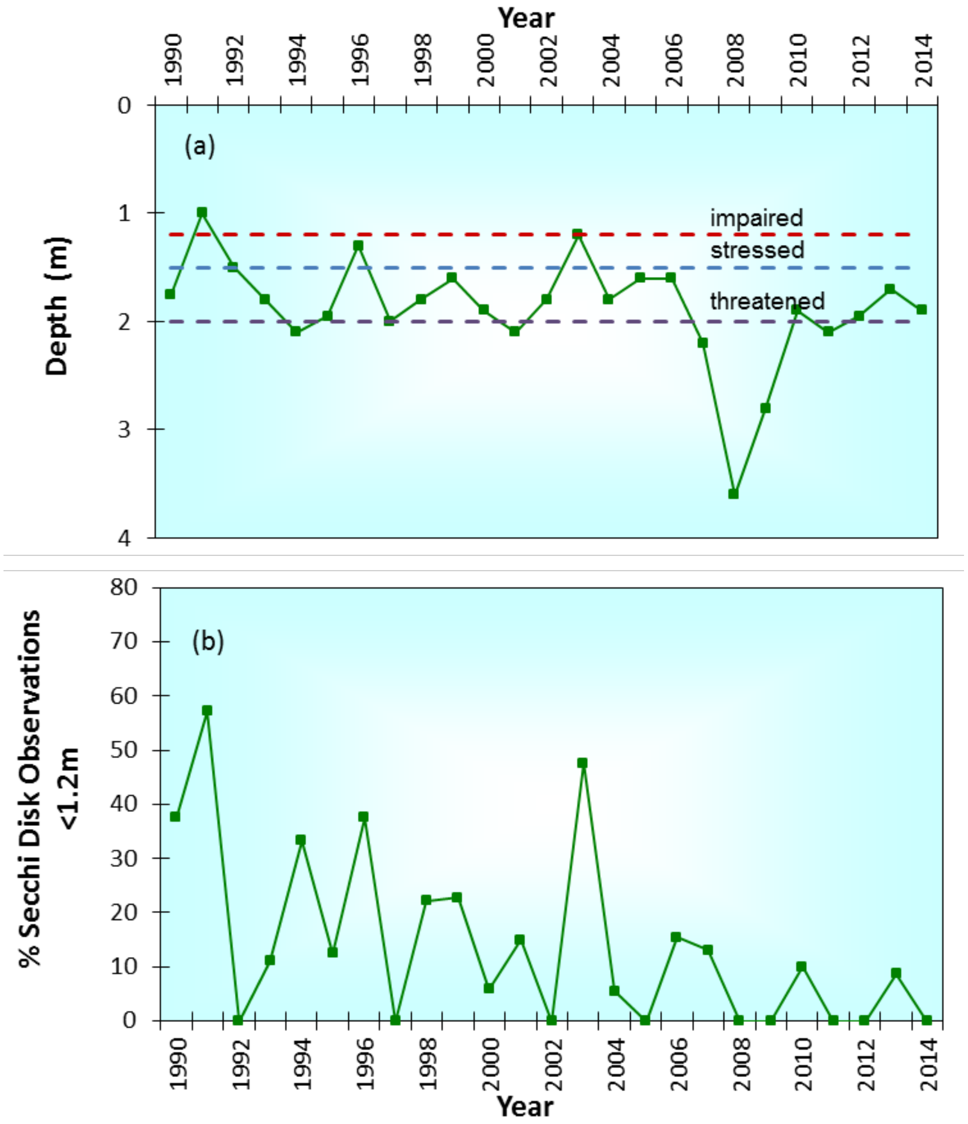


Figure 5-9. Long-term summer median Secchi disk transparency, Onondaga Lake South Deep, 1990–2014 for (a) the summer median value, and (b) the percent Secchi disk observations less than 1.2 meters.

Note: The points in panel (a) represent summer median values. NYSDEC values for impaired (1.2 m), stressed (1.5 m), and threatened conditions (2.0 m) are shown.

5.2.4 *Trends in Trophic State*

Summer (June–September) average values of the three trophic state indicator parameters (total phosphorus, chlorophyll-*a*, Secchi disk transparency) are presented for the 1998–2014 interval (Figure 5-10). These trophic indicators are expressed relative to the trophic state boundary values presented by Cooke et al. (2005). Although the specific values of these trophic boundaries are somewhat subjective, they do serve as convenient general indicators of lake productivity. According to these parameters, trophic conditions have varied only modestly since 2010. Total phosphorus and chlorophyll-*a* indicate a shift in the trophic state of Onondaga Lake from eutrophy to mesotrophy since 2008. Secchi disk transparency was higher in 2008 and 2009 due to grazing of particles by *Daphnia*, a large, filter feeding zooplankter. However, no systematic improvement in summer average Secchi disk transparency has been observed since 1998. Two factors likely contribute to this inconsistency for Secchi disk versus total phosphorus and chlorophyll-*a* (Effler et al. 2008): (1) inputs of inorganic particles that decrease clarity; and (2) the recent absence of the grazing effects of larger zooplankton that efficiently consume/remove phytoplankton as well as non-phytoplankton particles. The mud boils on upper Onondaga Creek have contributed to the diminished water clarity of the lake, and therefore to the disparity in trophic state based on Secchi disk versus the other two metrics. As observed in 2010, 2011, 2012 and 2013, efficient grazers of phytoplankton (i.e., *Daphnia*) continued to be mostly absent in 2014, consistent with the continuing large population of the Alewife (*Alosa pseudoharengus*). See Section 6 for a detailed discussion of food web dynamics. The observed decreases in total phosphorus and chlorophyll-*a* and the increase in Secchi disk transparency in 2014 relative to 2013 indicate a modest improvement in water quality.

Save the Rain tree planting

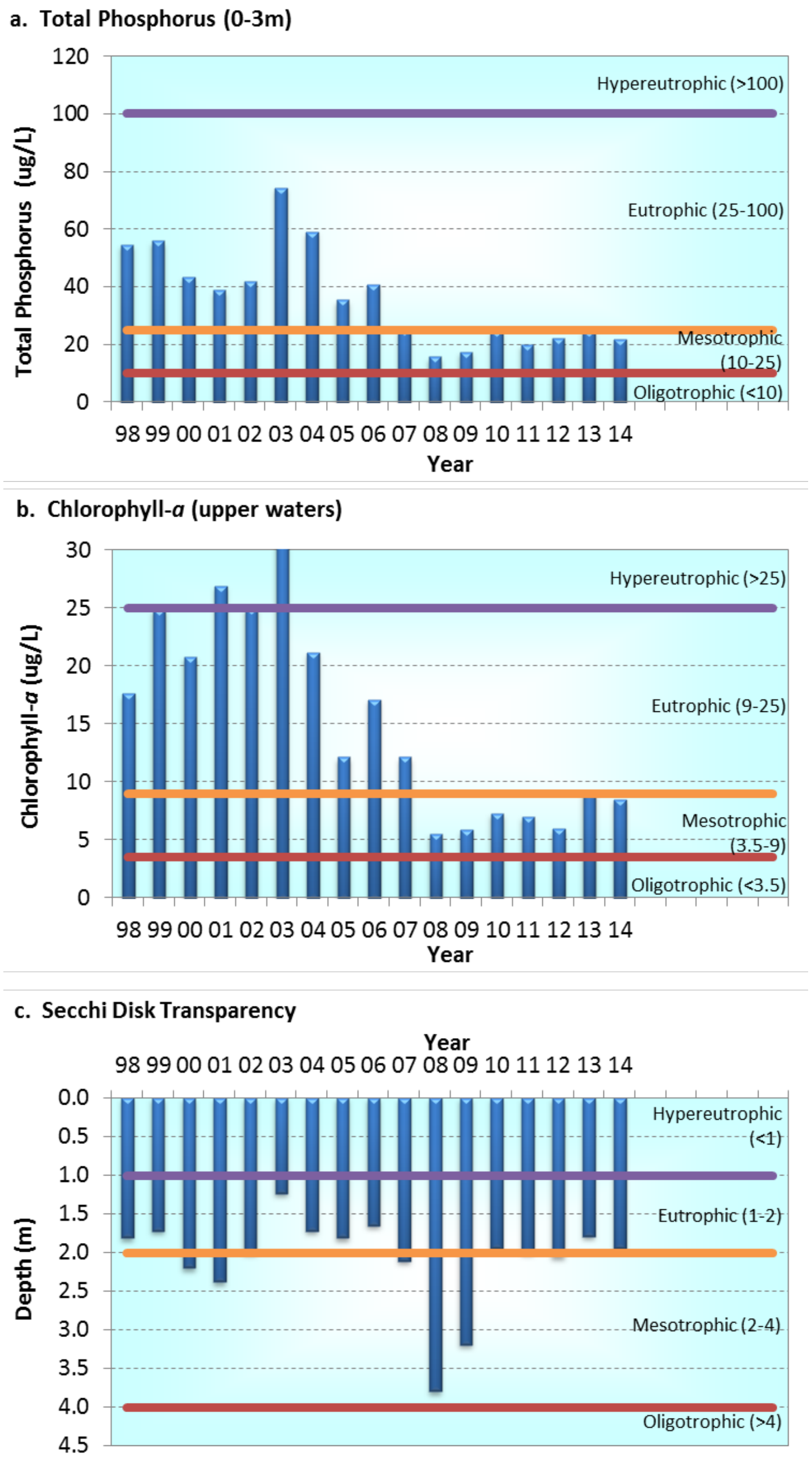


Figure 5-10. Time series of common trophic state indicators based on summer average (June–September) data, 1998–2014.

5.2.5 Comparisons to Other Regional Lakes

In lakes where phytoplankton production is limited by phosphorus, total phosphorus and chlorophyll-*a* are highly correlated. Data from regional lakes, including Onondaga, illustrate this relationship and provide a valuable regional context (Figure 5-11). Data for the Finger Lakes represent results of a NYSDEC survey conducted between 1996 and 1999. The NYSDEC study design called for sampling each Finger Lake monthly between June and August at a single mid-lake station, with the exception of Cayuga Lake, which was sampled at three locations (Callinan 2001). Data for Onondaga and Oneida Lakes have been averaged over these same summer months in this presentation, for data comparability. Oneida Lake data were provided by the Cornell Biological Field Station (Rudstam 2015). Oneida Lake is notably shallower than the Finger Lakes, has a larger proportion of the bottom suitable for dreissenid mussels, and does not develop stable thermal stratification during the summer, features that may contribute to the observed deviations from the other lakes.

Advanced wastewater treatment has resulted in major decreases in total phosphorus and chlorophyll-*a* levels in Onondaga Lake. A comparison of total phosphorus and chlorophyll-*a* conditions in Onondaga Lake to other regional lakes provides context for the magnitude of the water quality improvements that have been achieved. During the 1998–2005 interval total phosphorus and chlorophyll-*a* levels in Onondaga Lake far exceeded those measured in some of the eastern Finger Lakes and Oneida Lake (Figure 5-12). Since 2007, levels of these important water quality indicators have been similar to those measured in Otisco Lake and Oneida Lake. The absence of blue-green algal blooms in Onondaga Lake stands in contrast to the widespread occurrence of harmful algal blooms in lakes across New York State (see http://www.dec.ny.gov/chemical/77118.html for more information).

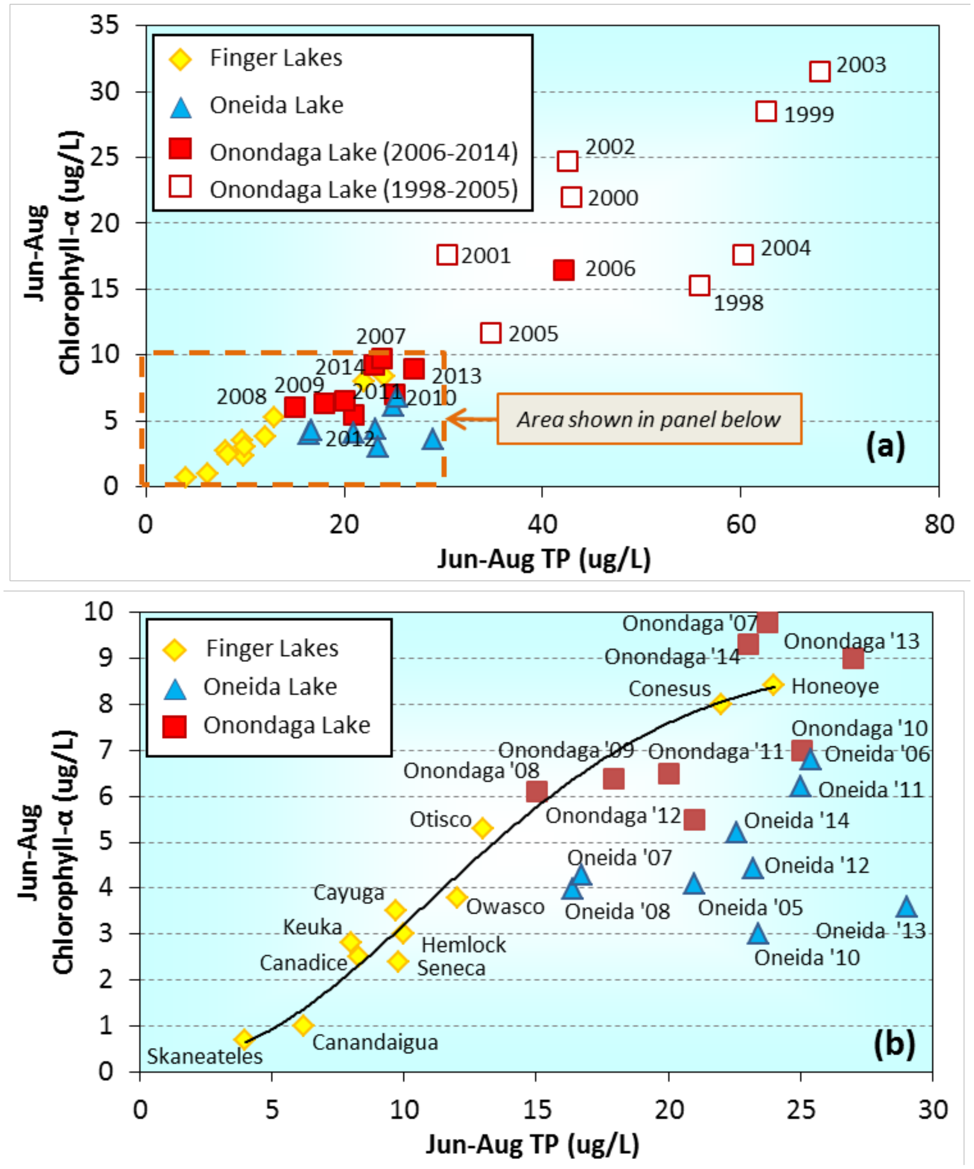


Figure 5-11. June to August average total phosphorus (TP) and chlorophyll-*a* concentrations in Onondaga Lake compared with selected regional lakes.

Note: (a) The top panel shows Onondaga Lake concentrations pre-Actiflo® (1998-2005) and post-Actiflo® (2006-2013. (b) The bottom panel represents the same data, scaled to show the 2007-2014 Onondaga Lake data and a best-fit trendline (R^2 = 0.97) of the Finger Lakes concentrations (1996-1999), and Oneida Lake concentrations (2005-present; Rudstam 2015).

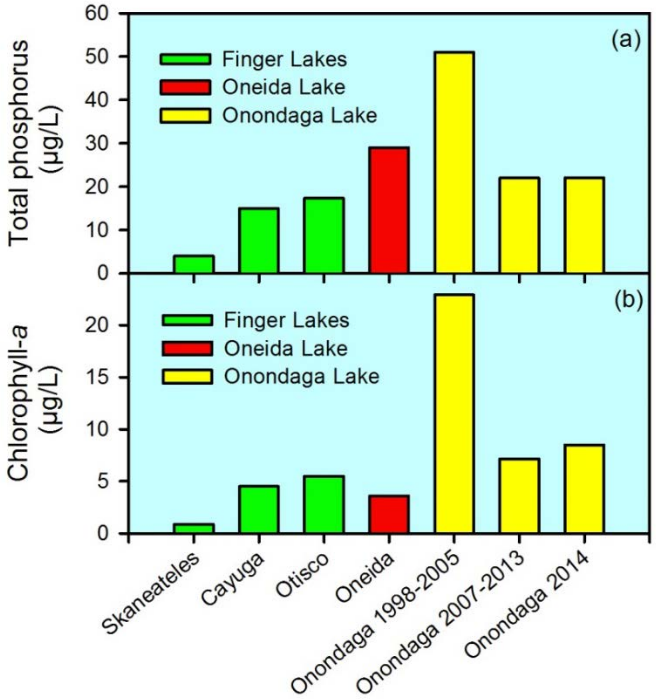


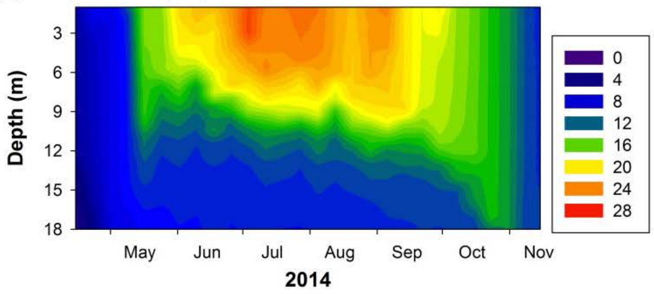
Figure 5-12. A comparison of trophic state metrics in Onondaga Lake and selected regional lakes: (a) summer average (June to September) total phosphorus concentrations and (b) summer average (June to September) chlorophyll-*a* concentrations.

Note: Skaneateles Lake data from 2011, courtesy of the Town of Skaneateles. Cayuga Lake data from 2013, courtesy of Cornell University. Otisco Lake data from 2010-2011, courtesy of NYSDEC. Oneida Lake data courtesy of Dr. Lars Rudstam.

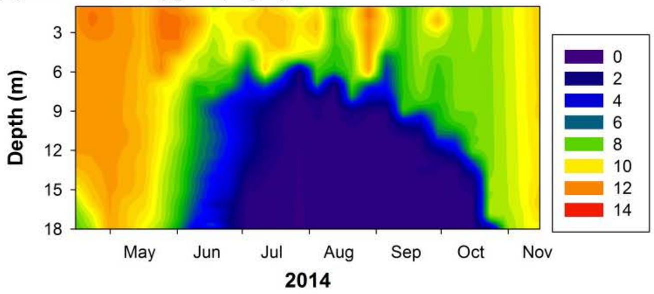
5.3 Dissolved Oxygen

Adequate dissolved oxygen (DO) content is critical for aquatic life and a common focus of water quality monitoring programs. Vertically detailed in-situ profiles of DO, temperature, specific conductance, and chlorophyll-*a* were collected at South Deep during 2014 and are presented here as color contour plots (Figure 5-13). These measurements were made at 1 meter depth increments over the spring to fall interval at South Deep with a monitoring buoy courtesy of Honeywell (http://www.upstatefreshwater.org/NRT-Data/Data/data.html). Dissolved oxygen concentrations were uniformly high throughout the water column through mid-May (Figure 5-13b). Depletion of DO from the lower layers began in mid-May with the onset of thermal stratification, and by mid-July the lake was largely anoxic below a depth of 6 meters (Figure 5-13b). The lower waters were replenished with DO by early November, following the occurrence of fall turnover. There was no noteworthy depletion of DO in the upper waters during the fall of 2014, and the minimum concentration remained well above the AWQS of 4 mg/L (Figure 5-13b).

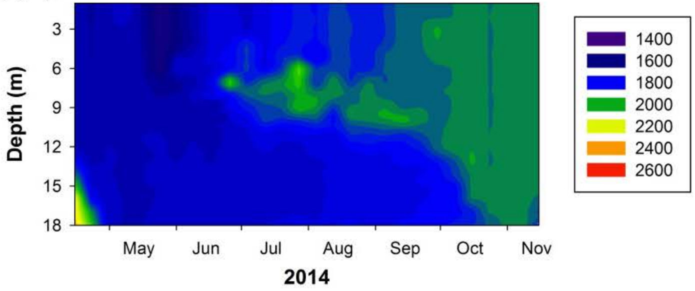
(a) temperature (°C)



(b) dissolved oxygen (mg/L)



(c) specific conductance (μS/cm)



(d) chlorophyll-*a* (μg/L)

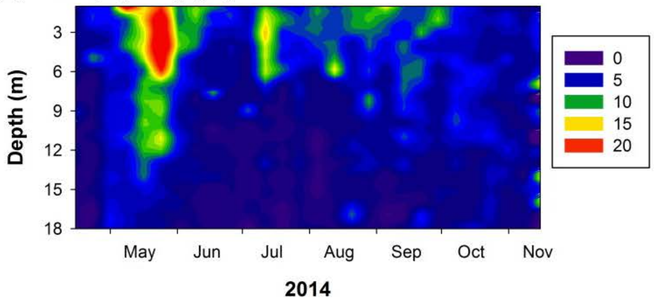


Figure 5-13. Color contour plots of Onondaga Lake in 2014, based on biweekly sensor profiles conducted at South Deep: (a) temperature (°C), (b) dissolved oxygen (mg/L), and (c) specific conductance (µS/cm), (d) chlorophyll-*a* (µg/L).

A high priority goal for rehabilitation of the lake was elimination of severe depletion of DO in the upper waters during the approach to fall turnover in October (Figure 5-14) and contravention of the related AWQS. This goal has been achieved through reductions in Metro loading of both ammonia (Figure 4-8) and total phosphorus (Figure 4-11). Other improvements in the lake's oxygen resources have been observed, particularly within the lower stratified layers (hypolimnion). Following the onset of summer stratification, these layers are subject to oxygen depletion from decay of depositing organic constituents and demand from the underlying sediments. Decreases in deposition of phytoplankton from reductions in Metro phosphorus loading have resulted in lower rates of DO depletion, manifested as a delay in the onset of anoxic conditions and decreases in "volume-days of anoxia" (Figure 5-15). Linear regression analysis indicates significant decreases in both volume days of anoxia (R^2=0.52, p<0.01) and volume days of anoxia + hypoxia (R^2=0.42, p<0.01) over the 1992–2014 interval. When evaluated over the 2000–2014 period, the decreasing trends for anoxic conditions (R^2=0.58, p<0.01) and anoxia + hypoxia (R^2=0.30, p=0.04) remained statistically significant. Since the Actiflo® process came on line in 2005, anoxia has been delayed for a period of several weeks in the lower waters. Some interannual variability is to be expected in this metric due to variations in the onset of stratification from natural meteorological variability. The implications of these improved conditions for the lake's fish community are discussed in Section 6.4.

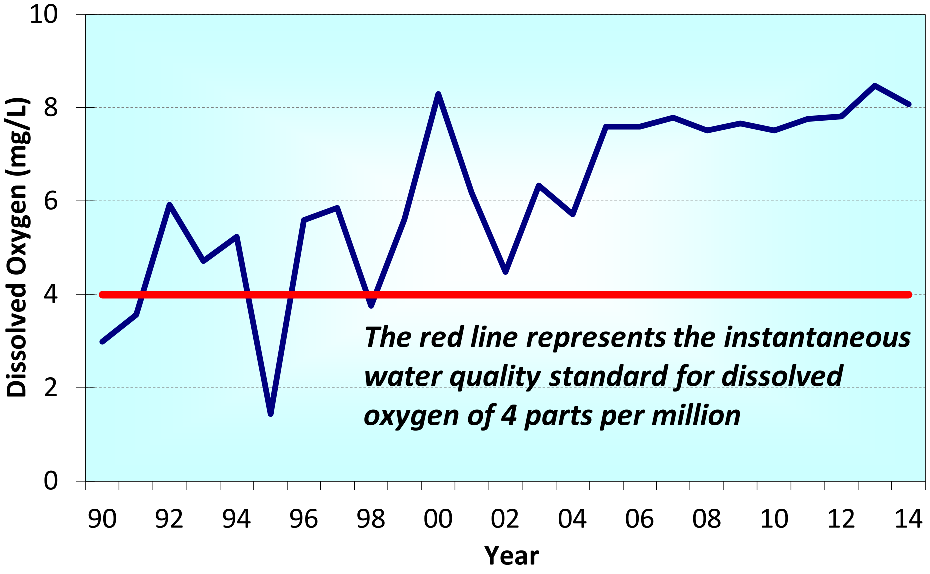


Figure 5-14. Minimum dissolved oxygen (DO) concentration in the upper waters (0-4 meters average) of Onondaga Lake during October, annually 1990–2014.

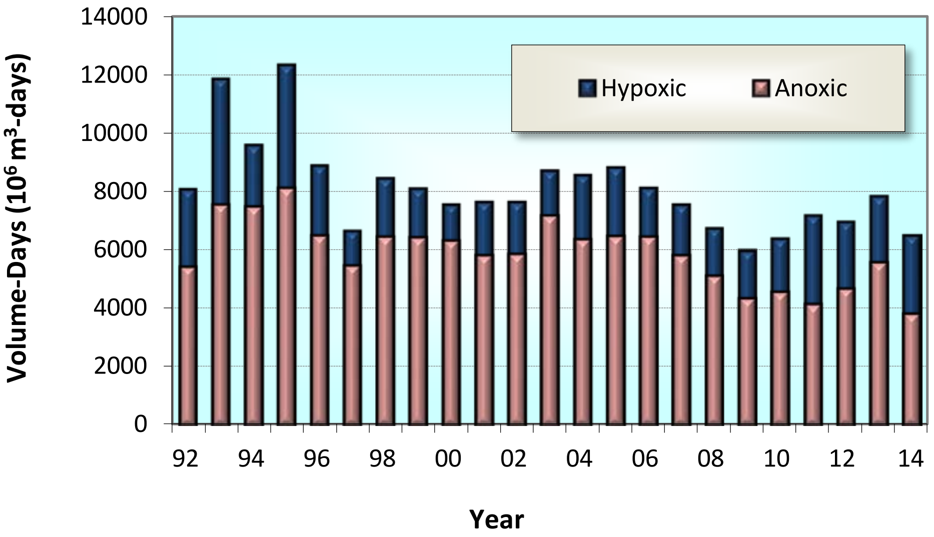


Figure 5-15. Volume-days of anoxia (dissolved oxygen less than 1 mg/L) and hypoxia (dissolved oxygen less than 4 mg/L), in Onondaga Lake, 1992–2014.

5.4 Ammonia, Nitrite, and Nitrate

Prior to the engineering improvements at Metro to bring about efficient year-round nitrification of wastewater, Onondaga Lake was impaired by elevated concentrations of ammonia (NH_3-N). Concentrations of this potentially harmful form of nitrogen exceeded the state ambient water quality standard for protection of aquatic life. Upgraded aeration treatment at Metro in the late 1990s and implementation of the biologically aerated filter (BAF) technology in 2004 significantly reduced ammonia concentrations in the upper waters of the lake (Figure 5-16, Figure 5-17a), enabling a more diverse biota. The lake is now in full compliance with the ambient water quality standards for ammonia (Table 5-1), and in 2008 was officially removed from the New York State's 303(d) list of impaired waterbodies for this water quality parameter.

Efficient year-round nitrification treatment from implementation of the BAF resulted in increased nitrate (NO_3-N) loading to the lake and increased in-lake concentrations (Figure 5-17b). These changes have had some unintended benefits for the lake rehabilitation initiatives, including diminished release of phosphorus and mercury from the sediments during intervals of anoxia (Matthews et al. 2013). A 3-year (2011–2013) whole-lake nitrate addition pilot test was conducted as part of the Honeywell cleanup with the objective of limiting release of methylmercury from the deep-water sediments through maintenance of nitrate concentrations > 1 mg/L. Based on the success of this pilot test, nitrate was added to the hypolimnion again in

2014. During the 2011-2013 nitrate addition pilot test an average of 73 metric tons of nitrate-N was added to the hypolimnion annually. In contrast, annual nitrate loading from Metro averaged 940 metric tons per year over the 2004–2013 interval.

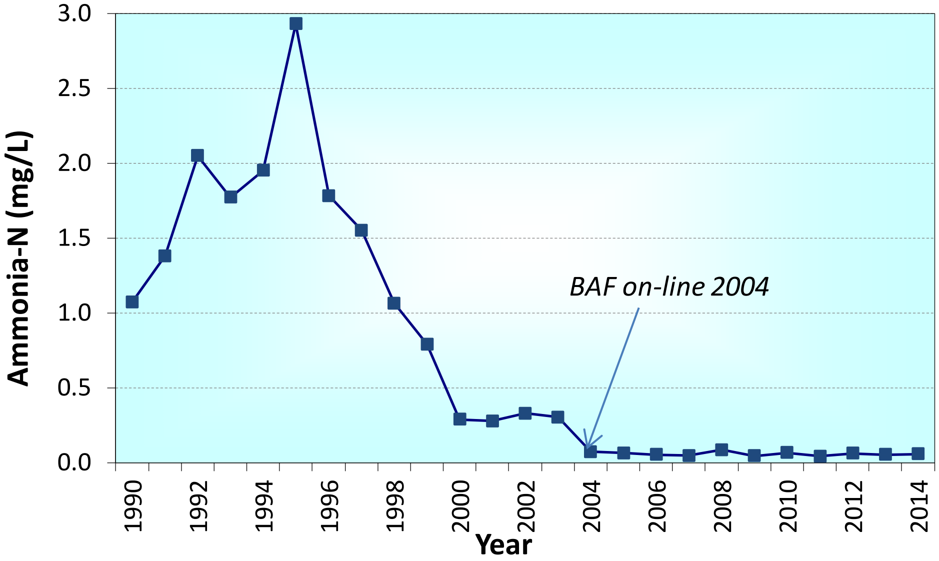


Figure 5-16. Summer average ammonia-N (NH_3-N) concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2014.

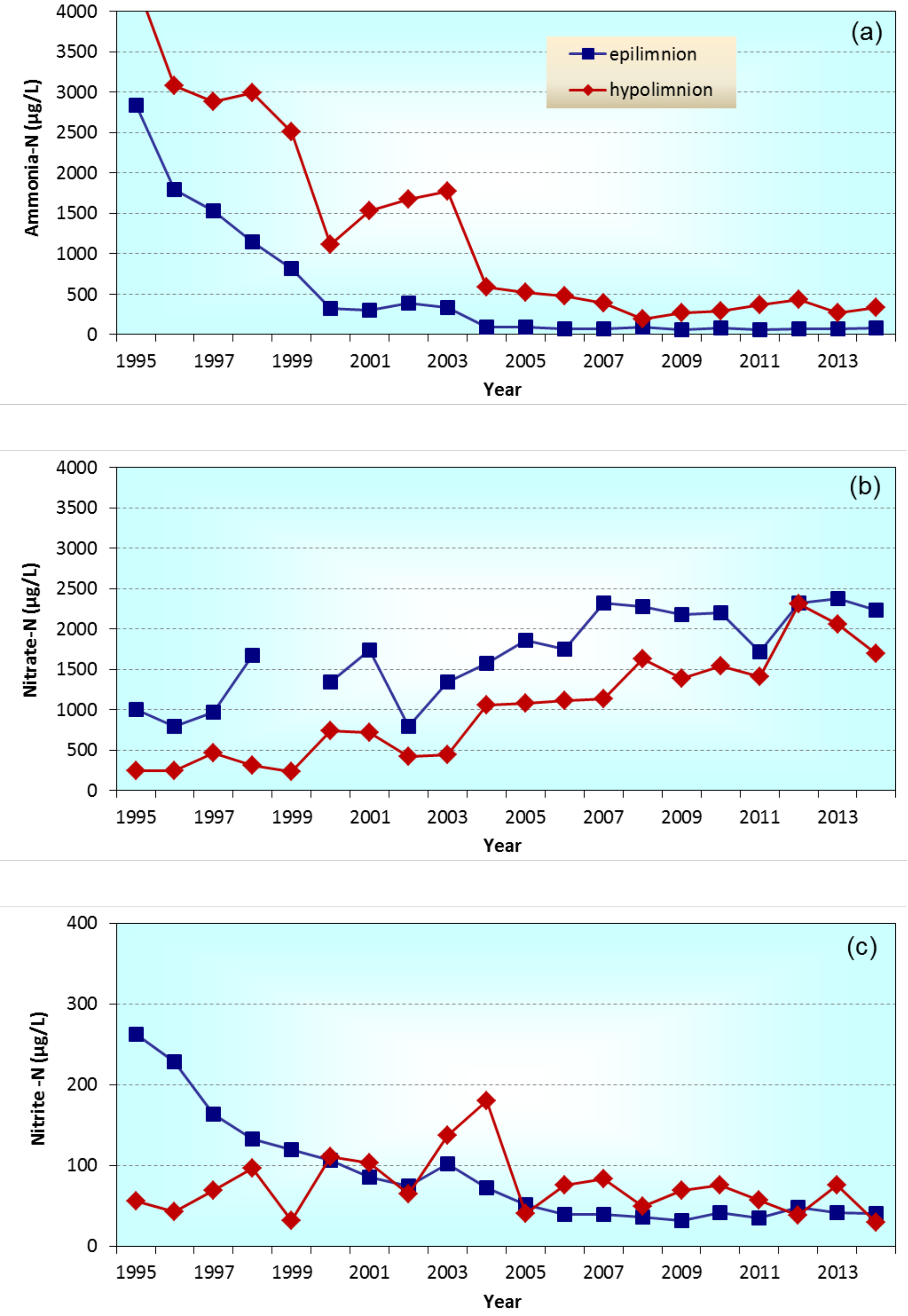


Figure 5-17. Summer average concentrations of nitrogen species in the epilimnion and hypolimnion of Onondaga Lake, 1995–2014: (a) ammonia-N, (b) nitrate-N, and (c) nitrite-N.

Table 5-1. Percent of Onondaga Lake ammonia measurements in compliance with ambient water quality standards, 1998–2014.

Depth (m)	Percent measurements in compliance, NYS Standards																
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	64	62	86	95	68	96	100	100	100	100	100	100	100	100	100	100	100
3	45	67	90	90	68	96	100	100	100	100	100	100	100	100	100	100	100
6	50	86	90	95	73	100	100	100	100	100	100	100	100	100	100	100	100
9	41	76	90	95	73	100	100	100	100	100	100	100	100	100	100	100	100
12	18	52	90	81	50	80	100	100	100	100	100	100	100	100	100	100	100
15	23	52	57	52	41	56	80	100	100	100	100	100	100	100	100	100	100
18	23	48	52	38	32	48	75	95	95	100	100	100	100	100	100	100	100

Nitrite (NO_2-N) concentrations also often exceeded the limit (0.1 mg/L) to protect against possible toxicity effects within the upper waters of the lake before the BAF upgrade at Metro. These exceedances were also eliminated with the lower in-lake nitrite concentrations that accompanied the treatment upgrade (Figure 5-17c). Exceedances of the AWQS now only occur in the lower layers of the lake when dissolved oxygen concentrations are less than 2 mg/L. These conditions reflect incomplete nitrification of ammonia within those lower lake depths. However, these exceedances are not limiting to fish habitat. Rather, the limiting condition is the low oxygen concentration in these lower layers during summer stratification. At oxygen levels required to support fish, these higher nitrite levels would likely not be observed because complete nitrification would occur.

5.5 Deep Water Conditions

The upgrades in treatment at Metro have resulted in profound changes in the lower waters of the lake, in addition to those described previously, associated with both the decreased loading of phosphorus and the increased inputs of nitrate (instead of ammonia). The improvements from reduced phosphorus loading were anticipated, following a well-established logic pattern for rehabilitation of culturally eutrophic lakes. Accordingly, reductions in phosphorus loading are expected to decrease algal growth and associated deposition, thereby decreasing the oxygen demand associated with its decay. This has been manifested as a delay in the onset of anoxia, described previously, which would be expected to translate to some reduction in the release of soluble reactive phosphorus (SRP) from the sediments. When transported to the upper waters by vertical mixing processes, SRP released from the sediments can act to augment phytoplankton growth.

Phosphorus release from the sediments has been greatly diminished by increased in-lake concentrations of nitrate (Matthews et al. 2013). In the presence of dissolved oxygen or nitrate, sediment phosphorus remains in particulate phase, tightly bound to ferric iron. When oxygen and nitrate are depleted from the surface sediments, iron is converted to the reduced ferrous form and soluble reactive phosphorus is released. Thus maintenance of high nitrate concentrations in the hypolimnion serves to effectively block the release of phosphorus from the sediments. In 2009, depletion of nitrate in the lower waters during August and September (Figure 5-18b) resulted in release of soluble reactive phosphorus from the profundal sediments (Figure 5-18c). The complete absence of sediment phosphorus release under the high nitrate concentrations of 2014 (Figure 5-18f) clearly demonstrates the positive effect of nitrate, even under anoxic conditions (Figure 5-18d). This is in stark contrast to the high rates of phosphorus release that prevailed in years when both dissolved oxygen and nitrate were depleted from the hypolimnion (Figure 5-19).

The mass of phosphorus accumulated in the hypolimnion during the summer stratification interval has decreased by 90% since the 1990s (Figure 5-19). Note that the decrease in sediment P release has been in response to both the decrease in primary production from the Metro phosphorus treatment upgrade and the increase in nitrate from the facility's year-round nitrification. Some interannual variations are to be expected due to differences in the duration of stratification and ambient mixing associated with natural meteorological variations. Moreover, the supply of nitrate to the lower waters in summer is now being augmented by Honeywell as a strategy to control sediment release of mercury. Sediment release rates of phosphorus have been particularly low since the initiation of nitrate addition in 2011 (Figure 5-19).

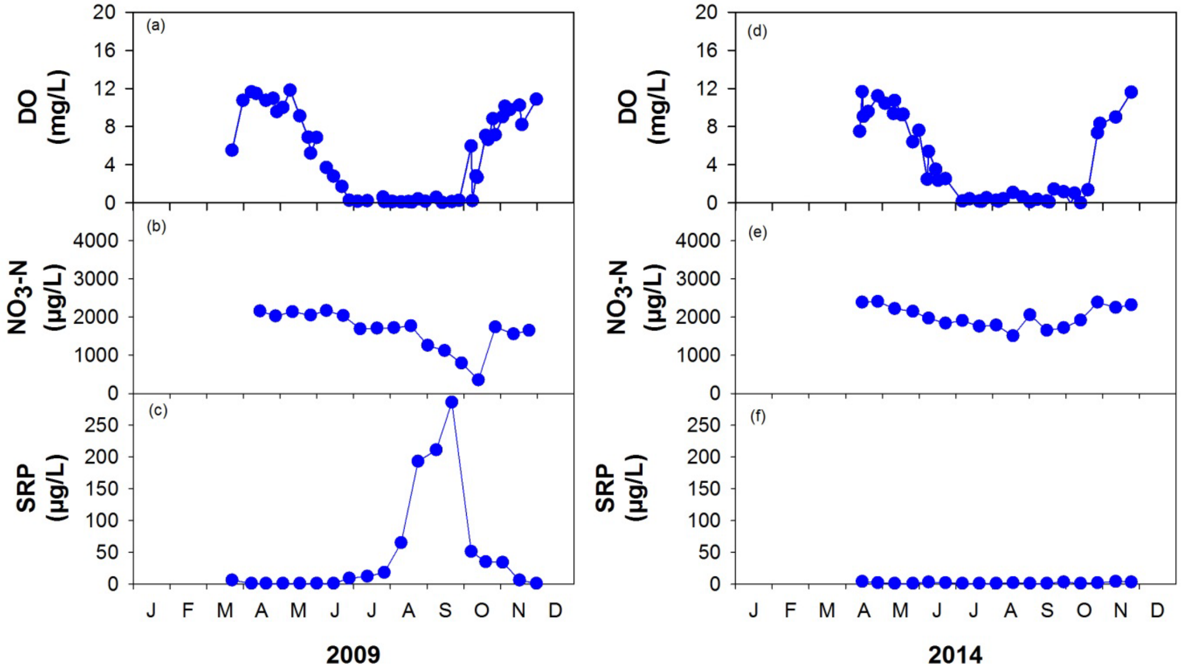


Figure 5-18. Time-series of concentration values in the deep waters of Onondaga Lake: (a) 2009 (18m) dissolved oxygen (DO), (b) 2009 (hypolimnion composite) nitrate (NO_3-N), (c) 2009 (18 m) soluble reactive phosphorus (SRP), (d) 2014 (18 m) dissolved oxygen (DO), (e) 2014 (18m) nitrate (NO_3-N), (f) 2014 (18m) soluble reactive phosphorus (SRP).

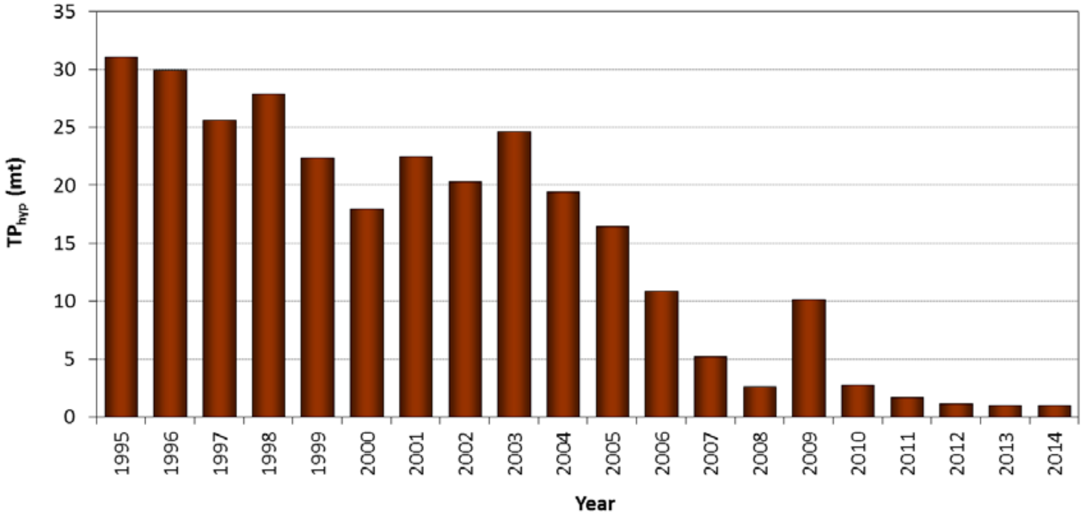


Figure 5-19. The maximum mass of total phosphorus (TP) accumulated in the hypolimnion during summer stratification, 1995–2014.

5.6 Compliance with AWQS

The 2014 monitoring results indicate that the open waters of Onondaga Lake were in compliance with most ambient water quality standards (AWQS), with exceptions noted in Table 5-2. The concentration of total dissolved solids (TDS), which primarily reflects the concentrations of the major cations and anions (calcium (Ca^{2+}), sodium (Na^{+}), magnesium (Mg^{2+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), chloride (Cl^{-}), sulfate (SO_4^{2-})), exceeded the AWQS of 500 mg/L by a wide margin. Exceedance of this standard is associated with the natural hydrogeology of the lake and not with anthropogenic effects. The bedrock in Onondaga County is comprised of Paleozoic sedimentary rocks with high concentrations of calcium and sulfate, which contribute to the high TDS levels in Onondaga Lake and its tributaries.

Table 5-2. Percentage of measurements in compliance with ambient water quality standards (AWQS) and guidance values in the upper and lower waters of Onondaga Lake at South Deep in 2014.

Parameter[5]	AWQS/Guidance Value	Upper Waters		Lower Waters	
		Depths	%	Depths	%
Dissolved Oxygen (n=213)	≥4 mg/L instantaneous[1]	2m	100%	12m	*52%*
Dissolved Oxygen (n=213)	≥5 mg/L daily average[1]	2m	100%	12m	*50%*
pH (n=17)	6.5–8.5	0–6m	100%	12–18m	100%
Total Phosphorus (n=9)	≤20 µg/L summer average[2]	0, 3m	*0%* *(22 µg/L)*	--	--
Ammonia (n=17)	variable[3]	0, 3, 6m	100%	12, 15, 18m	100%
Nitrite (n=17)	≤0.1 mg/L	3m	100%	15, 18m	100%
Total Dissolved Solids (n=17)	≤500 mg/L	3m	*0%*	15m	*0%*
Dissolved Mercury (n=3)	≤0.7 ng/L	3m	*67%*	18m	100%
Fecal Coliform Bacteria (n=7)	≤200 cfu/100 mL monthly geomean[4]	0m	100%	--	--

Notes:
Dashed lines indicate that compliance was not evaluated; parameters listed in bold are cited in the ACJ; occurrences of less than 100% compliance are highlighted in italic red text.

[1] Dissolved oxygen compliance based on buoy data from 2 m and 12 m depths (one to four profiles per day).
[2] Total phosphorus compliance based on the average for the June 1–September 30 period.
[3] The AWQS for ammonia varies as a function of pH and temperature.
[4] The AWQS for fecal coliform bacteria is specified as the monthly geometric mean being less than or equal to 200 colony forming units (cfu) per 100 milliliters (mL) during the period of Metro disinfection (April 1–October 15).
[5] n refers to the number of measurements for the upper and lower waters individually. For example, compliance with the AWQS for dissolved oxygen was based on 213 measurements from 2 m and 213 measurements from 12 m.

New York State has promulgated a narrative standard for phosphorus in water: "None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages" (NYSCRR §703.2). For ponded waters the narrative standard is interpreted using a guidance value of 20 µg/L, calculated as the average total phosphorus concentration in the lake's upper waters between June 1 and September 30. A total maximum daily load (TMDL) allocation for phosphorus inputs to Onondaga Lake has been developed to meet this water quality goal. The phosphorus TMDL was approved by USEPA on June 29, 2012. The 2014 summer average total phosphorus (TP) concentration in the lake's upper waters was 22 µg/L, slightly higher than the state's guidance value of 20 µg/L. Five of the nine TP values measured during the June–September period exceeded 20 µg/L.

Based on long-term consistent compliance with AWQS, quarterly sampling of metals in the lake was discontinued in 2013. Samples for analysis of total mercury, dissolved mercury, and methylmercury were collected from South Deep at two depths (3 meters and 18 meters) in May, August, and October of 2014. Sampling for mercury was not conducted at North Deep in 2014. Methylmercury is of particular concern because it bioaccumulates strongly in aquatic food webs, resulting in toxic effects at upper trophic levels when concentrations are high. The AWQS for dissolved mercury in Class B and C waters is 0.7 nanograms per liter (ng/L). This standard was exceeded in the upper waters in May. The time series of total mercury and methylmercury concentrations measured in both the upper and lower waters of Onondaga Lake since 1999 indicate a substantial reduction in the concentration of this heavy metal (Figure 5-20).

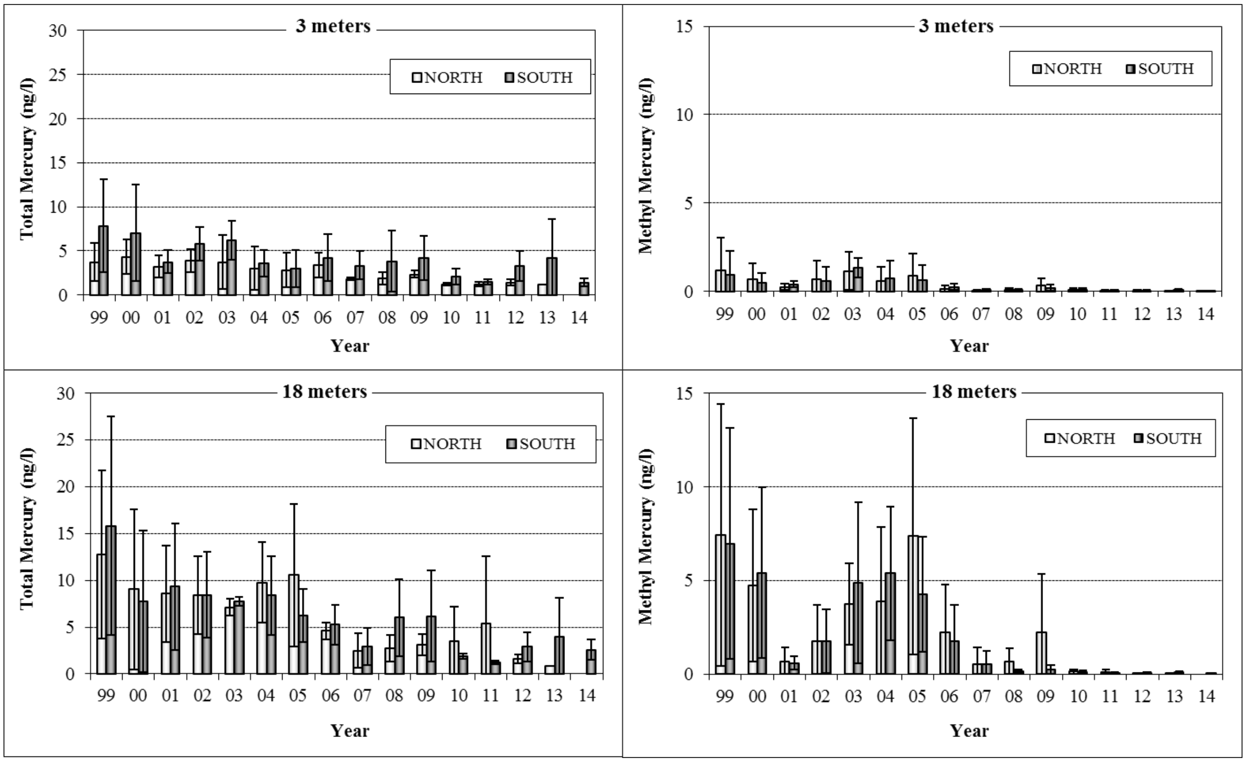


Figure 5-20. Time series of annual average mercury (Hg) concentrations at the North and South Deep stations of Onondaga Lake, 1999–2014 (a) total Hg at 3 m, (b) methyl Hg at 3 m, (c) total Hg at 18 m, and (d) methyl Hg at 18 m.

Note: The error bars depict one standard deviation of the annual mean concentration. North site sampling discontinued in 2014 and no error bar on north deep total and methyl Hg in 2013 data because only one useable sample.

Dissolved oxygen (DO) concentrations met the AWQS (Table 5-3) in the upper waters of Onondaga Lake throughout the 2014 sampling period. DO concentrations in the lower waters were below the minimum 4 mg/L during a portion of the summer stratified period. However, this situation is not uncommon in stratified lakes where the volume of the lower stratum (the hypolimnion) is relatively small. In New York, an estimated 70% of assessed lakes do not meet the minimum DO standards in the deep waters (NYSDEC Consolidated Assessment and Listing Methodology, May 2009). In the ***TMDL for Phosphorus in Onondaga Lake***, NYSDEC concluded that the Lake is unable to meet the existing statewide DO water quality standard at all times during the year in the lower depths of the Lake because natural conditions contribute to the depletion of oxygen in the hypolimnion. NYSDEC has not classified Onondaga Lake as trout water (T) or trout spawning water (TS). The onset of anoxia in the lake's lower waters is occurring later, suggesting improved water quality and habitat conditions.

Table 5-3. New York State water quality standards for dissolved oxygen.

AA, A, B, C, AA-Special	For trout spawning waters (TS), the DO concentration shall not be less than 7.0 mg/L from other than natural conditions. For trout waters (T), the minimum daily average shall not be less than 6.0 mg/L, and at no time shall the concentration be less than 5.0 mg/L. For non-trout 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 2014, the measured fecal coliform bacteria counts at the Onondaga Lake monitoring stations were in compliance with the ambient water quality standard (monthly geometric mean concentration from at least five samples less than or equal to 200 cfu/100 mL) at offshore and nearshore locations within the Class B portion of the lake. Three sites, located within the Class C segment of the lake's southeastern shoreline, exceeded the bacteria standard during the month of October, and one of these sites also exceeded the standard in April (see Section 5.7). The other locations within the Class C water segment met the ambient water quality standard for all monitored months.

5.7 Recreational Water Quality

The suitability of Onondaga Lake for water contact recreation is assessed using two parameters: fecal coliform bacteria and water clarity. Substantial inputs of bacteria and turbidity (causing reductions in clarity) often occur in both urban and agricultural areas during runoff events from the wash-off of pollutants from land surfaces and overflow of combined sewers. In New York State, fecal coliform bacteria (a class of bacteria present in the intestinal tract of all mammals) are used to indicate the potential presence of raw or partially treated sewage in water. Although most strains of fecal coliform bacteria are not harmful, the abundance of fecal coliform bacteria in water is correlated with the risk of encountering pathogenic (disease-causing) microorganisms, including bacteria, viruses, and parasites.

The applicable New York State ambient water quality standard for fecal coliform bacteria in surface water, as set forth in 6NYCRR Part 703.4, is as follows: for classes A, B, C, D, SB, SC - the monthly geometric mean concentration of fecal coliform bacteria (colony forming units, cfu, per 100 mL), from a minimum of five examinations, shall not exceed 200 cfu per 100 mL. The fecal coliform standard for classes B, C, D, and SB shall be met during all periods: (1) when disinfection is required for SPDES permitted discharges directly into, or affecting the best usage of the water; or (2) when NYSDEC determines it necessary to protect human health. The NYS Department of Health (NYSDOH) criterion for fecal coliform in bathing beaches are ≤ 1,000 per 100 mL for a single sample and ≤ 200 per 100 mL for a 30 day geometric mean. Presently, there is no public bathing beach located on Onondaga Lake.

The 30-day standard is applied on a monthly basis to assess bacterial contamination at nearshore locations (Figure 5-21) as well as at the open water sites North Deep and South Deep (refer to Figure 1-2). Bacteria levels in southern portions of the lake often increase following significant rainfall, and concentrations can vary by orders of magnitude due to the event-driven nature of the sources. Consequently, geometric means are appropriate for examining spatial and temporal trends. During the April to October interval of 2014, bacteria levels in Class B areas of Onondaga Lake did not exceed the standard established for contact recreation. Three sites (LS_HARB, LS_METRO, LS_OUT), located within the Class C segment of the lake's southeastern shoreline (Figure 5-21), exceeded the bacteria standard during the month of April. In addition, LS_OUT exceeded the standard in June and LS_METRO exceeded the standard in October. LS_HARB, LS_METRO, and LS_OUT are located near the outlets of Harbor Brook, Metro, and Onondaga Creek, respectively. Bacterial counts at the two offshore monitoring locations, North Deep and South Deep, were below the AWQS for fecal coliform bacteria throughout the 2014 assessment period.

Water clarity is measured at the same network of ten near shore stations. While there is no NYSDEC standard for water clarity, the NYSDOH has a swimming safety guidance value for designated bathing beaches of 4 feet (1.2 meters). The NYSDOH swimming safety guidance value was met in Class B waters throughout the summer recreational period of 2014 (Figure 5-22). Monitoring locations in the southern end of the lake, near the mouths of Onondaga Creek, Harbor Brook, and Ley Creek, regularly failed to meet this guidance value. Sediment inputs from the mud boils on upper Onondaga Creek likely contributed to the diminished water clarity in nearshore areas of the Class C segment in the southern portion of the lake. The guidance value for clarity was met in the Class C segment at the mouth of Ninemile Creek on 18 of the 22 monitoring dates (82%). Dreissenid (zebra, quagga) mussels likely have a significant positive impact on water clarity in the nearshore, while zooplankton have a greater effect on clarity in offshore regions.

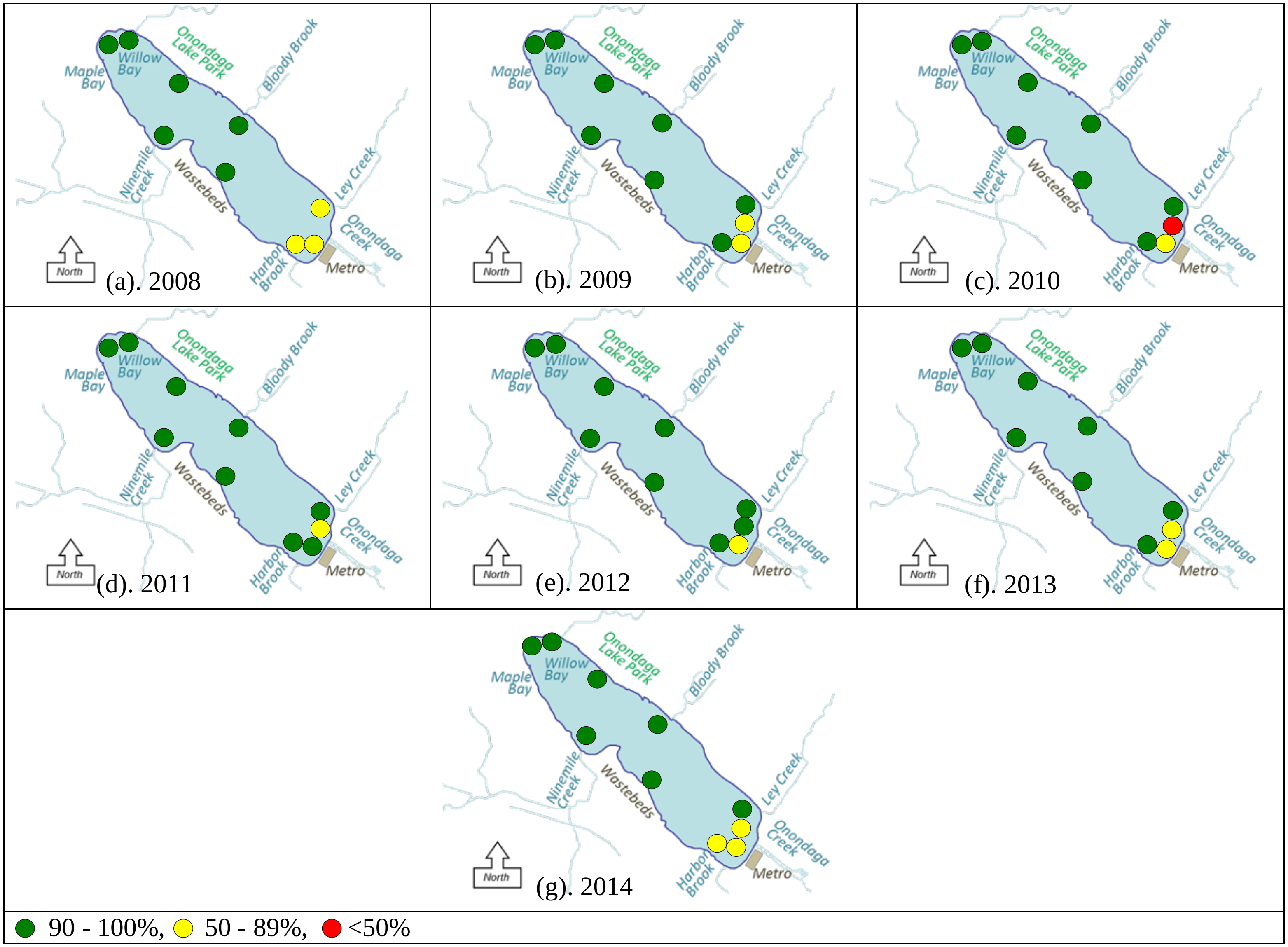


Figure 5-21. The percentage of months in compliance with the water quality standard for fecal coliform bacteria for nearshore stations in Onondaga Lake, April–October: (a) 2008, (b) 2009, (c) 2010, (d) 2011, (e) 2012, (f) 2013, and (g) 2014.

Note: Compliance is calculated for each location by comparing the monthly geometric mean of a minimum of five samples with the AWQS (200 cfu/100 mL).

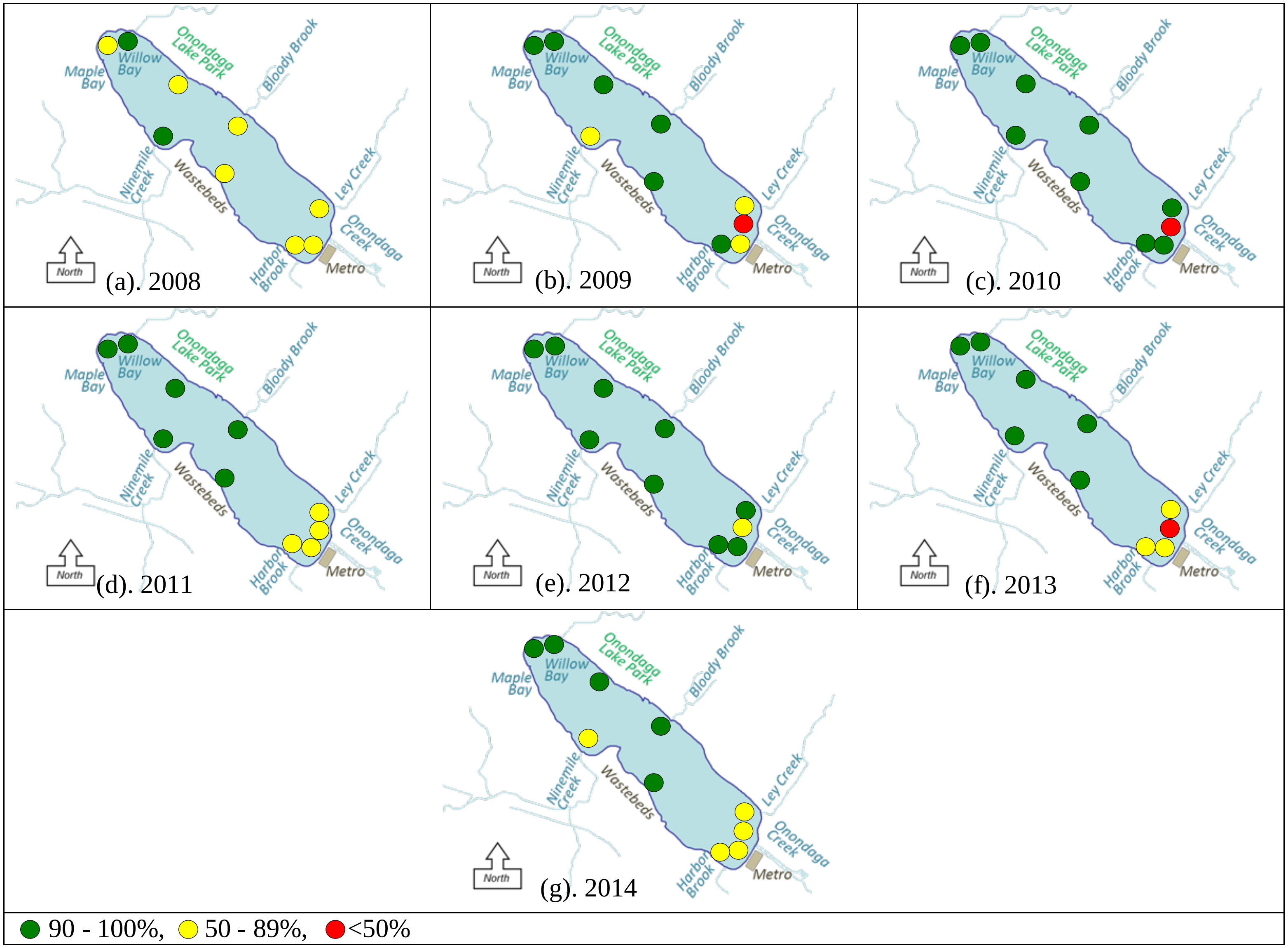


Figure 5-22. Percentage of nearshore Secchi disk transparency measurements greater than 1.2 meters (4 feet) during June–September: (a) 2008, (b) 2009, (c) 2010, (d) 2011, (e) 2012, (f) 2013, and (g) 2014.

5.8 Long-Term Trends in Water Quality

Advanced wastewater treatment at Metro has resulted in major reductions in loading of total phosphorus, ammonia, and nitrite to Onondaga Lake. The lake has responded positively to these loading reductions, with major improvements documented for a number of key water quality parameters. In this section long-term trends are identified using various statistical approaches, including seasonal Kendall tests, change-point analysis, and least squares linear regression models.

5.8.1 10–Year Water Quality Trends: 2005–2014

Water quality trends for the last 10 years (2005–2014) were evaluated statistically using the two-tailed seasonal Kendall test (Table 5-4). It is important to note that the 10-year period covered by this analysis (2005–2014) primarily reflects conditions following the major treatment upgrades at Metro in 2004 and 2005. The number of trends identified as significant and the strength of these trends has diminished as the 10-year analysis period has shifted further in time from the Metro upgrades. Nevertheless, significant decreasing trends were identified for ammonia, total phosphorus, soluble reactive phosphorus, and chlorophyll-*a* (Table 5-4). The significant increase in nitrate over the same period is primarily a manifestation of year-round nitrification at Metro. Honeywell's nitrate addition pilot project also increased nitrate levels in the hypolimnion during 2011–2014.

Table 5-4. Summary of statistically significant trends in lake concentrations during the 2005 to 2014 period, according to two-tailed Seasonal Kendall tests that account for serial correlation.

Note: See table footnotes for color code. "Upper waters" refers to the 0-3m depth interval and "lower waters" refers to the 12-18m interval.

Variables		South Basin		North Basin		Lake Outlet	
		upper waters	lower waters	upper waters	lower waters	0.6m	3.7m
Clarity	Secchi disk transparency	○	--	○	--	--	--
Bacteria	Fecal coliforms	○	--	○	--	**-9.5%**	--
Nitrogen	Ammonia (NH_3-N)	**-3.6%**	**-5.4%**	○	**-6.6%**	**-6.3%**	○
	Nitrite (NO_2-N)	○	○	○	○	○	○
	Nitrate (NO_3-N)	**2.2%**	**4.7%**	○	**3.8%**	○	**2.5%**
	Organic nitrogen as N	○	**1.5%**	○	○	○	○
	Total Kjeldahl nitrogen as N (TKN)	○	○	○	○	○	○
Phosphorus	Total phosphorus (TP)	**-7.1%**	**-10.6%**	**-9.5%**	**-12.0%**	**-10.2%**	**-7.2%**
	Soluble reactive phosphorus (SRP)	**-2.9%**	**-23.9%**	**-13.4%**	**-29.3%**	**-21.3%**	**-17.1%**

Table 5-4. Summary of statistically significant trends in lake concentrations during the 2005 to 2014 period, according to two-tailed Seasonal Kendall tests that account for serial correlation.

Note: See table footnotes for color code. "Upper waters" refers to the 0-3m depth interval and "lower waters" refers to the 12-18m interval.

Variables		South Basin		North Basin		Lake Outlet	
		upper waters	lower waters	upper waters	lower waters	0.6m	3.7m
Solids	Total suspended solids (TSS)	○	○	○	○	○	○
	Total dissolved solids (TDS)	○	○	○	○	○	○
Chlorophyll	Chlorophyll-*a*	**-5.5%**	--	○	--	--	--
	Phaeophytin-*a*	**-7.9%**	--	**-9.9%**	--	○	**-8.6%**
Carbon	Total organic carbon (TOC)	**-1.3%**	○	○	○	○	**-1.3%**
	Total inorganic carbon (TIC)	**-1.3%**	**-2.3%**	**-1.7%**	**-2.3%**	**-2.2%**	**-2.2%**
Other	Alkalinity as $CaCO_3$	○	○	○	○	○	○
	Calcium (Ca)	○	○	○	○	○	○
	Chloride (Cl)	○	○	○	○	○	○
	Specific conductance	○	○	○	○	○	○
	Dissolved oxygen (DO)	○	**0.8%**	○	**0.9%**	○	○
	Magnesium (Mg)	○	○	○	○	○	**-0.9%**
	Manganese (Mn)	**-1.8%**	○	○	○	**-3.1%**	**-1.1%**
	Sodium (Na)	○	○	○	○	○	○
	pH	○	○	○	○	**0.3%**	○
	Dissolved Silica (SiO_2)	○	○	○	○	○	○
	Sulfate (SO_4)	○	○	○	○	**-3.0%**	**-1.4%**
	Temperature	○	○	○	○	○	○

Notes:
Two-tailed Seasonal Kendall test accounting for serial correlation, evaluated at the 10% significance level.
Blue value (%) indicates decreasing trend
Red value (%) indicates increasing trend
○ indicates no trend
- dash indicates parameter not measured at this location.

5.8.2 Change-Point Analysis for Detection of Step Trends

Change-point analysis is a non-parametric approach developed to identify the occurrence and timing of statistically significant changes in time-series data. Change-point analysis can detect multiple changes in a time series, and for each change provide a confidence level that the change occurred and an estimate of the time of the change with a corresponding confidence interval. Unlike the Seasonal Kendall or linear regression approaches used previously in the AMP, change-point analysis is particularly well-suited for detection of step trends and for identification of multiple changes within a given time interval (e.g., a decrease followed by an increase). Software to conduct change-point analyses is available as a package for the **R** statistical environment (Killick and Eckley 2014) and as a Microsoft Excel add-in (Taylor 2003). Here we applied change-point analysis to two selected long-term time-series from the AMP database, total phosphorus and chlorophyll-*a* from the upper waters at South Deep during 1990–2014.

The change-point analysis for summer average total phosphorus (TP) concentrations during 1990–2014 detected significant changes in 1997 and in 2007 (Figure 5-23). TP concentrations decreased from 82 µg/L during 1990–1996 to 50 µg/L during 1997–2006 to 22 µg/L during 2007–2014. Note that 95% confidence intervals and confidence levels are provided for each significant change. Accordingly, there is a 95% probability that the first change occurred between 1992 and 1999, with a best estimate of 1997. Similarly, the 95% confidence interval for the second change is 2006–2007, with a best estimate of 2007. There is slightly more confidence in the second change (100%) than in the first (97%). The timing of these changes corresponds quite closely to known upgrades in phosphorus treatment at Metro.

Analysis of the long-term time series of summer average chlorophyll-*a* (Chl-*a*) concentrations indicated a single significant change in 2005 (95% confidence interval 2001–2006; Figure 5-24). Chl-*a* concentrations decreased from an average of 24 µg/L during 1990–2004 to 9 µg/L during 2006–2013. In addition, there was a significant decrease in interannual variability detected beginning in 1998. The first change-point (1998) represents the change in variance and the second change-point (2005) represents the change in the mean value. The estimated timing of the Chl-*a* decrease in 2005 coincided with the phosphorus treatment upgrades at Metro. These examples suggest that change-point analysis is a potentially useful tool for the detection of trends in the AMP.

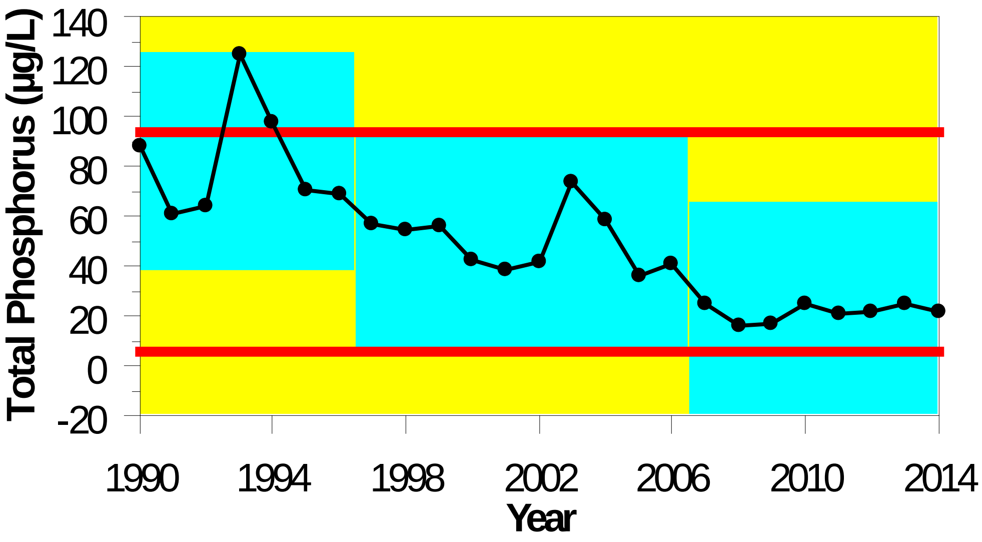


Table of Significant Changes for Total Phosphorus

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, without replacement

Year	Confidence Interval	Confidence Level	From	To
1997	(1992, 1999)	97%	82.3 µg/L	50.2 µg/L
2007	(2006, 2007)	100%	50.2 µg/L	21.6 µg/L

Figure 5-23. Change-point analysis for summer average total phosphorus concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2014.

Note: The red lines are control limits, the maximum range that the values are expected to vary over assuming no change has occurred. The blue background is the region expected to contain all the values based on the current model that two changes occurred.

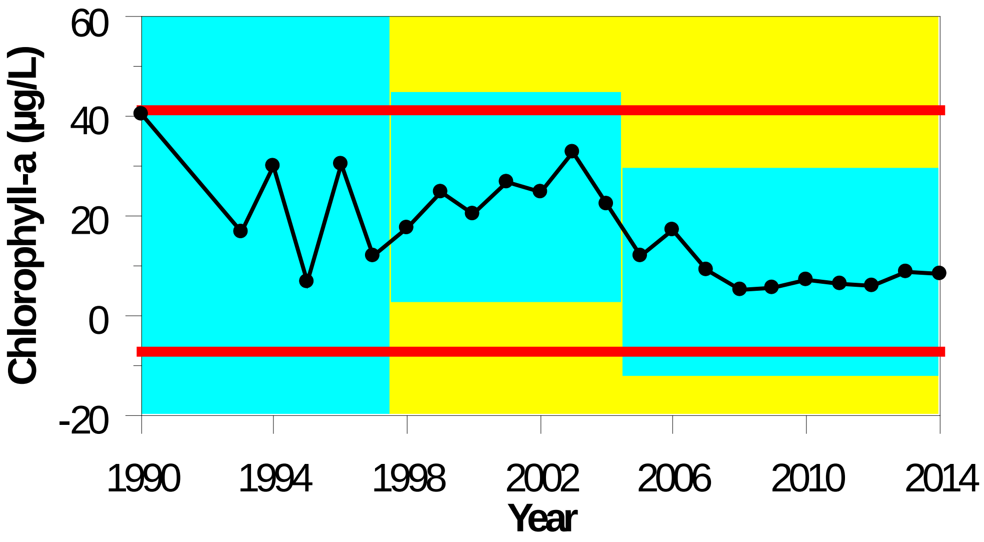


Table of Significant Changes for Chlorophyll-*a*

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, without replacement

Year	Confidence Interval	Confidence Level	From	To
2005	(2001, 2006)	100%	23.7 µg/L	8.8 µg/L

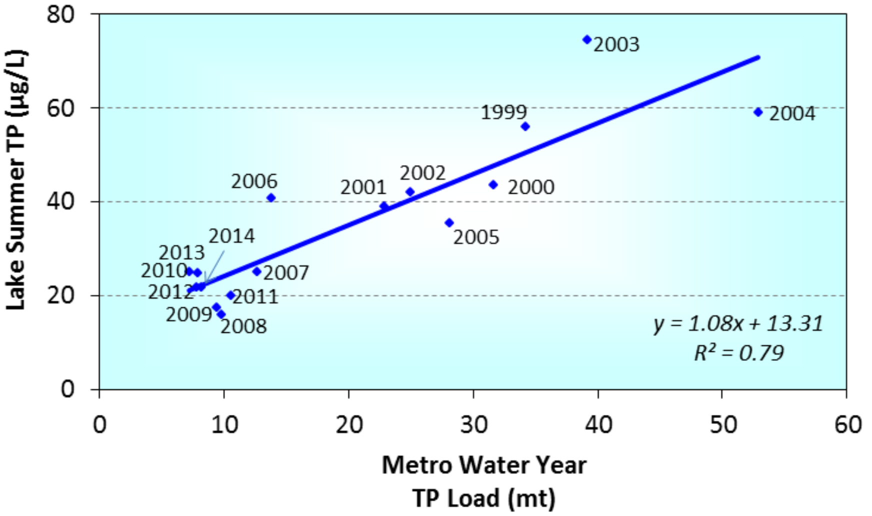
Figure 5-24. Change-point analysis for summer average chlorophyll-*a* concentrations in the upper waters (0-3 meters) of Onondaga Lake, 1990–2014.

Note: The red lines are control limits, the maximum range that the values are expected to vary over assuming no change has occurred. The blue background is the region expected to contain all the values based on the current model that one change occurred. The change indicated in 1998 is a change in variance and not a change in the mean value.

5.8.3 Drivers of Long-term Phosphorus Trends

Scatterplots of water year (October 1 to September 30) total phosphorus (TP) loading estimates and summer average (June 1 to September 30) TP concentrations for the 1999 to 2014 period depict systematic decreases in both loading and in-lake concentrations achieved by the upgrades in treatment at Metro (Figure 5-25). The water year time segmentation is more consistent with the specified summer interval of the in-lake total phosphorus guidance value than an annual load. Empirical analysis according to linear least-squares regression demonstrates that changes in Metro loads explained 79% (R^2 = 0.79) of the observed variations in the summer average total phosphorus concentration of the upper waters (Figures 5-25a). The relationship becomes substantially weaker (R^2 = 0.42) when tributary contributions are included in the independent variable (Figure 5-25b). The weaker empirical model from inclusion of tributary contributions is attributable to multiple factors, including (1) disproportionately large inputs of total phosphorus from tributaries during intervals of the year that do not contribute substantively to in-lake total phosphorus concentrations during summer, (2) large interannual variations in tributary total phosphorus loading associated with natural variations in runoff, and (3) differences in the in-lake behavior of tributary phosphorus inputs compared to those from Metro.

a. Lake TP Concentration vs Metro TP Load



b. Lake TP Concentration vs Total TP Load

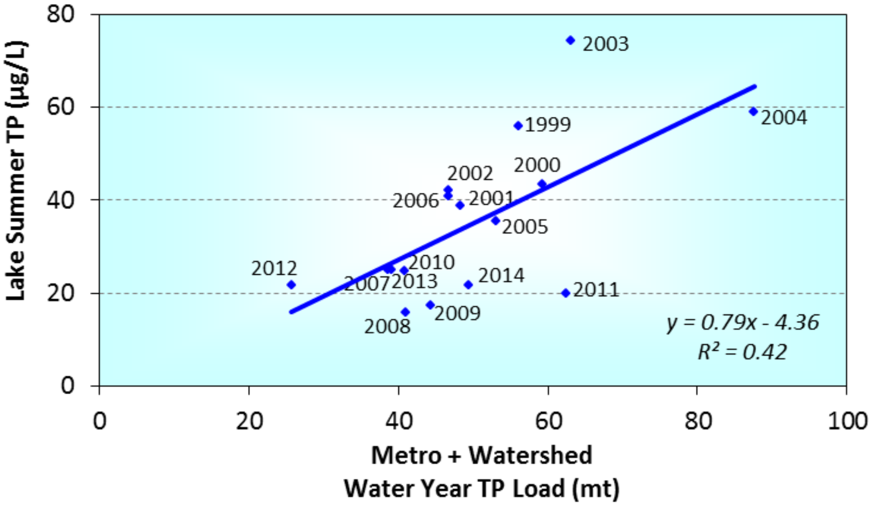


Figure 5-25. Evaluation of the relationship between summer (June–September) average total phosphorus (TP) concentration in the upper waters (0–3 meters) of Onondaga Lake and TP loading for the 1999–2014 period.

Note: Loads are presented on a water year (October 1–September 30) basis for (a) Metro, and (b) the sum of Metro and the tributaries.

5.8.4 Application of Empirical Models to Explain Contemporary Dynamics in Total Phosphorus and Chlorophyll-a

Summer average total phosphorus concentrations in the upper waters have varied from 15 (2008) to 41 µg/L (2006) over the nine year interval (2006–2014) following implementation of Actiflo® treatment. The regulatory goal of 20 µg/L has been met in three (2008, 2009, 2011) of these years. The drivers of the contemporary dynamics of trophic state metrics and their relative effects are of water quality and management interest, particularly given the year-to-year differences in the status of the lake related to the goal. Multiple linear regression models for summer average total phosphorus (TP_{epi}) and chlorophyll-*a* (Chl-a_{epi}) were developed and tested by Matthews et al. (2015) for the post-Actiflo® interval of 2006–2011, considering three potential drivers of year-to-year variations: the total phosphorus concentration of the Metro effluent (TP_{Metro}), tributary flow (Q_{ON}), and the presence of *Daphnia* (D). The models considered these drivers for the summer (June–September) interval, consistent with the specification for the total phosphorus goal. Tributary flow, a surrogate for phosphorus loading from the watershed, was represented as the summer average for Onondaga Creek (Q_{ON}, m^3/s). Flows for the other tributaries have been found to be strongly correlated to Q_{ON} (Effler 1996). The effect of *Daphnia* grazing (D) was represented as a categorical variable, either present (D = 1) or absent (D = 0). We have extended the original analysis to include the 2006–2014 interval.

The updated best-fit multiple regression relationships were

$$TP_{epi} = 241.4\,(TP_{Metro}) + 4.37\,(Q_{ON}) - 9.09\,(D) - 10.16 \qquad (1)$$

$$\text{Chl-}a_{epi} = 139.2\,(TP_{Metro}) + 2.35\,(Q_{ON}) - 3.52\,(D) - 10.86 \qquad (2)$$

These relationships explained 90% and 87% of the observed variations in TP_{epi} and Chl-a_{epi}, respectively (Figure 5-26). Despite the small sample size (n = 9 years), *p* values for both expressions were highly significant ($p<0.001$). The *p* values for the TP_{Metro}, Q_{ON}, and D components of the TP_{epi} model were 0.019, 0.004, and 0.015, respectively; for the Chl-a_{epi} model these were 0.015, 0.004 and 0.048.

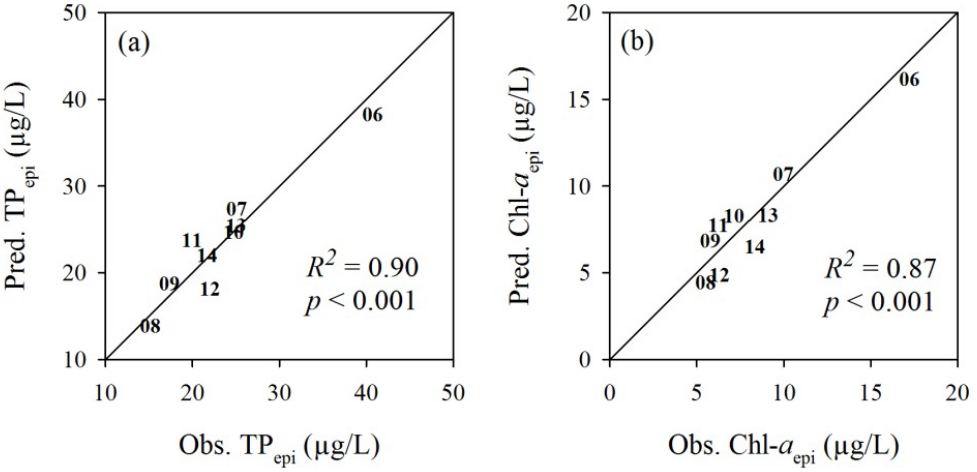


Figure 5-26. Performance of multiple linear regression models in describing contemporary (2006–2014) interannual variations in trophic state metrics: (a) TP_{epi}, and (b) Chl-a_{epi}.

The major improvements in trophic state metrics in Onondaga Lake over the last 30 years have been driven by decreases in the total phosphorus concentration of the Metro effluent, consistent with the historic dominance of the Metro load. With the decrease in the Metro load, other factors now contribute importantly to contemporary variability in trophic state. Inclusion of tributary flow and *Daphnia* as predictor variables in the empirical models for contemporary conditions reflects this change. Tributary phosphorus loading rates to Onondaga Lake have been observed to increase as runoff increases (Effler et al. 2009), supporting Q_{ON} as an appropriate independent variable. Lake total phosphorus concentrations have been reported to decrease as *Daphnia* populations increase (Shapiro and Wright 1984), reflecting efficient removal of phosphorus containing particles. Indeed, the lowest TP_{epi} values (15 and 17 µg/L) were observed in 2008 and 2009 when *Daphnia* were abundant. The inverse dependence of *Daphnia* abundance on planktivorous fish populations, as reported for Onondaga Lake (Wang et al. 2010), has been observed widely (Brooks and Dodson 1965, Carpenter et al. 1987, Rudstam et al. 1993, Lathrop et al. 1999).

5.8.5 N to P Ratio

The relative concentration of nutrients is an important determinant of the composition of the phytoplankton community. The effects of nutrient concentrations on phytoplankton speciation can have water quality management implications, particularly with respect to avoiding proliferation of cyanobacteria (blue-green algae). Cyanobacteria can cause noxious and potentially toxic conditions when present in high concentrations. The maintenance of high nitrogen to phosphorus ratios (N:P) in the upper productive layers of Onondaga Lake has been a long-term management strategy to discourage such noxious conditions. Data from a wide range of temperate lakes suggests that a total N to total P ratio (TN:TP) of 29:1 (by mass) differentiates between lakes with cyanobacteria dominance (TN:TP<29:1) and lakes without such dominance (TN:TP>29:1; Smith, 1983). The time series of the summer average (June 1–September 30) TN:TP ratio for the upper waters is presented for the 1998–2013 period (Figure 5-27). Total nitrogen (TN) was calculated as the sum of Total Kjeldahl N (TKN; organic nitrogen plus ammonia), nitrite, and nitrate.

The TN:TP ratio has remained above the literature N:P threshold for cyanobacteria dominance for the entire 1998 to 2014 period (Figure 5-27). The higher values from 2007 to 2014 reflect the effects of systematic decreases in total phosphorus loading from Metro, with mostly unchanging TN concentrations. This representation of the N:P ratio is in fact quite conservative, as the TN pool is dominated by dissolved forms while most of the TP pool in the upper waters of the lake is in particulate form and not available to support algal growth. The common occurrence of dense populations of filamentous cyanobacteria in summer from the late 1980s to early 2000s was likely due to a combination of lower N:P ratios and higher levels of P. Large cyanobacteria are better competitors when P levels are high both because they can get large enough to be inedible to grazers like *Daphnia*, and because they can regulate their buoyancy and better compete for light that can be limiting at high nutrient concentrations. Cyanobacteria have not been an important component of the algal community in recent years.

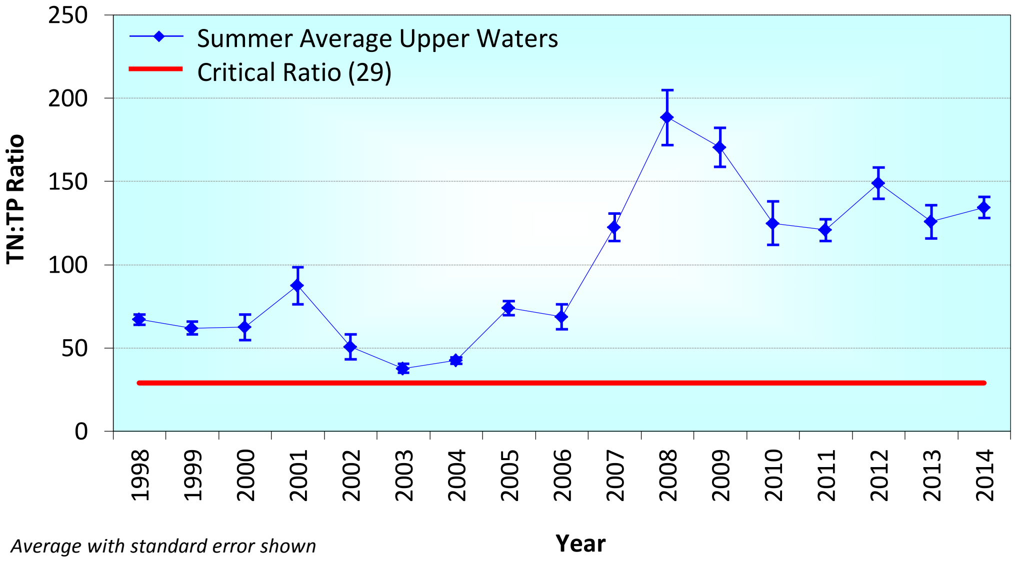


Figure 5-27. Summer average ratio of total nitrogen to total phosphorus (TN:TP, by weight) in the upper waters of Onondaga Lake, 1998–2014. Error bars represent plus and minus 1 standard error.

5.9 Attainment of Designated Uses

A report prepared by Upstate Freshwater Institute for Onondaga County Department of Water Environment Protection in 2015 presented an evaluation of the extent to which Onondaga Lake is presently meeting its designated uses, including public bathing and recreation, aquatic life support, fish consumption, natural resources habitat/hydrology, and aesthetics. The report was based on data collected by Onondaga County's Ambient Monitoring Program (AMP) through 2013. This evaluation focused on achievement of best uses designated for class "B" and "C" waters and status with respect to applicable New York State ambient water quality standards and guidelines. The report emphasized the following water quality parameters because they are cited specifically in the ACJ: dissolved oxygen, ammonia, turbidity, floatables, phosphorus, nitrogen, and bacteria. A summary of the report is provided here, and the full report is included as Appendix E-4.

Guidelines presented in the New York State Consolidated Assessment and Listing Methodology (CALM) served as the basis for evaluation of the extent to which Onondaga Lake is presently supporting the designated uses of public bathing and recreation, aquatic life support, fish consumption, natural resources habitat/hydrology, and aesthetics. Recreational uses of the lake, including the public bathing use are fully supported in Class B waters, which comprise the northern two-thirds of the lake. Public bathing is not a designated use in the southern third of the lake. Primary contact recreation is limited in the extreme southern end of the lake following runoff events due to elevated turbidity and high fecal coliform concentrations. The aquatic life use is fully supported throughout the lake as manifested in a diverse fish community and an improving macroinvertebrate community. The fish consumption use remains impaired on a lake-wide basis due to mercury, PCB, and dioxin contamination. These conclusions are generally consistent with those reached by NYSDEC in the 2014 Waterbody Inventory and Priority Waterbodies List (WI/PWL).

The water quality improvements achieved in Onondaga Lake are reflected in the recovery of lost uses, including swimming and other recreational uses, support of a robust biological community, and enhanced aesthetic appeal. Despite these improvements, water quality and biological conditions in Onondaga Lake will continue to be influenced by a variety of factors that are beyond the scope of current rehabilitation initiatives. Invasive species, such as dreissenid mussels, Alewife, and Round Goby, will continue to impact the food web and water quality conditions. Turbid inputs from the Tully Valley mudboils are presently uncontrolled and continue to cause deleterious effects on habitat conditions and aesthetics in Onondaga Creek and Onondaga Lake. Year-to-year variations in weather and long-term changes in climate will influence water quality and the biological community.

Section 6. Biology and Food Web: 2014 Results and Trends

In this section of the Annual Report, the extensive AMP data describing the phytoplankton, macrophyte, zooplankton, dreissenid mussel, and fish communities that form the Onondaga Lake food web are reviewed. The goals for the biological monitoring program are summarized according to program component: phytoplankton (Appendix A-8), macrophytes (Appendix A-9), zooplankton (Appendix A-10), and fish (Appendix A-11).

As phosphorus concentrations in Onondaga Lake have declined to mesotrophic levels (see Section 5.2.4) biological conditions have responded. Improved light penetration, a consequence of lower algal abundance resulting from the reduced phosphorus concentrations, has resulted in expansion of macrophyte beds. This expanded coverage of macrophytes throughout the littoral zone has improved habitat and shelter for many fish and other aquatic organisms.

6.1 Primary Producers

6.1.1 Phytoplankton

The algal biomass in Onondaga Lake has been below 2 mg/L (April through October averages) since 2007, and 2014 was no exception with an average phytoplankton biomass of 1.06 mg/L (Figure 6-1). This is lower than reported for meso-eutrophic systems (3-5 mg/L, Wetzel 2001). Average biomass in 2014 was the lowest on record since 2008 and peak biomass did not exceed 3 mg/L (Figure 6-2).

Algal biomass has significantly declined since 1998; although there has been no further decline since 2008. We attribute the low algal biomass to lower phosphorus loading since implementation of enhanced phosphorus removal at the Metro water treatment plant. In 2008 and 2009, algal biovolume was also affected by grazing from large zooplankton. Large zooplankton were rare in 2014. A detailed report on lower trophic levels of Onondaga Lake can be found in Appendix F-1.

The dominant algal genera in 2014 were similar to past years with the exception of relatively high dinoflagellate abundances. Diatoms were the most abundant group followed by cryptophytes, chlorophytes and dinoflagellates. The spring diatom peak consisted mostly of *Diatoma* and *Synedra* with a fall peak of *Synedra* and *Cyclotella*. *Cryptomonas* and *Rhodomonas* were abundant throughout the year. The most abundant algal genus in 2013, the diatom *Uroselenia*, was not detected in 2014. The composition of the phytoplankton community has changed from one dominated by undesirable bluegreen algae (Cyanobacteria) and dinoflagellates (Pyrrhophyta) through the early 2000s (Appendix F-1, Figure 11) to one dominated by more desirable diatoms (Bacillariophyta) and green algae (Chlorophyta; Table 6-1; Figure 6-2). Large bluegreens (cyanobacteria) have almost disappeared from the lake. In 2014, small amounts of bluegreens were present in the fall but peak biomass was only 0.1 mg/L (Figure 6-2). The disappearance of bluegreens is one of the most striking changes in Onondaga Lake over the last decades. Bluegreen blooms still occur each year in nearby Oneida Lake, which has similar phosphorus concentrations as current values in Onondaga Lake.

PhycoTech Inc. of St. Josephs, MI. Ann L. St Amand has been identifying the Onondaga Lake phytoplankton community since 1990. Each year, Dr. St. Amand and her staff at PhycoTech provide the detailed taxonomic information needed to characterize the Onondaga Lake ecosystem.

Figure 6-1. Temporal trend of average annual phytoplankton biovolume (April–October) in Onondaga Lake from 1998–2014.

Note: Annual biovolume decreased substantially during this period (linear regression, $R^2 = 0.67$, $p<0.0001$*). However, there has been no decline in biovolume since the low values recorded in 2008. The 2014 average biovolume was the second lowest on record.*

Table 6-1. Scientific and common names for major phytoplankton groups.

Scientific Division	Common Name
Cyanophyta (Cyanobacteria)	Blue-green algae
Pyrrhophyta	Dinoflagellates
Bacillariophyta	Diatoms
Chlorophyta	Green algae
Cryptophyta	Brown algae
Chrysophyta	Golden algae
Haptophyta	Brown algae

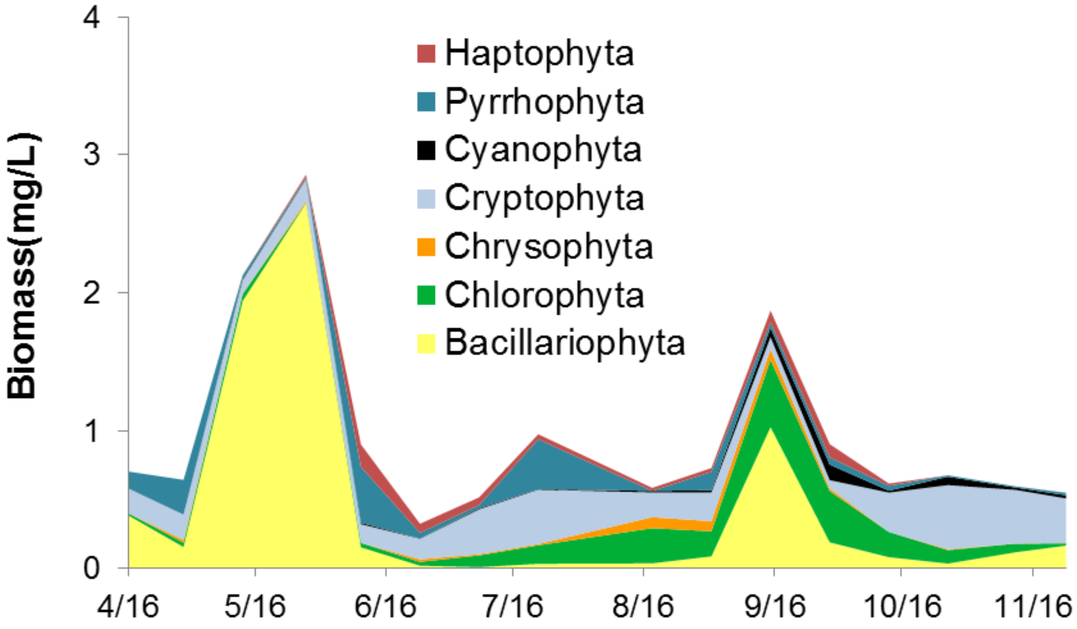


Figure 6-2. Phytoplankton community structure and biomass, 2014.

6.1.2 Macrophytes

Macrophytes in Onondaga Lake

Macrophytes play a critical role in lake ecosystems. Macrophytes provide food for waterfowl and wildlife, protect small fish, create spawning habitats, act as refuges for zooplankton, and oxygenate water. They reduce erosion by providing bottom stability and diminishing wave action. Macrophytes also play a crucial role in nutrient transport from the sediments (James et al. 2001). As part of the ACJ, the AMP included extensive sampling of the macrophyte community every five years (2000, 2005, and 2010) to document species occurrence and biomass. In addition, aerial photographs of the littoral zone (i.e., depths 6 m or less) were collected annually (2000–2013), when water clarity allowed, to determine plant distribution. Macrophytes increased substantially from 2000–2013 with over 350 acres covered since 2009. Because of this expansion, the annual aerial survey is not scheduled again until 2018, however the 2013 Onondaga Lake macrophyte monitoring report is included in Appendix F-2 for reference.

6.2 Zooplankton

The zooplankton community is a central component of the lake ecosystem; these grazing aquatic animals affect the abundance and species composition of the phytoplankton community. Zooplankton, in turn, are a critical food for many species of fish, particularly in early stages of development. The size structure and abundance of the Onondaga Lake zooplankton community is tracked annually as part of the AMP. A detailed report on Onondaga Lake zooplankton monitoring results can be found in Appendix F-1. In Onondaga Lake, zooplankton and benthic mussels are the most important grazers of phytoplankton.

The size structure of the zooplankton community (i.e., the relative abundance of small and large species) is a consequence of the grazing pressure exerted on zooplankton by fish. The community composition changed dramatically during several time periods; in late summer 2002 as Alewife (*Alosa pseudoharengus*) increased in abundance, in summer 2008 following Alewife declines, and again during summer 2009 when Alewife abundance rebounded (Figure 6-3). Alewife preferentially feed on larger zooplankton species. When Alewife populations are high, the population of larger zooplankton species declines. With reduced Alewife predation, the population of larger zooplankton species increases (Figure 6-3).

The average total zooplankton biomass (Apr-Oct, dry wt) in 2014 was 31.4 µg/L; which is the lowest value on record in Onondaga Lake (Figure 6-4). Zooplankton biomass has been low since 2010 and there has been an overall long-term decline. Variability among years, such as the increase in 2008 and 2009, is due to the low abundance of planktivorous Alewife in those two years (Figure 6-4). Changes over time indicate that the decline in nutrient concentrations caused a 3-5 fold decline in zooplankton and the increase in fish zooplanktivory caused a 2-3 fold decline. The average individual length of the zooplankton community in Onondaga Lake in 2014 was similar to 2010–2013 and indicative of high planktivory rates (Figure 6-5). The species and size composition resembled those in 2003–2007 and 2010–2013, but were quite different from what was observed in 2008 and 2009 when the Alewife population was low (Figure 6-4).

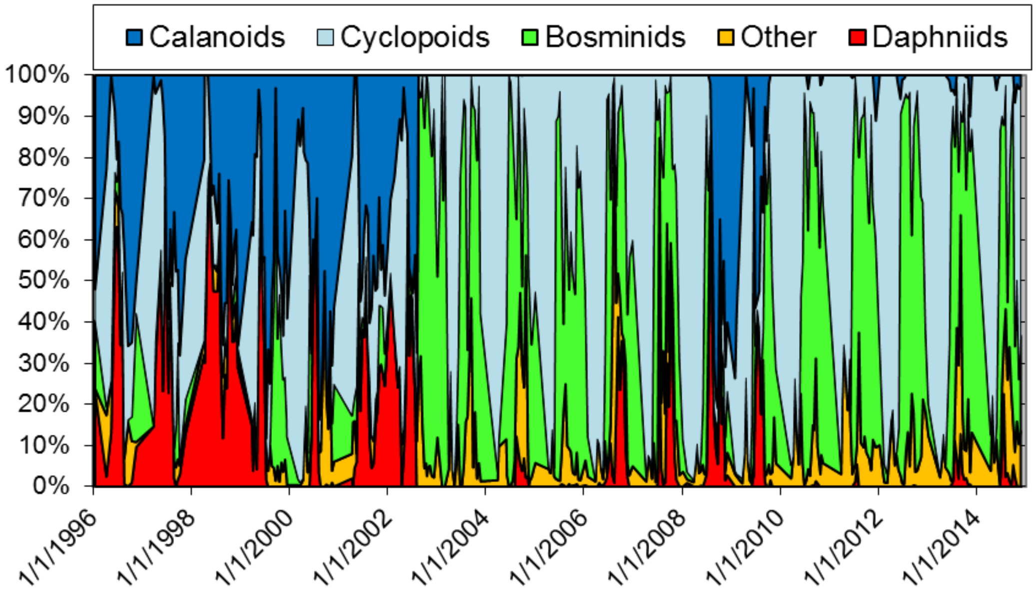


Figure 6-3. Proportion by biomass of major zooplankton groups. Calanoid copepods and daphnids are large taxa and cyclopoid copepods and bosminids are small.

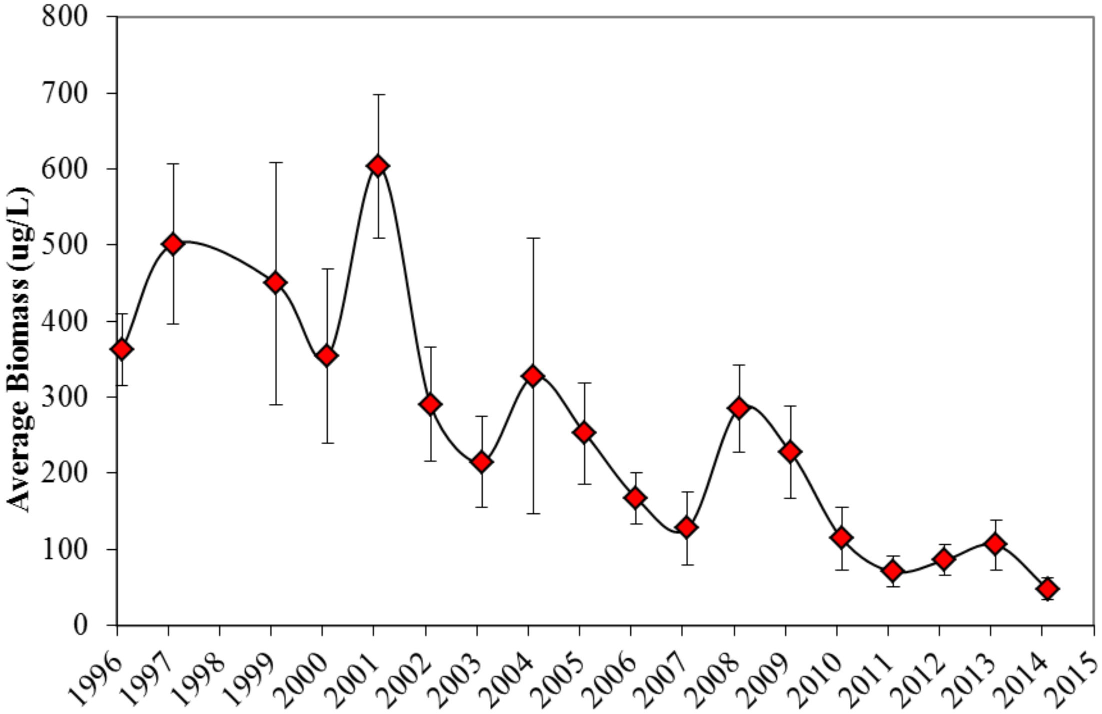


Figure 6-4. Average zooplankton biomass of all taxa 1996-2014, Onondaga Lake. Error bars represent one standard error.

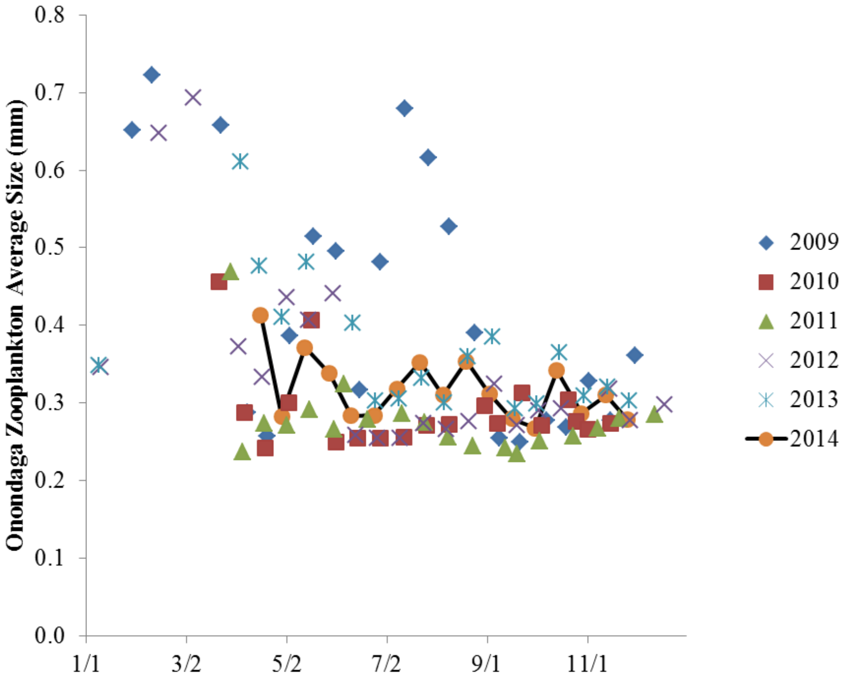


Figure 6-5. Average crustacean zooplankton length (mm) in Onondaga Lake in 2009–2014 based on standard samples and excluding *Cercopagis*. Average lengths were below 0.42 mm for all samples indicating high fish planktivory in 2014. Lines connect the values from 2014.

The temporal changes in the zooplankton community are linked to changes in predation by the dominant fish planktivore in the lake, the Alewife (Wang et al. 2010). A detailed report on Onondaga Lake Alewife monitoring results can be found in Appendix F-5. Alewife density in spring of 2008 and 2009 were below 100 fish ha, but density rebounded in the spring of 2010 due to a strong 2009 year class. The data from Onondaga Lake support the strong structuring effect of fish planktivory, especially Alewife, on the species composition and size structure of zooplankton (Brooks and Dodson 1965, Post et al. 2008, Wang et al. 2010). The exotic predatory zooplankton species, *Cercopagis pengoi*, was observed in 2014 and at higher abundance than in 2010–2013, but lower than in some earlier years in the 2000s. This species is more likely to negatively affect *Bosmina* than *Daphnia* (Warner et al. 2006). *Bosmina* did decline between 6/24 and 7/8 as *Cercopagis* biomass peaked in Onondaga Lake. Populations of *Daphnia* can exert strong influence on the phytoplankton community (Sommer et al. 1986, Mills and Forney 1988, Sommer et al. 2012). High water clarity and low phytoplankton biovolume was observed in 2008 and 2009 associated with the combination of high grazing from large zooplankton, decreased phosphorus loading, and possibly increased grazing by dreissenids. Although algal biovolume in 2014 was higher than in 2008, it was lower than 2010–2013. Thus, in contrast to earlier years, low phytoplankton biomass in 2014 was not accompanied by high *Daphnia* abundance.

The low biomass of *Daphnia* from 2003–2007 and then again in 2010–2014 is attributed to the presence of abundant Alewife during these time periods (Figure 6-6). *Daphnia* was abundant in 2008 and 2009, and primarily consisted of *D. mendotae* with lower abundance of *D. retrocurva*. *D. mendotae* was present from mid-July to early December in 2008, and from mid-June through August in 2009. We interpret the change in August 2009 to be the result of both individual and population growth of the large 2009 Alewife year class. All *Daphnia* species have been virtually absent in the lake since fall of 2009 (Figure 6-6).

Continued high Alewife abundance had an important cascading effect on lower levels of the food web in 2014. Alewife feeding selectively on larger zooplankton leads to lower biomass and smaller average size of the crustacean zooplankton. Smaller zooplankton are less efficient grazers of phytoplankton than larger ones, and phytoplankton abundance increases as a result.

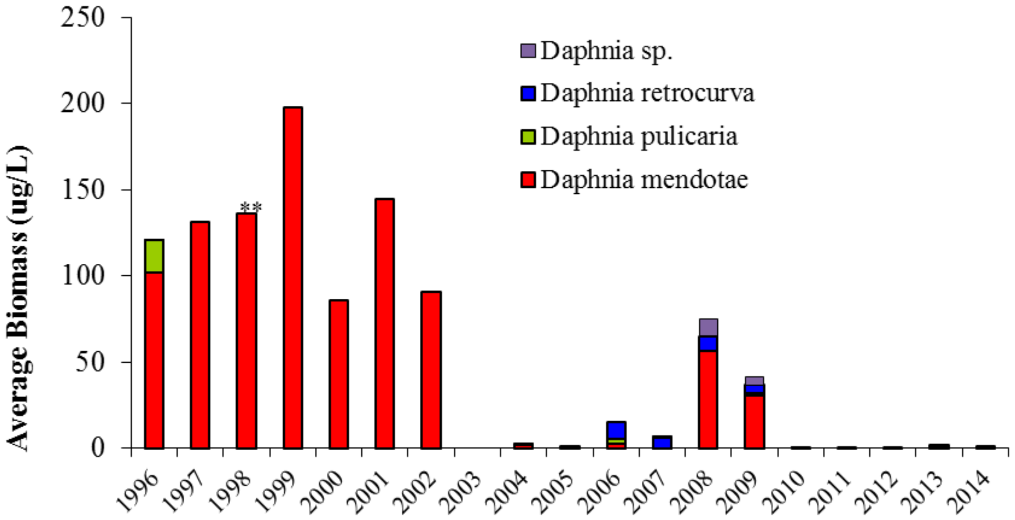
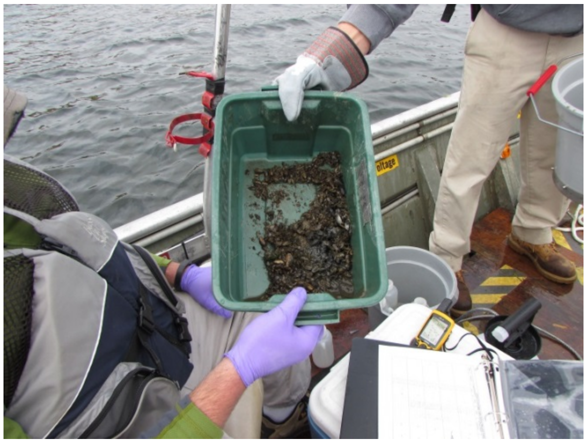


Figure 6-6. Biomass of various *Daphnia* species during the growing season in Onondaga Lake. Daphnids were almost non-existent in 2014. ** No biomass data available for 1998. The average biomass for 1998 is chosen as 125 µg/L only to show the species composition for that year.



Dreissenid Mussel Sample from Onondaga Lake, 2014.

6.3 Dreissenid Mussels

Zebra mussels (*Dreissena polymorpha*) were introduced into the Great Lakes from Eurasia in ballast water from international shipping. They were first recorded in Onondaga Lake in 1992, although they did not become abundant until 2000 (Mills et al. 1993, Spada et al. 2002). A second related species, the quagga mussel (*Dreissena bugensis*), was also detected in Onondaga Lake in 1992 and again in 2002 (Mills et al. 1993, Onondaga County 2003). Their abundance and distribution has been tracked as part of the AMP using consistent methods since 2005. One modification was made in 2011 when the maximum depth sampled increased from 4.5 m to 6.0 m to determine if quagga mussels had colonized deeper areas of the lake. Assessments in 2014 also included the depths 6.0–7.5 m. Analyses of the time trends are in Appendix F-3.

Dreissenid density and biomass increased in Onondaga Lake from 2005 to 2007 at water depths 0–4.5 m and then remained above 5,000/m^2 and 13 g/m^2, respectively, through 2012. This increase was initially due to an increase in zebra mussels, but quagga mussels started to increase in the lake in 2007 and was the dominant species by biomass from 2009 through 2012, particularly at water depths between 3–4.5 m. Zebra mussel densities declined further to 1,683/m^2 (2.2 g/m^2) in 2013 but then increased to 5,512 m^2 in 2014. Dreissenid densities in 2013 and 2014 were significantly lower than in 2007; biomass in 2014 was significantly lower than in 2007 and 2008 but not significantly different from others years. (Figure 6-7). When deeper depths were sampled from 2011 to 2014, quagga mussel also dominated water depth between 4.5–7.5 m. Total dreissenid biomass was highest in water depths greater than 3 m once quagga mussels became dominant, but higher at 1.5–3 m in years when zebra mussels dominated (2005, 2007 and 2008) (Figure 6-8). The two species coexist at shallower water depths (0–3.0 m) with the proportion of quagga mussels by biomass ranging between 20 and 80% without a time trend from 2008 through 2014 (Figure 6-8). Quagga mussels were consistently larger than zebra mussels at all depths, indicating that quagga mussels have a growth advantage over zebra mussels in both shallow and deeper areas. Quagga mussels largely displaced zebra mussels in water deeper than 3 m but both species coexist in shallower water.

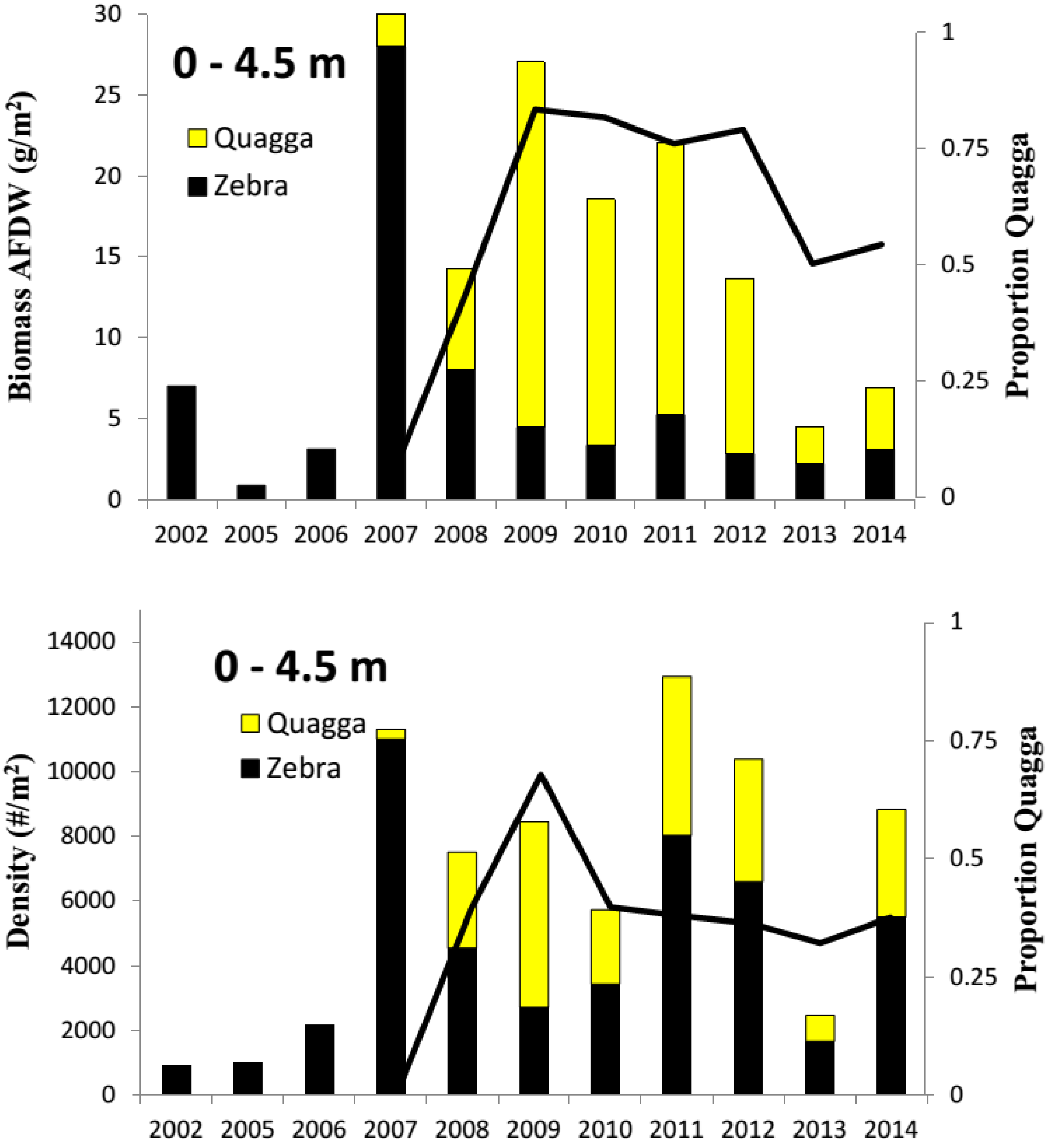


Figure 6-7. Development of the zebra and quagga mussel population (density and biomass) in Onondaga Lake from 2002 to 2014 in water 0–4.5 m depth. The line represents the proportion of quagga mussel.

Note: Thirty six samples were collected along 12 transects.

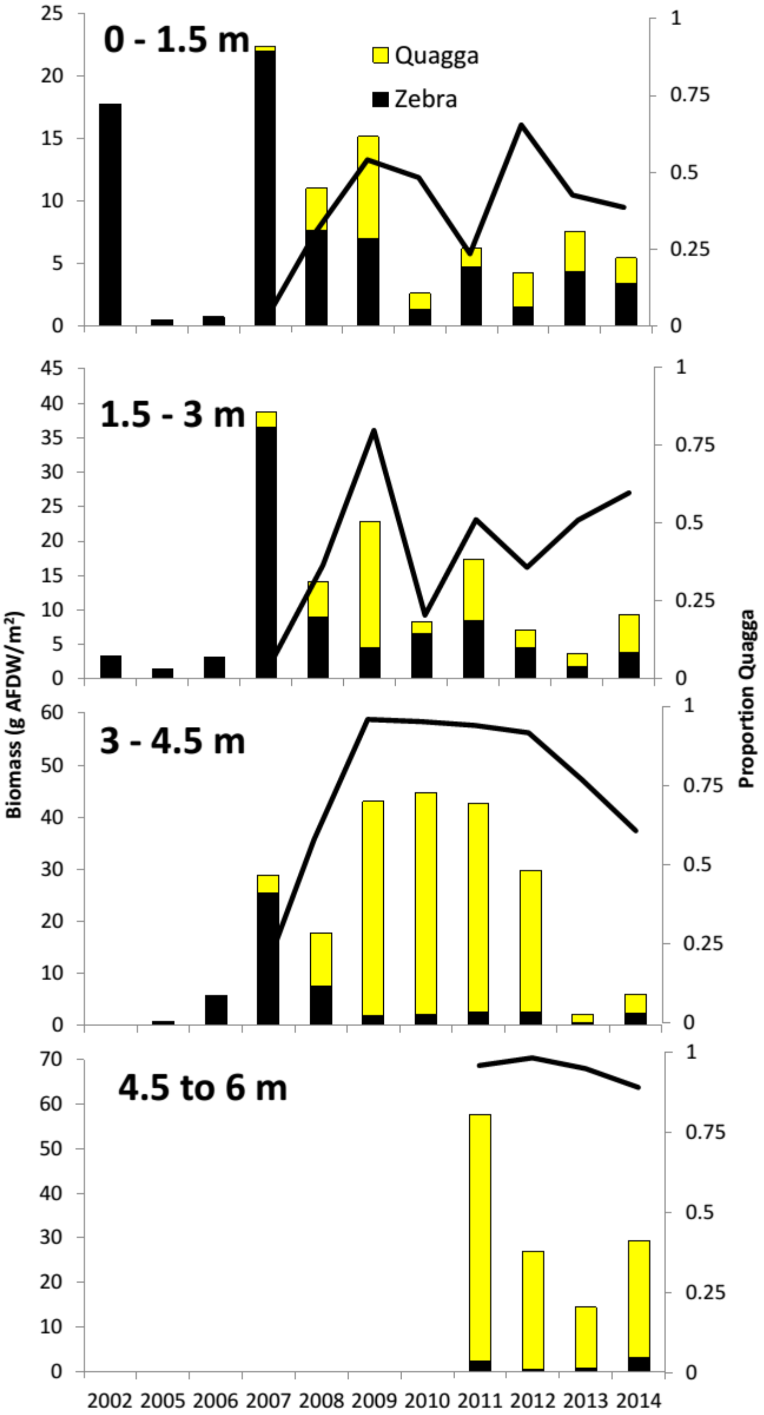


Figure 6-8. Density and biomass of zebra and quagga mussels in four depth regions: 0–1.5 m, 1.5–3 m, 3–4.5 m and 4.5–6 m depths. Sampling in the 4.5–6 m depth strata started in 2011.

Note: x-axis skips 2003–2004; y-axis is different on each plot. Thirty six samples were collected along 12 transects from 2005-2010. From 2011-2014 a total of 48 samples were collected along 12 transects.

6.4 Fish

Largemouth Bass collected from Onondaga Lake

Changes in the fish community of Onondaga Lake have occurred as water quality and habitat conditions have improved. The significant reduction in ammonia and phosphorus input, resulting in the shift from eutrophic to mesotrophic conditions over the past several years, has expanded available fish habitat in both the littoral and pelagic zones. Fish communities are good indicators of aquatic ecosystem conditions because they integrate physical, chemical, and biological conditions and express them in terms of species composition, age and growth characteristics, and reproductive success. Since 2000, an extensive fisheries monitoring program has been included in the AMP, incorporating multiple types of sampling gear to assess nesting, larval, juvenile, and adult stages of the fish community. Since 2000, more than 170,000 individual fish have been captured or observed from Onondaga Lake by Onondaga County's sampling efforts, representing fifty-three species (Table 6-2). Growth and survival of Largemouth Bass are summarized in a separate report (Appendix F-4).

Honeywell implemented an annual biological monitoring program in 2008 to assess mercury concentration in fish tissue. As part of that program, State University of New York College of Environmental Science and Forestry (SUNY-ESF) students conduct sampling to assess the fish community and to calculate population estimates of several sport fish species. During development of Honeywell's monitoring program, project scientists conferred with County employees working on the biological programs to reduce duplication and provide complementary information to the AMP. Some of the SUNY-ESF data are incorporated into this report to provide a more holistic assessment of the overall fish community in Onondaga Lake.

The challenge in data analysis and interpretation is the multitude of abiotic and biotic factors affecting the fish community, including annual variability in weather and climate, interactions among species, food web effects, and invasive species. The following section provides an overview of the lake's fish community in 2014, an assessment of trends observed since the onset of the AMP biological program in 2000, and an assessment of changes in the fish community that integrates data from the Honeywell program from 2008 to 2014.

Table 6-2. Fish species identified in Onondaga Lake, 2000–2014 (all gear types).

Abundant Species (>1000 individuals)		Common Species (50-1000 individuals)		Uncommon Species (<50 individuals)	
Alewife	Golden Shiner	Bluntnose Minnow	Longnose Gar	Black Bullhead	Quillback
Banded Killifish	Largemouth Bass	Bowfin	Northern Pike	Black Crappie	Rainbow Smelt
Bluegill	Pumpkinseed	Channel Catfish	Rock Bass	Brook Stickleback	Rainbow Trout
Brown Bullhead	Smallmouth Bass	Emerald Shiner	Shorthead Redhorse	Brown Trout	Rudd
CommonCarp	White Perch	Fathead Minnow	Tessellated Darter	Chain Pickerel	Silver Redhorse
Gizzard Shad	White Sucker	Freshwater Drum	Walleye	Creek Chub	Spotfin Shiner
Brook Silverside	Yellow Perch	Logperch		Goldfish	Spottail Shiner
Round Goby				Greater Redhorse	Tadpole Madtom
				Green Sunfish	Tiger Muskie
				Johnny Darter	Trout Perch
				Lake Sturgeon	White Bass
				Longnose Dace	Yellow Bullhead
				Northern Hogsucker	

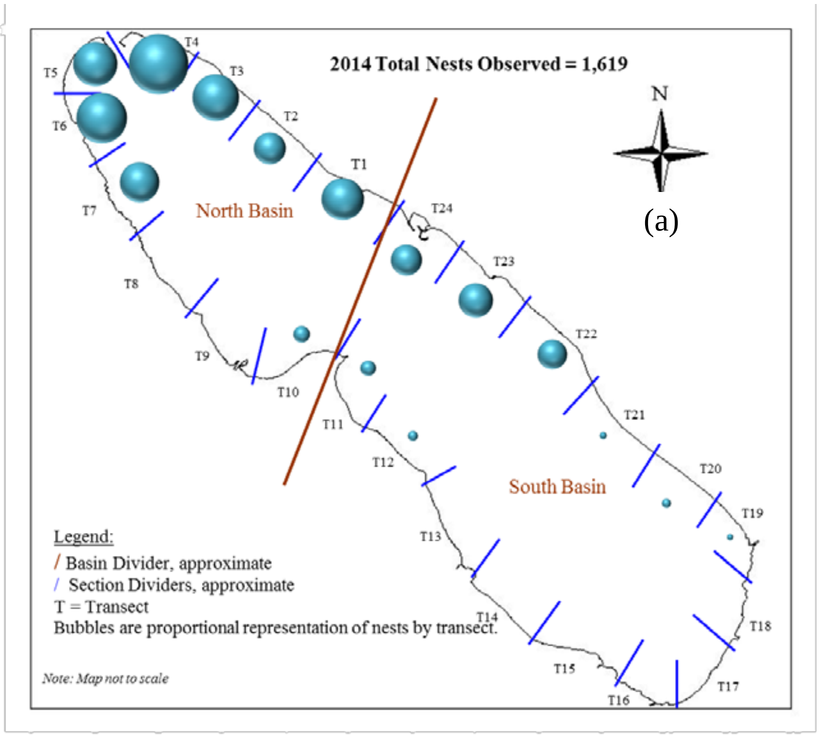
6.4.1 Reproduction and Recruitment

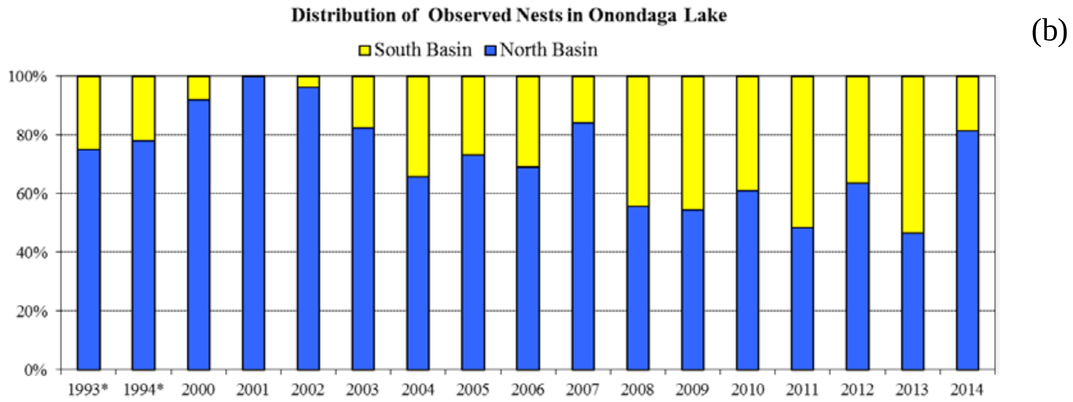
OCDWEP Technicians Juvenile Seining

Several methods are used in the AMP to assess fish reproduction and recruitment (i.e., juvenile survival to the adult life stage), including nesting surveys and separate sampling of larval, juvenile, and adult fish. Evaluation of larval and juvenile fish provides information on the overall health of the fish community within the lake and the success of annual reproduction. Additionally, younger life stages tend to be less tolerant of undesirable water quality conditions (e.g., conditions of elevated ammonia or low oxygen concentrations) than are adults of the same species. Fish are known to have variable recruitment from year to year; environmental factors including water quality, habitat availability, wind, water level, and water temperature during and following spawning affect reproductive success. In addition, predation, disease, and competition can affect the reproductive success of many species.

6.4.1.1 Nesting

Centrarchid species (Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Pumpkinseed (*Lepomis gibbosus*), Bluegill (*Lepomis macrochirus*), Rock Bass (*Ambloplites rupestris*)) and Brown Bullhead (*Ameiurus nebulosus*) construct nests in the littoral zone of the lake. Each year, the AMP team conducts nesting surveys to estimate the number and spatial distribution of the nests of these species. Since 2000, most fish nests in Onondaga Lake have been documented in the north basin (average 69%, range 46% to 100%), presumably because of better habitat conditions there. This is consistent with the spatial pattern documented by Arrigo (1998) in the early 1990s when approximately 75% of nests documented in that study were found in the north basin. More recently (2008–2013) nests have been more evenly distributed between the north and south basins. The increased nesting activity observed in the southern basin of the lake (2008–2013) was likely influenced by the increased macrophyte coverage of the littoral zone over the last decade. Dense beds of macrophytes may reduce the effects of wind-induced waves that can cover eggs with sediment and dislodge eggs from nesting areas. However, 81% of the 1,619 nests observed in 2014 were in the north basin (Figure 6-9). The lack of nesting in the south basin in 2014 was likely due to the Honeywell's dredging and capping activities in that area of the lake. The majority of the nests observed in 2014 (59%) were described as unknown (nest observed without an adult fish present). Pumpkinseed accounted for 37% of the total nests identified (Table 6-3). Lesser amounts of Largemouth Bass (2.5%) and Brown Bullhead (1%) were also observed.





	1993*	1994*	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
North Basin	75%	78%	92%	100%	96%	82%	66%	73%	68.9%	84.1%	55.4%	54.4%	61.0%	48.5%	63.6%	46.4%	81.3%
South Basin	25%	22%	8%	0%	4%	18%	34%	27%	31.1%	15.9%	44.6%	45.6%	39.0%	51.5%	36.4%	53.6%	18.7%
Nest count by basin																	
North Basin	958	1291	3301	1887	2042	1430	1409	739	848	1759	3941	1085	1250	1159	1537	1620	1316
South Basin	319	364	287	0	85	307	737	273	383	332	3170	910	800	1231	879	1872	303
Total	1277	1655	3588	1887	2127	1737	2146	1012	1231	2091	7111	1995	2050	2390	2416	3492	1619

**Historic nest distribution. 1993 and 1994 data from Arrigo 1998.*

Figure 6-9. Fish nesting survey map (a) and comparison of north vs. south 1993–2014 (b).

Table 6-3. Fish species nesting in Onondaga Lake, 2014.

Species	Total Number of Nests	Percent of Total
Bullhead (species unknown)	18	1.1%
Bluegill	1	0.1%
Rock Bass	1	0.1%
Pumpkinseed	494	30.5%
Lepomis spp.	109	6.7%
Largemouth Bass	41	2.5%
Other	955	59%

Note: Lepomis spp.refers to Bluegill and Pumpkinseed when unable to differentiate species in the field. Other refers to unidentified species.

Nesting Colony of *Lepomis* spp. (Bluegill and Pumpkinseed) observed in Onondaga Lake.

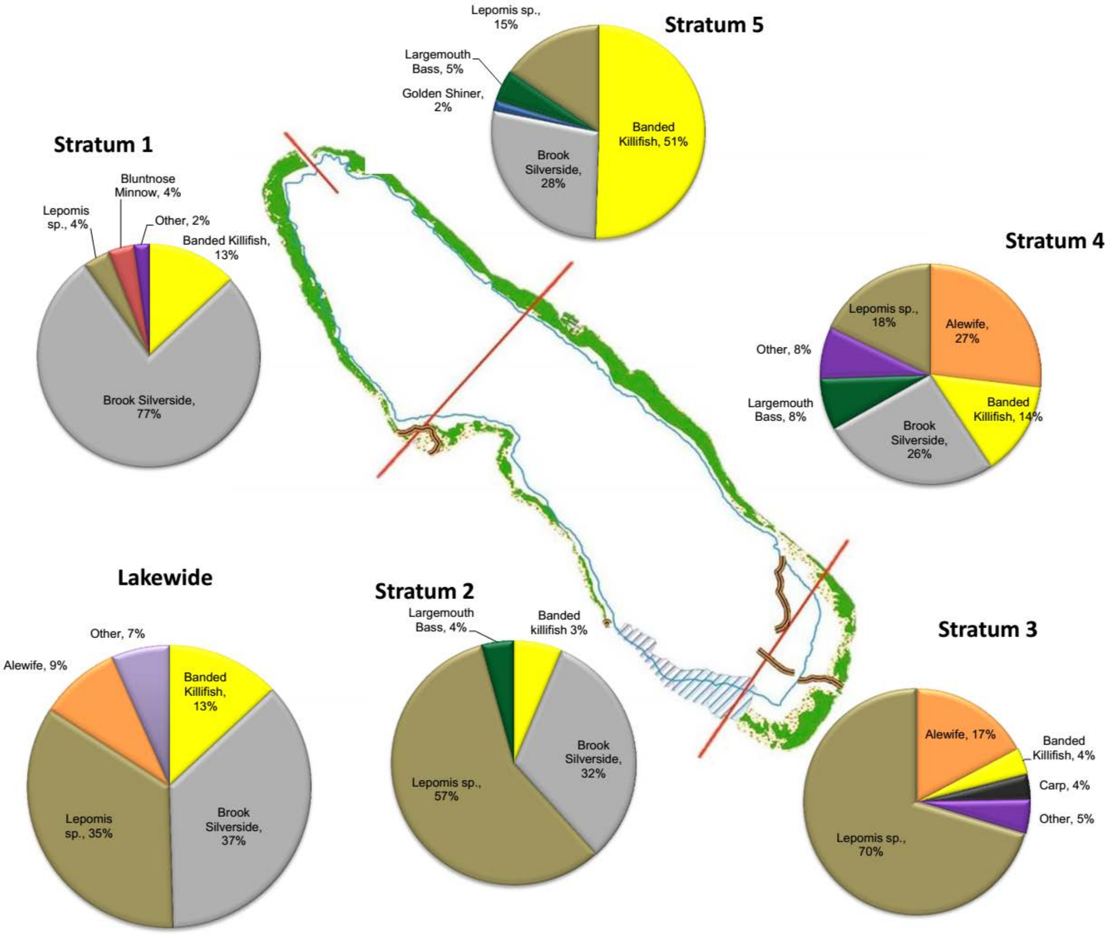
6.4.1.2 Larval, young-of-year, juvenile assessment

A total of 1,828 larval fish representing 10 species were collected during the 2014 larval seine events. Brook Silverside (*Labidesthes sicculus*) were the most common fish collected comprising 37% of the lakewide catch followed by Lepomis species (Bluegill and Pumpkinseed) 35%, Banded Killifish (*Fundulus diaphanus*) 13%, and Alewife 9%. Smaller numbers of Bluntnose Minnow (*Pimephales notatus*), Golden Shiner (*Notemigonus crysoleucas*), Common Carp (*Cyprinus carpio*), Round Goby (*Neogobius melanostomus*), and Largemouth Bass were also collected. Overall catch per unit effort (CPUE) was lower in 2014, compared to 2013, but higher than those reported from 2000 through 2003 and 2012; the number of species collected in 2014 (10) also was lower than 2013 (12) (Figure 6-10).

Seining of juveniles in 2014, off Hiawatha Point in Onondaga Lake.

Littoral zone seining was conducted three times during the summer and early fall of 2014 to assess young-of-year (YOY) and juvenile (age 1+ or greater, not yet mature) abundance and diversity. Young-of-year Bluegill, Pumpkinseed, Rock Bass, Largemouth Bass, Brown Bullhead, Longnose Gar (*Lepisosteus osseus*), and Golden Shiner, were captured in 2014. A total of 564 young-of-year fish representing 7 species were captured. Largemouth Bass and Lepomis species (Pumpkinseed and Bluegill) young-of-year were the most abundant species collected, comprising 89% and 6% of the total catch, respectively. The remaining species together accounted for 5% of the lakewide catch (Figure 6-11). Largemouth Bass was the most abundant species collected in each of the individual strata. Overall catch per unit effort in 2014 was lower than reported in 2013 and prior to 2008 (except 2006), but higher than in most recent years (2009–2012). The most apparent change in 2014 was the increase in catch rates for YOY Largemouth Bass compared to previous years. In 2014 the catch per unit effort for Largemouth Bass was 11.2, the highest since 2000 except for 2005 when the catch rate was 17.0.

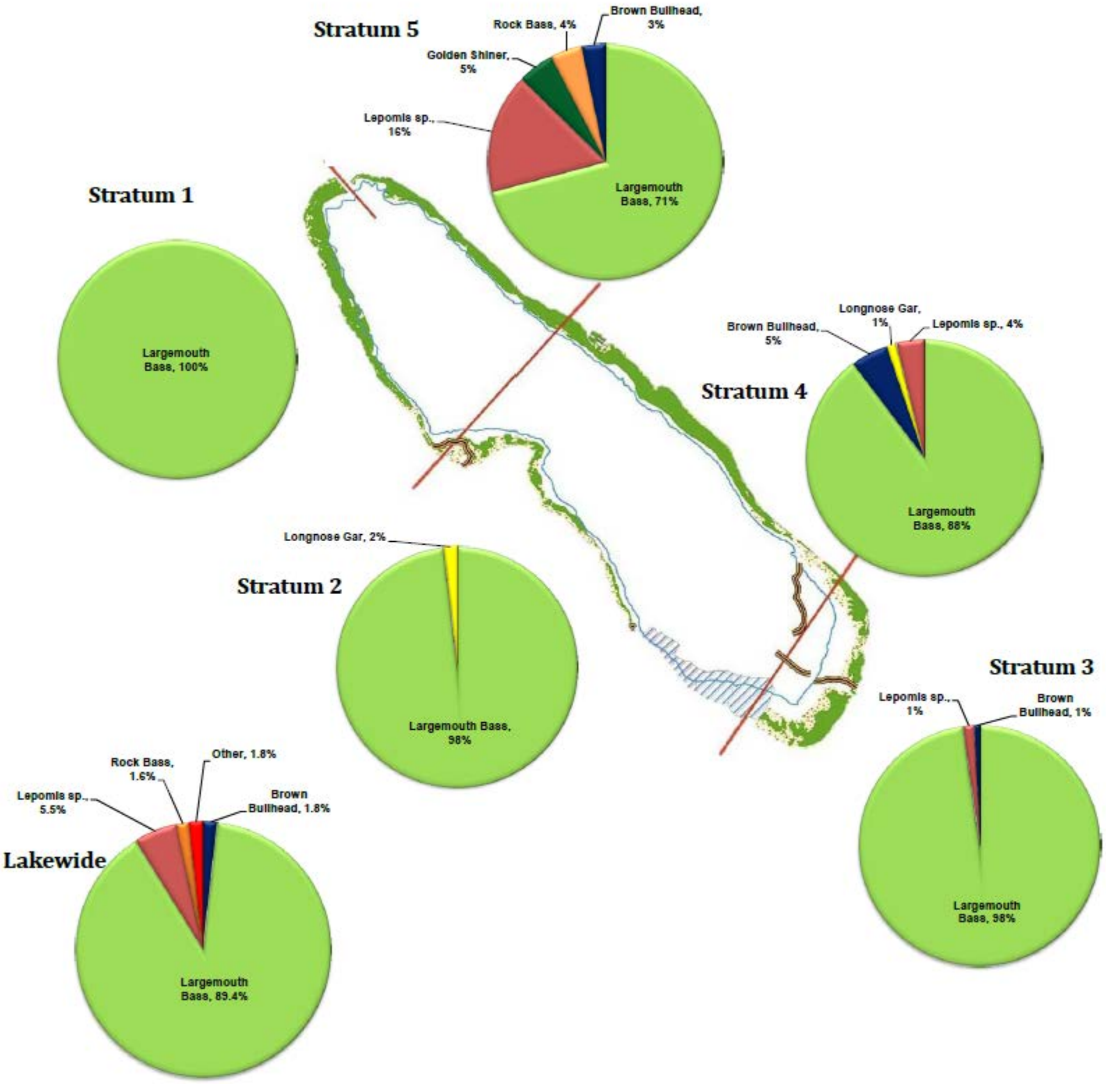
Juvenile abundance was evaluated based on the life stage description of "juvenile" in the seining events with 10 species and 118 individuals identified. Largemouth Bass, Pumpkinseed, and Bluegill were the most common species collected, comprising 27%, 24%, and 17% of the total catch, respectively. Lesser amounts of Rock Bass (8.5%), Brown Bullhead (5.9%), Common Carp (5.9%), and Gizzard Shad (5.9%) were captured. The remaining three species (Golden Shiner, Green Sunfish (*Lepomis cyanellus*), and Yellow Bullhead) composed less than 6% of the total catch (Figure 6-12). Compared to previous years, the number of juvenile fish species collected in 2014 was lower with the exception of 2013 when 8 species were reported. The incidental capture of species such as Walleye (*Sander vitreus*), Longnose Gar, Northern Pike (*Esox lucius*) and Freshwater Drum (*Aplodinotus grunniens*) in previous years did not occur in 2013 or 2014. Those species likely immigrate into the lake from the Seneca River and, when present in the early life stages, are commonly represented by only a few individuals that are captured infrequently.



Year	2000	2002	2003	2012	2013	2014
Overall CPUE	38.64	47.33	47.7	194.73	462.67	391
Richness	20	12	9	9	12	10

Figure 6-10. Relative abundance of larval fish in 2014 by stratum and species (fish collection by larval seining).

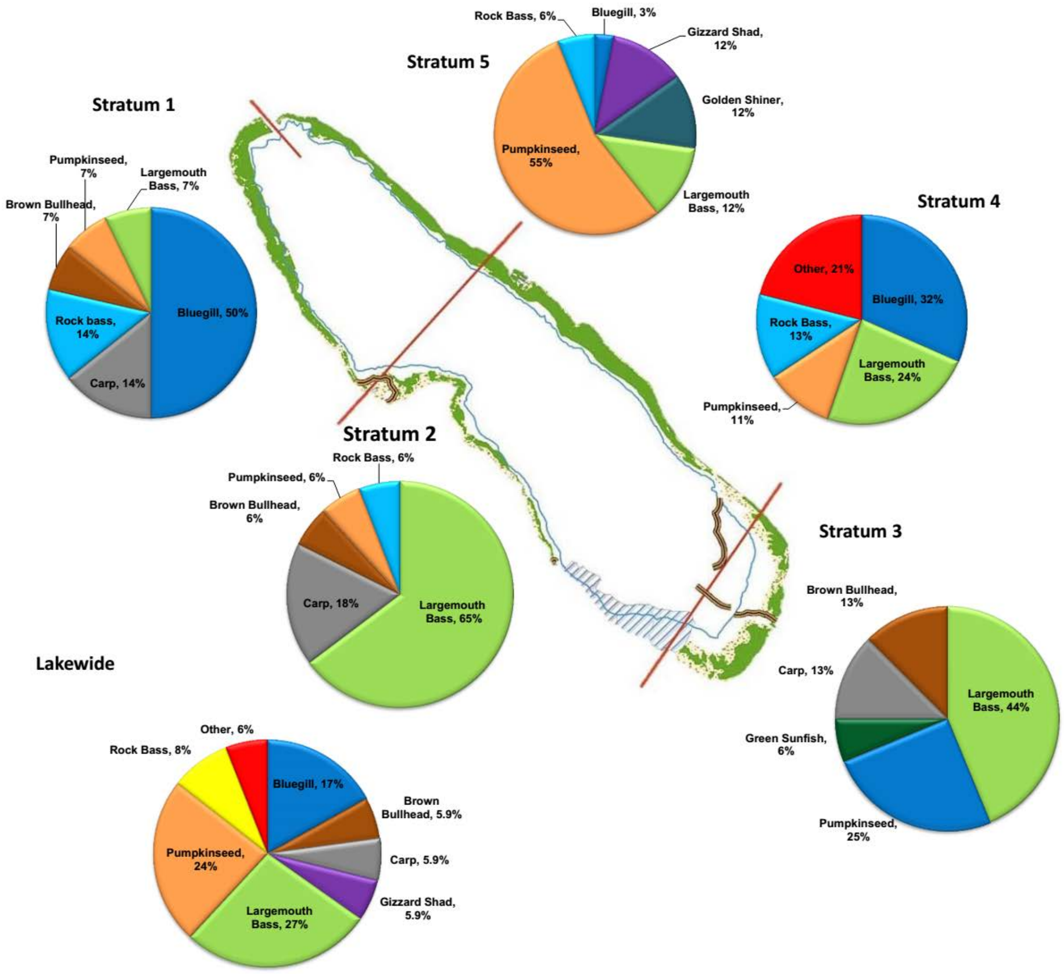
Note: The area of each pie is not proportional to its total. Brown lines at the south end of the lake and near Ninemile Creek identify the location of silt curtains associated with dredging and capping activities. The blue hashing represents the area impacted by dredging in 2012 and 2013.



Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Overall CPUE	17.4	127.0	23.1	36.3	27.6	57.5	9.9	16.4	16.9	2.5	5.8	4.2	6.5	14.9	12.3
Richness	14	13	14	9	9	12	5	8	13	10	9	9	7	10	7

Figure 6-11. Relative abundance of young-of-year fish in 2014 by stratum and species (sampled by seining).

Note: The area of each pie is not proportional to its total. Brown lines at the south end of the lake and near Ninemile Creek identify the location of silt curtains associated with dredging and capping activities. The blue hashing represents the area impacted by dredging in 2012 and 2013.



Note: The area of each pie is not proportional to its total.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Overall CPUE	1.75	9.15	53.54	3.16	0.49	21.36	3.06	4.74	3.69	1.71	3.01	0.94	2.61	5.93	2.6
Richness	18	20	16	14	11	14	13	11	14	15	14	16	15	8	10

Figure 6-12. Relative abundance of juvenile fish in 2014 by stratum and species. Life stage indicated as juvenile during seining (young-of-year excluded).

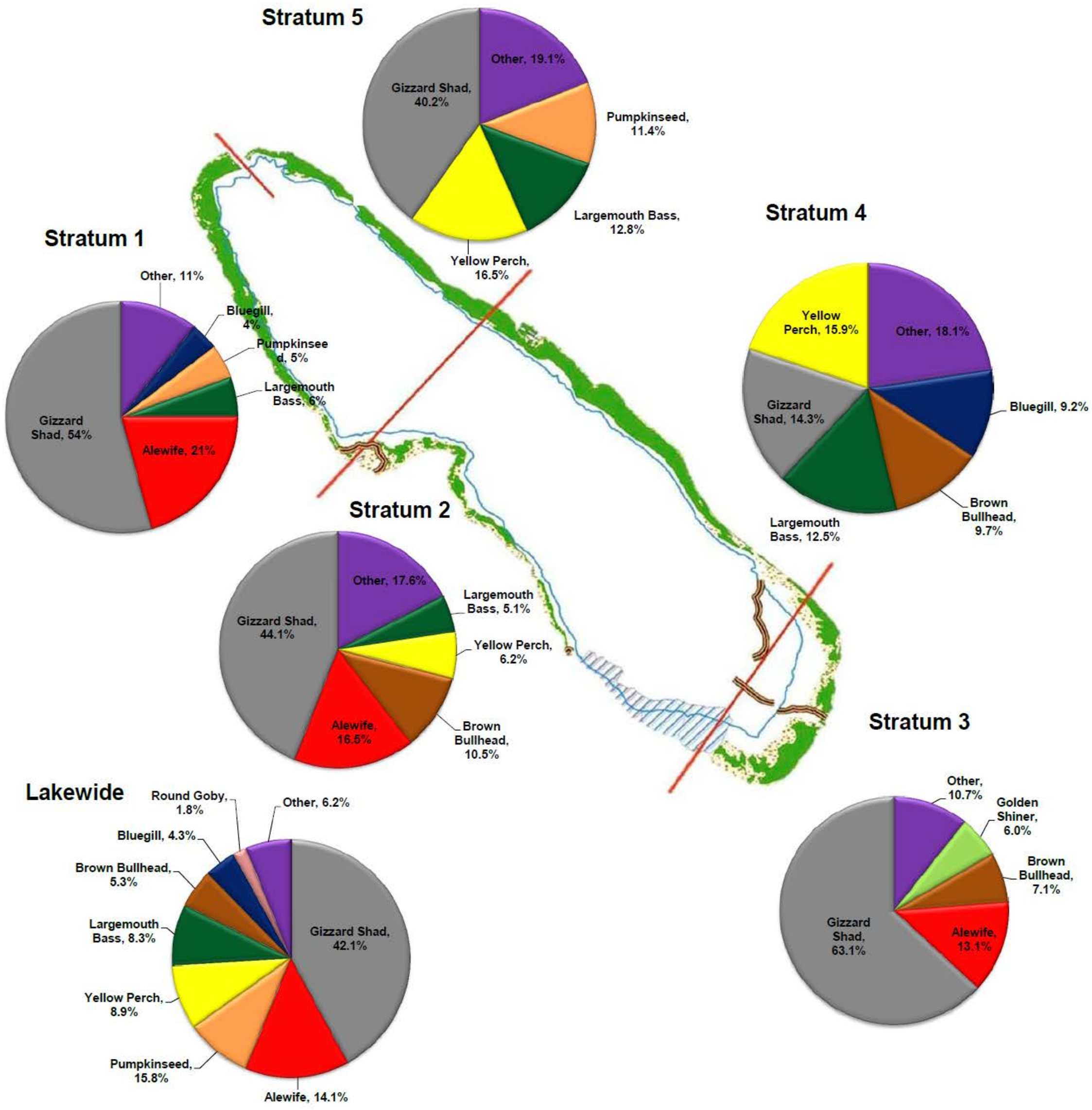
Note: Brown lines at the south end of the lake and near Ninemile Creek identify the location of silt curtains associated with dredging and capping activities. The blue hashing represents the area impacted by dredging in 2012 and 2013.

6.4.2 Fish Community

6.4.2.1 Abundance

Littoral adults are sampled by boat electrofishing in the littoral zone. Some adults, particularly the smaller species (minnows and killifishes) are captured during the littoral juvenile seining as well. A total of 3,524 fish, representing 26 species, was collected during the fall boat electrofishing event. Eight of the 26 species accounted for 94% of the catch. Gizzard Shad (*Dorosoma cepedianum*) was the most abundant species collected making up 42% of the catch, followed by Alewife (14% of catch), Pumpkinseed (16%), Yellow Perch (9%), Largemouth Bass (8%), Brown Bullhead (5%), Bluegill (4%), and Round Goby (2%). The remaining eighteen species collected together constituted 6.2% of the catch. Overall CPUE was 1,016 fish per hour (Figure 6-13).

OCDWEP Staff Electrofishing
(Collecting fish for the Save the Rain Clean Water Fair fish display)

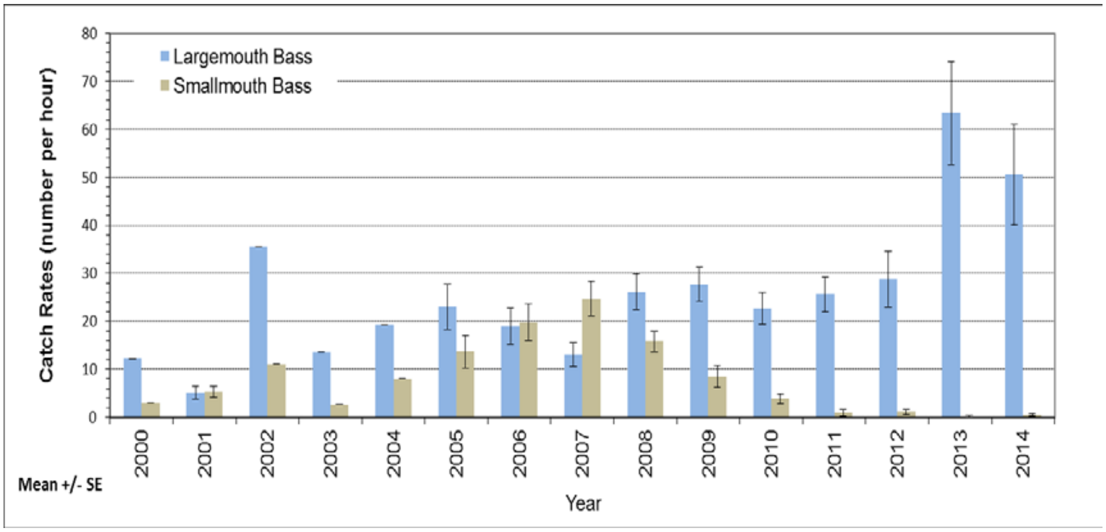


Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Overall CPUE	254.2	196.5	634.2	519.9	2098.2	1158.5	371.2	471.3	802	814.1	1297.7	2345	1668.3	1019.4	1016.5
Richness	23	21	25	21	26	25	25	21	24	28	28	25	28	23	26

Figure 6-13. Relative abundance of littoral adult fish in 2014 by species and stratum (based on "counts" only; counts and estimates for Gizzard Shad and Alewife only).

Note: Brown lines at the south end of the lake and near Ninemile Creek identify the location of silt curtains associated with dredging and capping activities. The blue hashing represents the area impacted by dredging in 2012 and 2013.

Largemouth Bass and Smallmouth Bass are two of the principle warm water predators in Onondaga Lake. However, since 2002 Largemouth Bass have been the more prevalent of the two species (Figure 6-14). A marked increase in littoral zone catch rates for Largemouth Bass was observed in 2013 with 63 fish captured per hour, the highest observed since the start of the AMP in 2000. In 2014 Largemouth Bass catch rates were 50 fish captured per hour, second only to those reported in 2013 (Figure 6-14). Conversely, the observed catch rate for Smallmouth Bass of 0.5 fish caught per hour was the second lowest reported since 2000. The declining catch rates observed for the Smallmouth Bass are likely indicative of the changing conditions in the littoral zone with increased macrophyte coverage more suitable for Largemouth Bass (Stuber et al. 1982, Edwards et al. 1983). Smallmouth Bass prefer clear-water lakes and cool streams with moderate current, and rock and gravel substrate (Robbins and MacCrimmon 1974). Increases in the relative abundance of Largemouth Bass over Smallmouth Bass also have occurred in Oneida Lake and Canadarago Lake, two other New York lakes with increasing macrophyte coverage (Jackson et al. 2012, Brooking et al. 2012). Honeywell International is in the final stages of a lake bottom restoration project. A habitat layer of gravel/cobble will be placed over approximately 234 hectares of the littoral zone in the south basin, likely enhancing Smallmouth Bass habitat. For more information on Largemouth Bass in Onondaga Lake please see Appendix F-4.



Mean CPUE, entire year

Sample Period	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Largemouth Bass	12.2	5.1	35.5	13.6	19.2	23.1	19.0	13.1	26.1	27.7	22.7	25.7	28.7	63.4	50.6
Smallmouth Bass	3.0	5.2	11.0	2.7	8.1	13.6	19.8	24.7	15.8	8.5	3.9	0.9	1.1	0.2	0.5

Figure 6-14. Trend in annual average catch rates (number per hour) from fall electrofishing events of Largemouth and Smallmouth Bass combined in Onondaga Lake from 2000 to 2014.

Overall trends in catch rates have varied by species since 2000 (Figure 6-15). Several species including Smallmouth Bass, White Perch (*Morone Americana*), and Channel Catfish (*Ictalurus punctatus*) have had reduced catch rates over the past several years, while other species such as White Sucker and Walleye had less variation in catch rates. However, catch rates of several species including Largemouth Bass, Brown Bullhead, and Yellow Perch have generally increased since 2000 with consistently higher CPUE since 2007 (Figure 6-15). These patterns likely reflect biological interactions within the fish community and changing habitats in the lake, including increased macrophyte coverage and increased mussel abundance. Species such as Gizzard Shad are susceptible to winter induced mortality and commonly show variations in yearly catch rates at the periphery of their geographic range, most notably during long, harsh winters. It is likely that the reasons for changes in abundance are more complex and species-specific and reflect changes in overall lake productivity as well as increased littoral zone habitat diversity.

Bluegill (Left) and Pumpkinseed (Right) collected from Onondaga Lake.

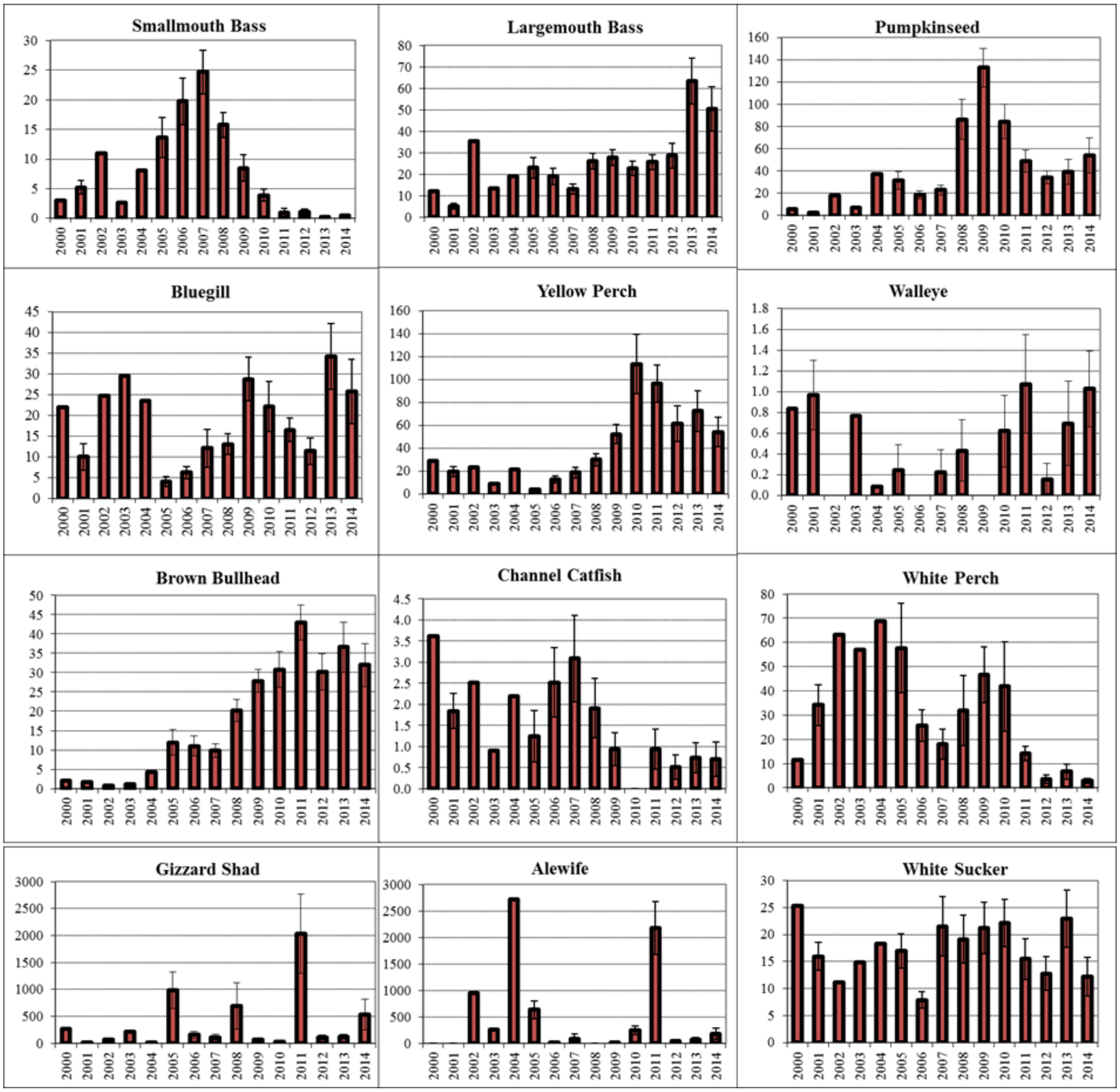


Figure 6-15. Trends in catch per unit effort (CPUE) of select fish species captured by electrofishing 2000–2014.

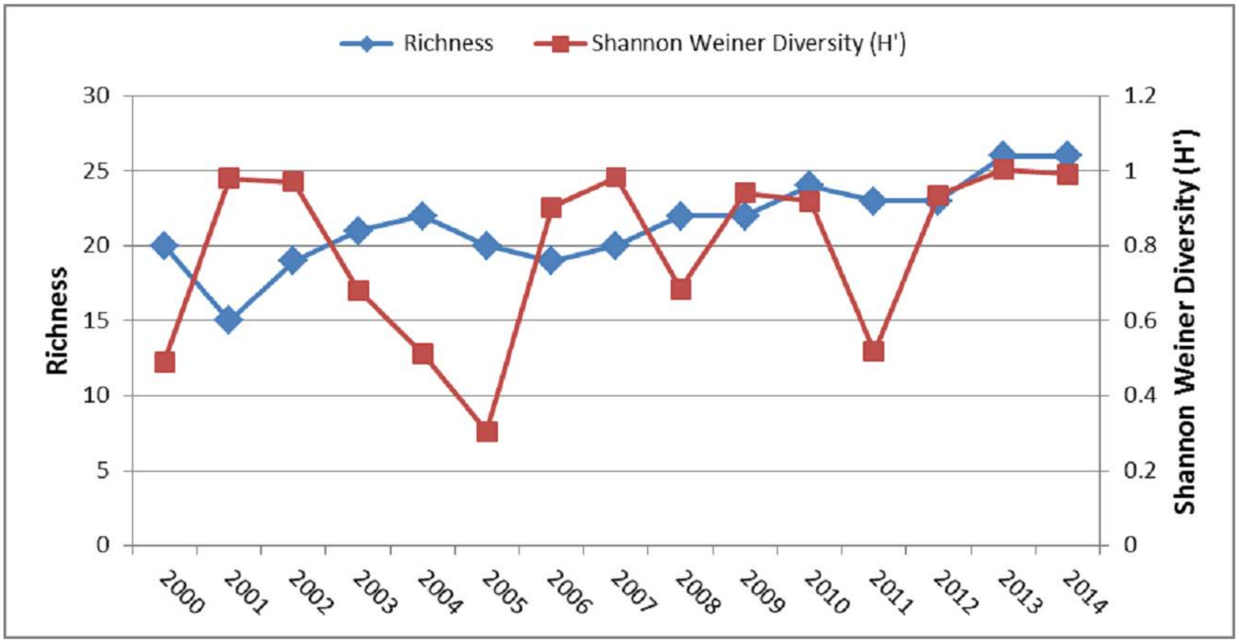
Note: CPUE for gamefish (Smallmouth Bass, Largemouth Bass, Pumpkinseed, Bluegill, Yellow Perch, Walleye, Brown Bullhead, and Channel Catfish) is calculated from all 24 transects. CPUE for non-gamefish (White Sucker, Gizzard Shad, Alewife, and White Perch) are calculated from only the one-half of the transects where all fish are collected (every other transect). Because of the difficulty in netting clupeids (shad and alewives), the CPUE for these species is calculated from a combination of fish that are boated and estimates of the number of fish missed. Note: Y-axis differs for each species.

6.4.2.2 Richness and Diversity

In Onondaga Lake, adult species richness (i.e., number of species) collected during electrofishing events has gradually increased since 2000. A total of 26 adult species were captured during the electrofishing survey in 2014, the highest reported value since 2000 with the exception of 2013 at which time 26 species were also captured (Figure 6-16). Minor fluctuations in species richness over the past six years are primarily due to the incidental catches of uncommon species such as Black Bullhead (*Ameiurus melas*), White Bass (*Morone chrysops)*, and Quillback (*Carpiodes cyprinus*) and the introduction of invasive species such as Round Goby. Onondaga Lake is part of the Three Rivers System, which provides a corridor for fish movement between the lake and the waterways connected to the Seneca, Oneida, and Oswego rivers as is evident based on tag returns since 1987 (Gandino 1996, Siniscal 2009). Since the monitoring program started in 2000, 53 species have been identified in the lake.

Fish community diversity fluctuates in response to changes in seasonal and environmental variables and inter-species competition, among other factors. In Onondaga Lake, changes in diversity are highly influenced by periodic peaks and crashes of two species of clupeid (herring family), Alewife and Gizzard Shad. Abundance of these two species is highly variable because both species periodically exhibit significant winter mortality. Extremes in recruitment are seen as well; both fish periodically produce very strong year classes that dominate the catch for years, as Alewife can live to ten years and Gizzard Shad even longer. Shannon-Weiner diversity (H'), an index that considers richness and relative abundance, has fluctuated over the past 14 years due largely to shifts in abundance of clupeids, with the highest value (1.00) observed in 2013 and the lowest value (0.30) observed in 2005. The 2014 value was 0.99 (Figure 6-16).

White Bass captured from Onondaga Lake.



Electrofishing (Adult fish only)															
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Richness	20	15	19	21	22	20	19	20	22	22	24	23	23	26	26
Shannon Weiner Diversity (H')	0.49	0.98	0.97	0.68	0.51	0.3	0.9	0.98	0.69	0.94	0.92	0.52	0.94	1.00	0.99

Figure 6-16. Trends in adult fish Shannon-Weiner Diversity (H’) and Richness 2000–2014.

Trap nets are passive gear, which are used to sample littoral zone fish and have been used by ESF since 1987 on Onondaga Lake. Because vulnerability to different gear types is not the same for all species of fish, direct comparisons to electrofishing will not be made; however, the combination of the two data sets allows for a more complete assessment of the overall fish community in Onondaga Lake.

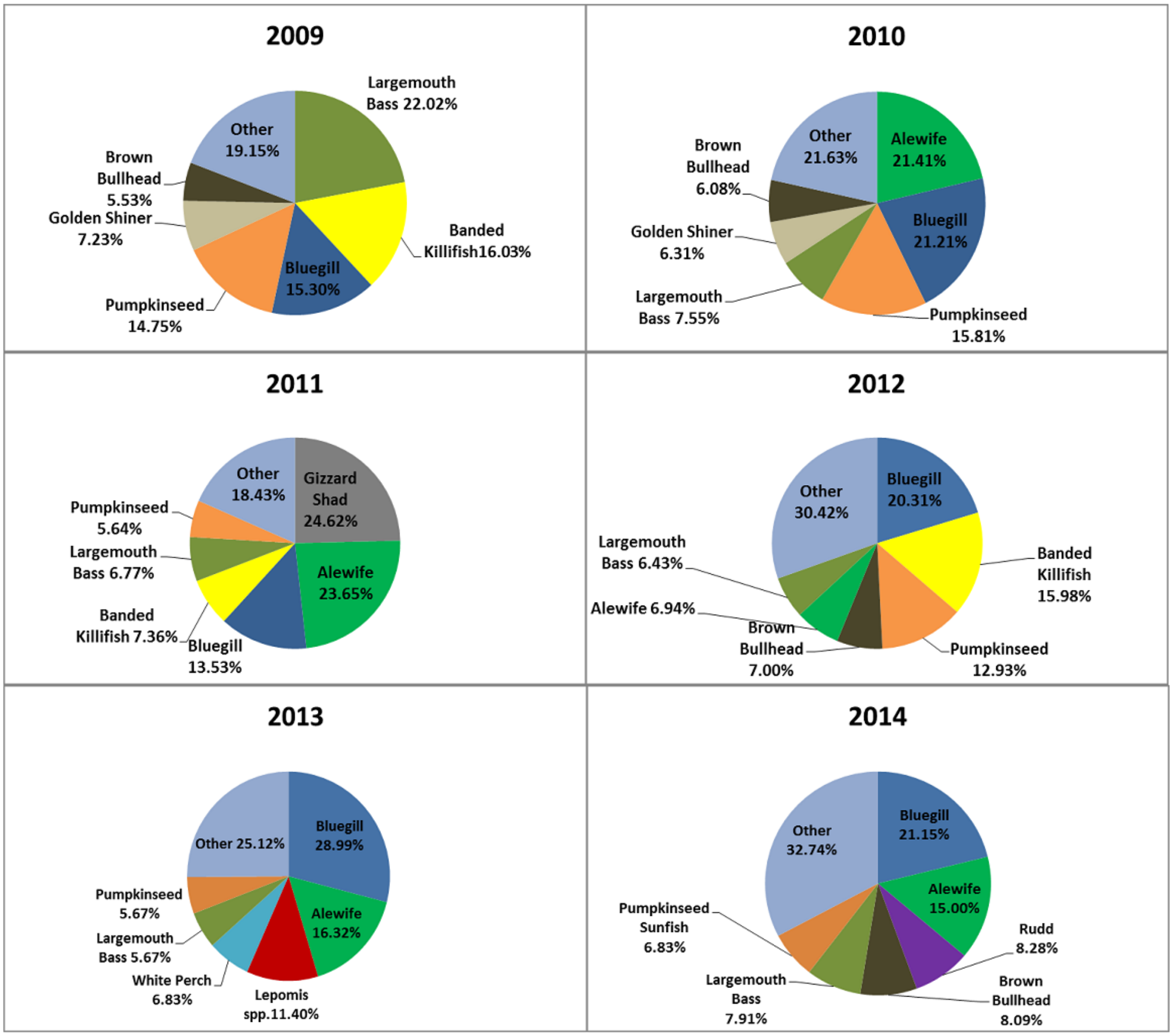
Trap net catches from 1987–1996 were dominated by pollution tolerant species, including Gizzard Shad and White Perch (Arrigo 1998; Gandino 1996; Tango 1999). However, by 2005 Alewife, instead of Gizzard Shad and White Perch, dominated the catches (Siniscal 2009). Since 2008 as part of the Honeywell monitoring program, monthly trap net sampling is conducted by SUNY-ESF students from May through October at ten locations around the lake. Overall catches in trap nets were:

- 8,857 in 2009,

- 6,134 in 2010,
- 6,295 in 2011,
- 3,373 in 2012,
- 5,589 in 2013
- 3,806 in 2014

Lepomis sp. (Pumpkinseed and Bluegill) were the most frequently collected species in all years with the exception of 2011 when Alewife and Gizzard Shad were the most frequent species collected (Figure 6-17). Although the total catch in 2009 was the highest reported, species richness was the lowest compared to all years except for 2014. Additionally, the total catch in 2014 was the lowest compared to all years except 2012, yet species diversity and evenness was the highest that year.

The Onondaga Lake fish community has undergone a series of successions of pelagic planktivores. Alewife dominated the planktivore community in the 1950s, 1960s, and 1970s as documented by huge numbers of concretions (well-preserved fossils in which muscles were replaced by combustible, chalk-like material enriched in calcium and fatty acids) washed ashore (Dence 1956, Sondheimer et al. 1966, Wilcox and Effler 1981). Alewife were absent in the late 1960's (Waterman 1971), likely because of high numbers of White Perch (Noble and Forney 1969). Alewife were present in 1978 (Meyer and Effler 1980) and through the 1980s, but were absent in 1989 through 1991 when the population was dominated by Gizzard Shad and White Perch (Ringler et al. 1996). The current sampling indicates that Alewife are once again the dominant planktivore species. These patterns likely reflect the changing habitats in the lake, including increased macrophyte coverage, increased mussel abundance, and changes in the fish community associated with water quality improvements that may lead to a stable equilibrium in the future.

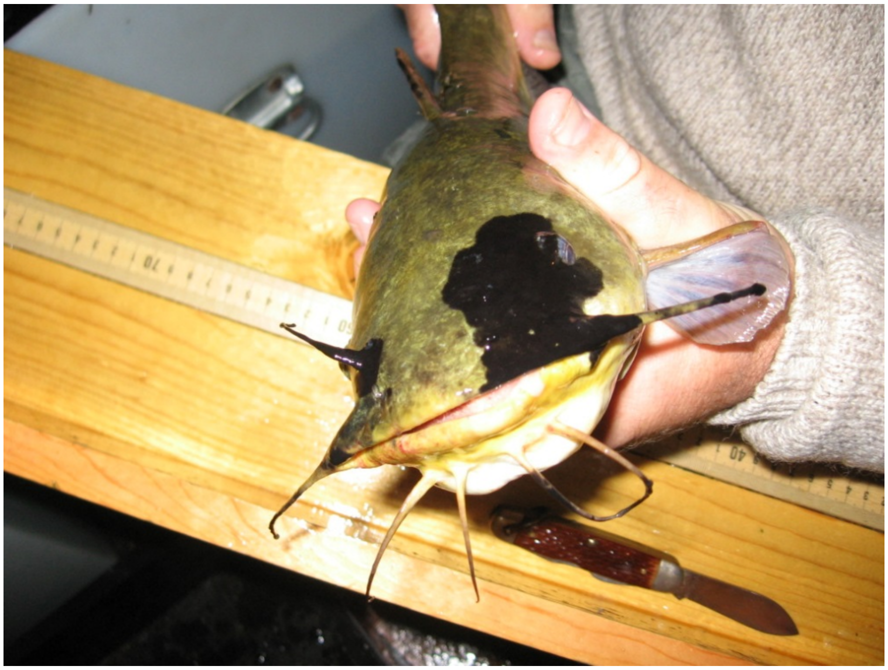


	2009	2010	2011	2012	2013	2014	Overall
Total Fish Captured	8857	6134	6295	3373	5589	3806	34054
Richness	33	37	36	35	35	31	45
Shannon Diversity	2.35	2.34	2.26	2.56	2.39	2.59	2.42
Evenness	0.67	0.65	0.63	0.72	0.67	0.75	0.68

Figure 6-17. Relative abundance of fish collected in trap nets from Onondaga Lake by SUNY-ESF, 2009–2014.

6.4.3 Fish Abnormalities

The occurrence of physical abnormalities in adult fish captured during AMP sampling is monitored using a standardized protocol of identifying Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies (DELTFM). Data are used for trend analysis and to compare fish collected from Onondaga Lake to those collected in other areas. Fish abnormalities can result from chemical contamination; biological agents such as bacteria, viruses, or fungi; or interactions among multiple stressors and is a good measure of whether an ecosystem is improving or not.



Brown Bullhead with black pigmentation collected from Onondaga Lake in 2012.

Note: Brown bullhead can exhibit irregular areas of black and/or yellow pigmentation on the body and mouth, with black pigmentation being more common. This abnormal pigmentation may or may not progress to neoplasia.

Overall, DELTFM abnormalities increased from 2003 to 2009, but have decreased since then. DELTFM abnormalities began declining in 2010 and steadily decreased to 2% in 2013 and increased to 3.9% in 2014 (Figure 6-18). The majority of abnormalities in the Onondaga Lake fish community in 2014 were lesions (44%) and deformities (44%). Twelve species of adult fish were identified with DELTFM abnormalities in 2014, similar to 2013 and recent years. The species contributing the most to the DELTFM total in 2014 were Brown Bullhead (47% of total), Largemouth Bass (9%), Northern Pike (7%), Gizzard Shad (7%), Yellow Perch (*Perca flavescens*) (4.7%), Channel Catfish (4.7%), White Sucker (*Catostomus commersoni*) (4.7%), and Yellow Bullhead (*Ameiurus natalis*) (4.7%). Largemouth Bass sampled in 2014 were observed to have a DELTFM frequency of 2.5%, lower than the Brown Bullhead frequency of 11%. The remaining 10 species observed had DELTFM frequency of less than 2%.

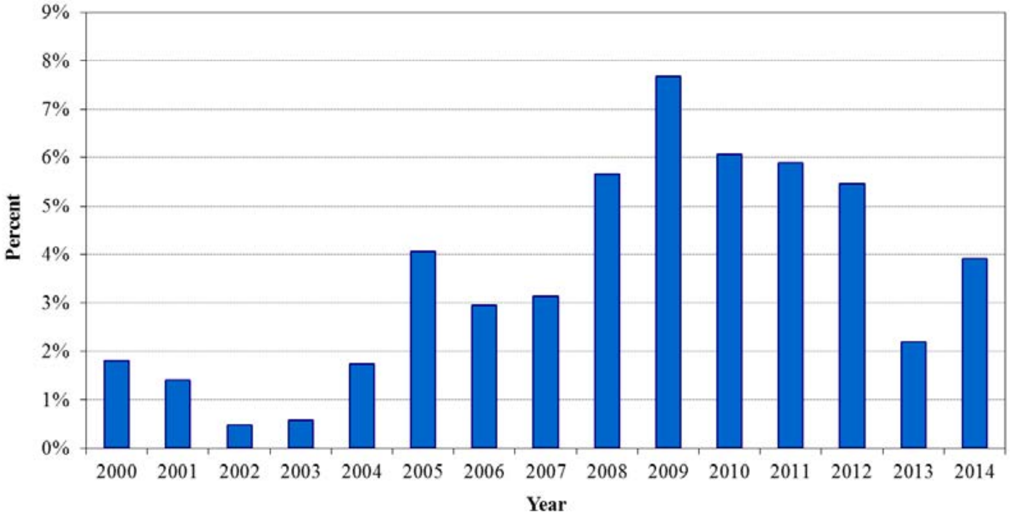


Figure 6-18. Percent of adult fish captured during AMP sampling with DELTFM abnormalities.

Note: DELTFM are defined as Deformities, Erosions, Lesions, Tumors, Fungus, and/or Malignancies. The increase in recent years is mostly due to an increase in the brown bullhead catch and a higher proportion of those Brown Bullhead having skin lesions. Analysis by Cornell University of Onondaga Lake Brown Bullhead in 2008 found a variety of pathogens including: Trichodina, Saprolegnia, Digenean infestations, Micrococcus luteus, and Aeromonas sobria.

The incidence of lesions and tumors in Brown Bullhead in Onondaga Lake from 2000 to 2014 was compared with similar data from the Chesapeake Bay watershed, Great Lakes, and Cape Cod (Baumann et al. 2008, Pinkney et al. 2004; Figure 6-19). Prior to 2007, occurrences of lesions and tumors in Onondaga Lake Brown Bullhead were within the range associated with reference sites (typically <5% incidence). From 2007–2009 a shift in occurrence was observed to levels more similar to contaminated sites from regional waters. The cause of this shift is not known, but may have been due to several identified pathogens affecting Brown Bullhead in 2008. The incidence of lesions and tumors in Brown Bullhead in Onondaga Lake has continued to decline since 2008, suggesting a recovery of the population from these pathogens. The incidence of lesions and tumors in Brown Bullhead in Onondaga Lake in 2014 was 1.7% and is within the range associated with regional reference sites (Figure 6-19).

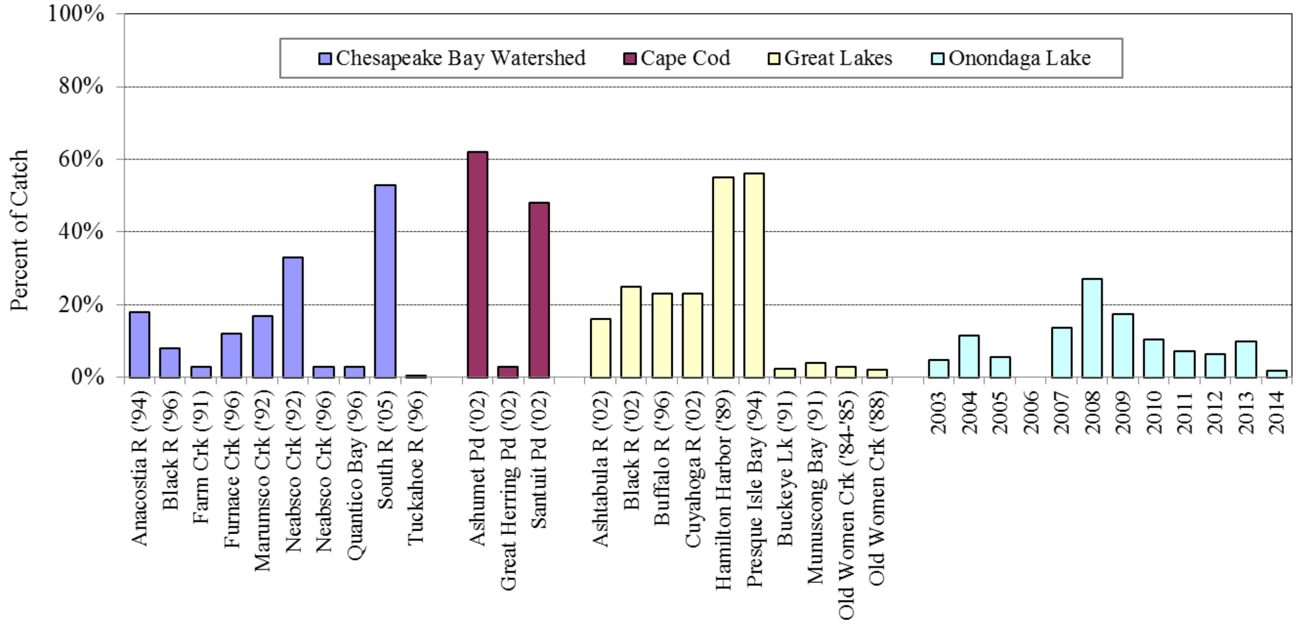


Figure 6-19. Occurrence of lesions and tumors in Brown Bullhead from Onondaga Lake and other regional waters.

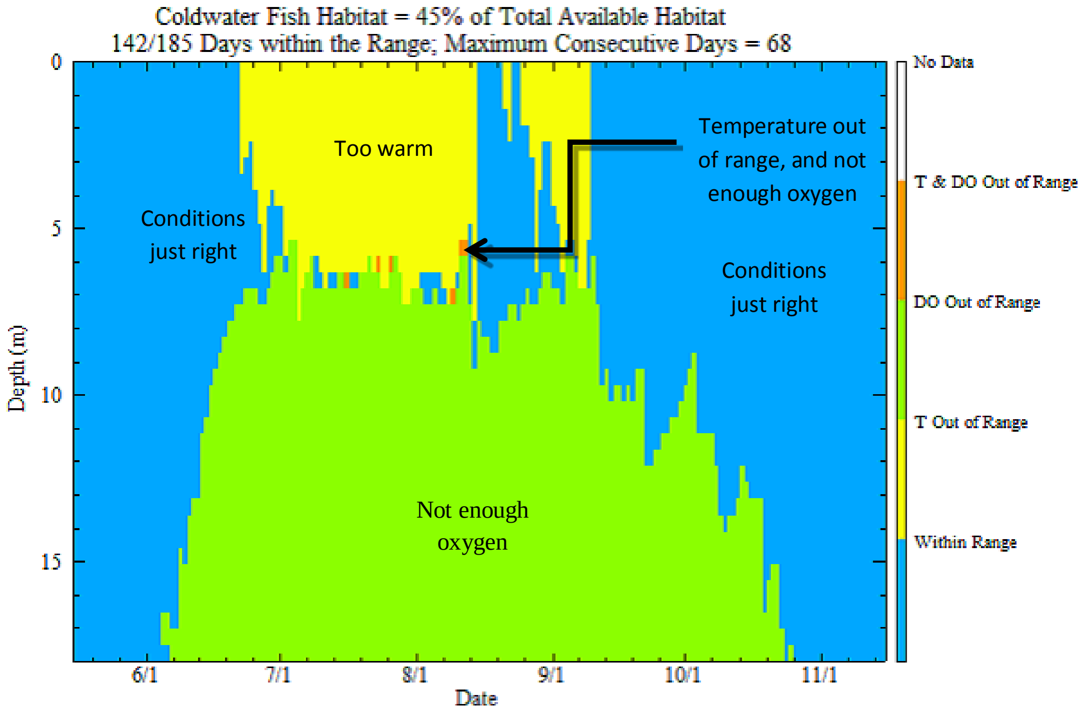
Note: Onondaga Lake Brown Bullhead data includes Lesions, Tumors and Malignancies, and does not include Deformities, Erosions or Fungal Infections. The following locations were identified as reference sites in the cited reports: Cape Cod – Great Herring Pond and Santuit Pond; Great Lakes: Buckeye Lake, Munuscong Bay, and Old Women Creek. Sources: Baumann et al. 2008, Pinkney et al. 2004. The year of each study is provided for reference.

6.4.4 Coolwater and Coldwater Habitat

Dissolved oxygen (DO) and water temperature largely determine the amount of habitat available for the different species that make up the Onondaga Lake fish community. The Data Visualization Tool (DVT) provides insight into the habitat available for coolwater and coldwater fish communities, or “fish space”. The fish space metric is useful for tracking changes in habitat based on DO and water temperature, two variables that determine the ability of coolwater and coldwater species to maintain a population. Optimal DO and water temperature requirements differ for coldwater and coolwater fish species as shown on Figures 6-20 and 6-21, respectively.

Available habitat for the coldwater fish community is calculated as a percent of the theoretical total, using volume-days as the measurement. For example, if half the lake’s water volume had suitable DO and temperature conditions for half of the selected time period, the percent available habitat is 25% for a given year. The 6-month period from May 15 through November 15 (185 days) is used because it encompasses the summer season when the upper waters of the lake can reach temperatures that are potentially stressful to the coldwater fish community. Moreover, the water quality monitoring buoy is deployed over this period and high frequency data are available. In Figures 6-20 and 6-21, the blue color represents the depth and timing of water temperatures and DO concentrations that are suitable for coldwater and coolwater fish habitat, respectively. Yellow represents where and when temperatures are out of range, and green represents where and when DO is out of range. Orange represents conditions where and when both temperature and DO are out of the range.

Overall, there has been a general lack of trends in coldwater and coolwater habitat in the past few years. The summer of 2014 was warm and surface water temperatures within the lake exceeded preferred conditions for coldwater species for a majority of the summer. (Figure 6-20). This effect was less pronounced for coolwater species with surface water temperatures exceeding preferred conditions briefly in early and late July (Figure 6-21).



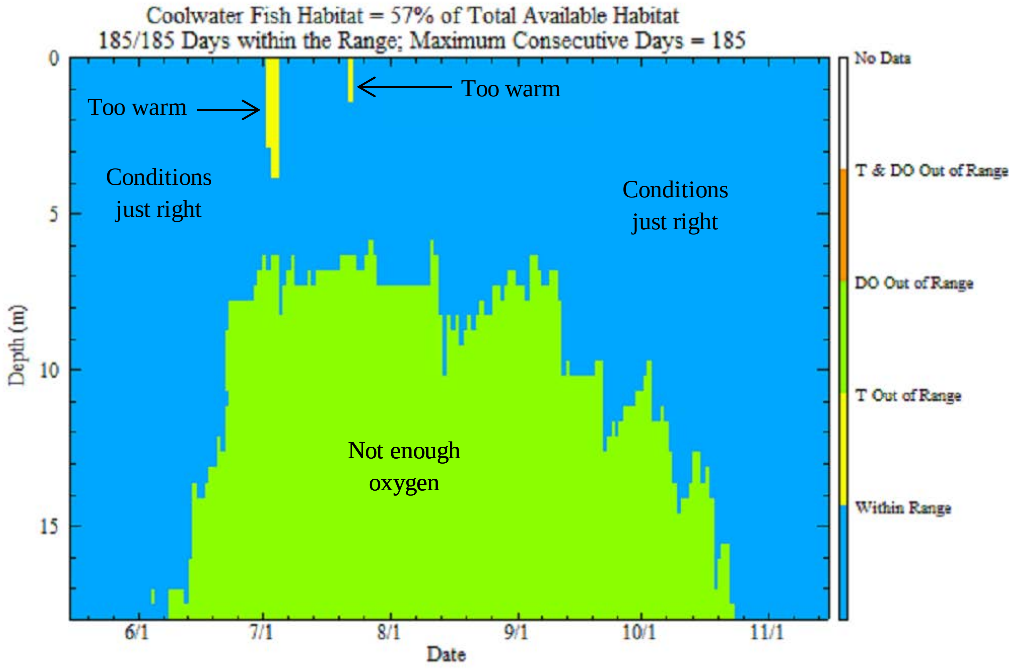
Year	% Avail. Habitat[2]	Total # Days in Range (max 185)[3]	# Consec. Days in Range (max 185)[3]	Year	% Avail. Habitat[2]	Total # Days in Range (max 185)[3]	# Consec. Days in Range (max 185)[3]
2001	33	140	72	**2008**	40	124	67
2002	30	95	49	**2009**	47	156	80
2003	31	125	47	**2010**	45	142	71
2004	32	161	67	**2011**	37	131	77
2005	34	115	59	**2012**	40	119	68
2006	39	131	80	**2013**	43	153	70
2007	36	138	65	**2014**	45	142	68

[1] Default DVT criteria: temperature ≤ 22ºC and DO ≥ 6 mg/L between May 15 and November 15.

[2] Assumes entire volume of the lake (May 15 to November 15) is available.

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

Figure 6-20. Coldwater fish habitat in Onondaga Lake in 2014 and trends in coldwater habitat availability 2000–2014.



Year	% Avail. Habitat[2]	Total # Days in Range (max 185)[3]	# Consec. Days in Range (max 185)[3]	Year	% Avail. Habitat[2]	Total # Days in Range (max 185)[3]	# Consec. Days in Range (max 185)[3]
2001	46	185	185	**2008**	53	185	185
2002	40	153	67	**2009**	56	185	185
2003	39	172	87	**2010**	55	180	95
2004	45	185	185	**2011**	46	172	106
2005	43	162	89	**2012**	46	155	94
2006	47	179	101	**2013**	48	180	115
2007	49	184	102	**2014**	57	185	185

[1] Default DVT criteria: temperature ≤ 25ºC and DO ≥ 5 mg/L between May 15 and November 15.

[2] Assumes entire volume of the lake (May 15 to November 15) is available.

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

Figure 6-21. Coolwater fish habitat in Onondaga Lake in 2014 and trends in coolwater habitat availability 2000–2014.

6.5 Integrated Assessment of the Food Web

The Onondaga Lake ecosystem is continuing to change, although overall nutrient status and indicators have stabilized over the past few years (i.e., ammonia and phosphorus concentrations have remained relatively consistent since 2006). The reduced phosphorus and ammonia concentrations have resulted in a decrease in algal productivity and virtual elimination of noxious blue-green algal blooms. However, other less desirable species including Alewife, dreissenid mussels, Rudd (*Scardinius erythrophthalmus*), and recently Round Goby now are abundant in Onondaga Lake and apparently have benefited from the water quality improvements. Exotic species dominate the food webs of many lakes, including Onondaga Lake. Alewife have had several successful year classes which have reduced the abundance of large *Daphnia*, resulting in less grazing on phytoplankton thereby decreasing Secchi disk transparency values to those more typical of eutrophic conditions. A detailed report on Alewife abundance in Onondaga Lake in 2014 can be found in Appendix F-5. Zebra mussel and quagga mussel have continued to expand deeper into the lake and Round Goby and Rudd populations have continued to increase each year. Increased macrophyte coverage has expanded nearshore habitat for many fish and presumably other aquatic animal species.

6.5.1 Influence of Alewife, Dreissenid Mussels, Round Gobies, and Rudd

Alewife Gill Netting Onondaga Lake, 2014.

Understanding Onondaga Lake's recovery is complex, and reductions in nutrients do not account for all of the changes observed in recent years. Phytoplankton biomass in the lake has declined as a result of reduced phosphorus loading from Metro, but differences between years are affected by the abundance and efficiency of grazing organisms. New species of fish that have entered Onondaga Lake have had varying degrees of influence on the biota. However, the influence of Alewife may be the most pronounced because the size structure of the zooplankton community is directly affected by Alewife. Alewife densities in the spring of 2014 were similar to observations made since 2010 and higher than densities during the low Alewife years of 2008 and 2009, but lower than estimates from 2005–2007. This general pattern is consistent with the zooplankton composition. Large *Daphnia*, which are correlated with higher water transparency, were only present in high abundance in years prior to 2002 and in 2008–2009; years with low Alewife abundance (Wang et al. 2010). For more information on the influence Alewife have on Onondaga Lake please see Appendix F-5.

Like most lakes, the community structure of young-of-year fish populations in Onondaga Lake varies annually and has been well documented in this and previous studies (Gandino 1996, Arrigo 1998, Siniscal 2009). Reproductive success of any species is a complex process controlled by many biotic and abiotic variables. Abundance of food resources, predation, climatic condition, habitat quality, and anthropogenic influences all play a role in the level of reproductive success. Young-of-year Bluegill and Pumpkinseed in Onondaga Lake have experienced sustained reductions in recruitment since 2006, possibly as a result of increased mortality during the pelagic larval phase from Alewife predation. Nesting surveys and the subsequent capture of larvae indicate centrarchids are reproducing in the lake; however, the reduced abundance of Pumpkinseed and Bluegill young-of-year indicates high mortality between the egg stage and the juvenile stage. Largemouth Bass dominated the young-of-year catch; this species defends the nest and young for several weeks, and the young remain in the littoral zone after leaving the nest, potentially providing some protection from predation by Alewife and other species.

Alewife are preyed on by larger, fish-eating species such as Smallmouth Bass, Northern Pike, and Walleye and have been frequently observed being regurgitated by Largemouth Bass during electrofishing sampling events during this study. Studies conducted from 1987 to 1996 described Walleye populations as being low (Ringler et al. 1996); however, studies conducted in 2005 and 2006 (Siniscal 2009) documented substantial increases in Walleye abundance compared to earlier studies. Alewife increased dramatically in Onondaga County's electrofishing samples in 2003 and remained high in 2004 to 2007, possibly providing a food source for Walleye that was absent before their establishment in Onondaga Lake.

Zebra Mussels (Left side) and a Quagga Mussels (Right side) collected from Onondaga Lake 2014.

Dreissenid mussels, both zebra mussel and quagga mussel, are invasive ecosystem engineers with large effects on the ecosystem through filtering and alteration of the benthic habitat (reviews in Karatayev et al. 1997, Karatayev et al. 2002, Higgins and VanderZanden 2010, Mayer et al. 2014). Both species arrived to North America and Lake Erie in the mid-1980s (Carlton 2008, Mills et al. 1993, Mills et al. 1996). Zebra mussels then spread rapidly and by 1993 were common across the Great Lakes and in many inland lakes, and had reached the Gulf of Mexico through the Mississippi River and the Atlantic Coast through the Hudson River (Benson 2014). Its congener, the quagga mussel, spread more slowly (Karatayev et al. 2011, Benson 2014). Even so, the quagga mussel did arrive at Lake Ontario in 1990 and was found in Onondaga Lake in 1992 (Mills et al. 1993). Quagga mussels have displaced zebra mussels in many areas, especially in deeper lakes where quagga mussels are found both in shallow and deep, cold water (Mills et al. 1996, Nalepa et al. 2010, Watkins et al. 2007, Watkins et al. 2012). Not a single zebra mussel was found in samples taken deeper than 30 m in Lake Ontario during the last whole lake survey in 2008 (Birkett et al. 2015). A similar range expansion of quagga mussels and displacement of zebra mussels have occurred in Europe (Orlova 2014, Matthews et al. 2014). In general, it takes longer time for quagga than for zebra mussels to reach maximum abundance after the initial colonization of a lake (average of 13 years for quagga mussels versus 2.5 years for zebra mussels, Karatayev et al. 2011, Karatayev et al. 2014b). However, both species produce large number of veligers suggesting that a fast population increase is possible for both species. The reason for this difference in the time to reach peak abundance after colonization is unknown. For more information on zebra and quagga mussels in Onondaga Lake please see Appendix F-3.

The displacement of zebra mussels by quagga mussels may increase the effects of these ecosystem engineers. As quagga mussels are found in all water depths from nearshore waters to several hundred meters depth and can colonize soft bottoms, they can build up higher lake-wide biomass than zebra mussels (Watkins et al. 2007, Nalepa et al. 2010). Therefore, the displacement of zebra mussels by quagga mussels does not only replace one filter feeder by another with little additional changes to the ecosystem, it increases the ecosystem effects of dreissenid mussels. Deep-living quagga mussels are likely the major cause for the observed decrease in the spring diatom bloom in Lake Michigan with associated negative effects on both the benthic amphipod *Diporeia* and spring zooplankton (Vanderploeg et al. 2010). Understanding the mechanisms involved in this replacement process is therefore of interest both to population ecologists concerned with species replacement mechanisms and to ecosystem ecologists studying the system-wide effects of dreissenids.

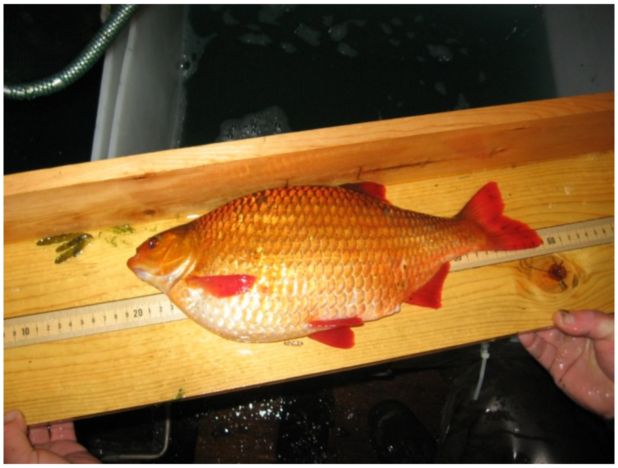
Although less is known about quagga mussels than zebra mussels (Karatayev et al. 2014a), there are several physiological and behavioral differences between the two species that may contribute to the replacement of zebra mussels by quagga mussels. Compared to zebra mussels, quagga mussels have lower metabolic rates, are more resistant to starvation, and can grow and reproduce in lower temperatures (Baldwin et al. 2002, Stoeckmann 2003, Roe and MacIsaac 1997, Karatayev et al. 2014a, Garton et al. 2014). Quagga mussels can therefore build up dense populations in deep, cold water and produce a larger number of veligers giving them an advantage over zebra mussels in the lottery for settling space (Claxton and Mackie 1998, Karatayev et al. 2014a). Results from investigations of filtering rates that directly compared the two species varies, with some finding no differences (Ackerman 1999, Naddafi and Rudstam 2014b) other finding lower weight specific clearance rates for quagga mussels (Baldwin et al. 2002, Hetherington et al. 2015). Quagga mussels also grow faster at low food concentrations (Diggins 2001, Baldwin et al. 2002). Therefore, the documented ability of zebra mussels to decrease algal abundance may result in low-food conditions which would favor quagga mussels (Mills et al. 1996, Mills et al. 1999, Negley et al. 2003). Predation has no direct role in the displacement process as quagga mussels are more vulnerable to predation because of their thinner shells, less aggregation behavior, lower propensity to seek shelter, and lower attachment strength (Kobak and Kakareko 2009, Peyer et al. 2009, Naddafi and Rudstam 2013, Naddafi and Rudstam 2014a, Naddafi and Rudstam 2014b, Czarnoleski and Müller 2014). However, this anti-predation adaptation has a cost, and Naddafi and Rudstam (2014a) showed that quagga mussels grew faster than zebra mussels in the presence of predator cues but not when predator cues were absent. Thus, zebra mussels invest more energy in predator defenses, expenditures that may infer too high a growth disadvantage in a new environment with less efficient predators feeding on these mussels (Naddafi and Rudstam 2014c). If true, the relative abundance of zebra mussels may increase in systems invaded by fish adapted to feed on mussels like the Round Goby (Kornis et al. 2012, Houghton and Janssen 2014). This species was first observed in Onondaga Lake in 2010 (Upstate Freshwater Institute et al. 2014).

The proliferation of zebra and quagga mussels in the Onondaga Lake may be helping to support the increased abundance of several species by providing an abundant food source. Pumpkinseed, Freshwater Drum, Yellow Perch, Common Carp, Lake Sturgeon (*Acipenser fulvescens*), and Round Goby feed on mussels and are likely benefiting from the increasing abundance of these mussels. Siniscal (2009) reported that the dominant Lepomis species shifted from Bluegill in the 1990’s (Gandino 1996) to Pumpkinseed in 2005 and 2006. He speculated that the switch in the littoral sunfish community from Bluegill dominance in 1993 to Pumpkinseed dominance in 2005 and 2006 could be a result of the introduction of dreissenid mussels. Adult Pumpkinseed are known to feed on mollusks, while Bluegill tend to feed preferentially on zooplankton (Werner 2004). He postulated that the shift in the dominant species of Lepomis captured in trapnets may be a combined effect of Pumpkinseed concentration in near shore areas and successful feeding on zebra mussels, and Bluegill utilization of zooplankton resources away from the littoral zone. Consumption of mussels by multiple fish species provides a connection between the benthic-based food web and the pelagic-based food web. The increasing complexity of the overall food web in Onondaga Lake is an important sign that the lake is recovering from past environmental perturbations.

The impact of zebra and quagga mussel populations on Onondaga Lake currently is not fully understood, but likely plays a role in the food web dynamics. Both quagga and zebra mussels filter large amounts of water (up to two liters per day as an adult) in order to draw in phytoplankton, small zooplankton, and bacteria they use as food. The removal of phytoplankton through this filtering action potentially could increase water clarity and reduce food availability for fish and other organisms. Additionally, waste produced by mussels could potentially affect the nitrogen and phosphorous budgets of Onondaga Lake.

Round Goby

Round Gobies were first collected in Onondaga Lake in 2010 and have continued to increase in abundance to date. Like Alewife they are preyed on by larger, fish-eating species and have been frequently observed being regurgitated by Largemouth Bass during electrofishing sampling events in Onondaga Lake. Hurley (2013) reported that Round Gobies were the most common food source of Largemouth Bass in Onondaga Lake based on the analysis of 137 stomach samples collected between May and July 2013. Where abundant, Round Goby can cause declines in native fish populations through its aggressive defense of nesting sites, predation on native fish and their eggs, and competition for food resources (Werner 2004). Additionally, Round Gobies spawn every 18-20 days and potentially up to six times during a breeding season. This reproductive pattern gives them an ecological advantage over native species which usually spawn only once (Dubs and Corkum 1996). Impacts of Round Goby invasion in Onondaga Lake are uncertain however, in areas where the Round Goby has been established they have had a severely negative impact on native benthic fish populations, such as the Mottled Sculpin (*Cottus bairdi*) and Logperch (*Percina caprodes*), from some areas of the Great Lakes.



Rudd

The first documented occurrence of Rudd in Onondaga Lake was in 1994 when Arrigo (1998) captured three individuals. Every year since 2008 ESF, as part of the Honeywell monitoring program, has captured Rudd in trap nets with increasing frequency. In 2008, 12 Rudd were collected increasing to 315 Rudd collected in 2014. Hybridization between Rudd and Golden Shiner is probable, and such hybridization could threaten the genetic integrity of Golden Shiner (Burkhead and Williams 1991). Impacts on other native fishes are also a possibility. Rudd likely serve as prey for predatory fish until growth limits predation. Eklov and Hamrin (1989) found that Northern Pike selected Rudd over Eurasian perch (*Perca fluviatilis*) in laboratory and field enclosure experiments, suggesting the potential to disrupt natural predator-prey relationships. Competition with native fishes for food is also a concern. In New Zealand, young-of-year Rudd fed on zooplankton and chironomids and larger Rudd fed on benthic invertebrates but became increasingly herbivorous at increased lengths (Hicks 2003). Feeding on zooplankton and chironomids could lead to competition between Rudd and many native fishes especially during early life history stages. If the Rudd populations continue to increase in Onondaga Lake additional research maybe warranted to better understand any potential effects.

6.5.2 Macrophyte Coverage and Implications for Fishery

In lakes, fish community structure and stability have been associated with the presence, abundance, species composition, and structural heterogeneity of macrophytes (Weaver et al., 1996). Macrophytes can contribute to increased fish abundance compared to areas or water bodies low or devoid of macrophytes (Valley et al. 2004); however, aquatic vegetation can have both positive and negative effects on warmwater fisheries. Excessive plant growth can monopolize light and nutrients in a lake and prevent stored energy from ascending the food chain. At high densities, aquatic plants reduce the ability of predatory species to find and capture forage species (Colle and Shireman 1980). This condition often results in overcrowding and stunting of panfish species, as well as reduced growth rates of predatory fish. On the positive side, aquatic plants convert toxic ammonia to usable nitrates, provide habitat for invertebrates and positively affect fish densities by increasing production at the lower end of the food chain (Wiley et al. 1984). In addition, vegetation provides escape cover for the young of most warm-water fish species and spawning habitat for many. Fish behavior related to macrophytes also has been described as an important factor influencing fish communities. Many fish associate with either the water surface immediately above the plants, the edge of the dense stands, “pockets” formed in the plant beds, or the bottom directly below dense canopy formations for foraging and predator avoidance (Killgore et al., 1989). Research suggests that, up to a certain point, there is a positive relationship between macrophyte coverage and Largemouth Bass production. A review of the literature estimates optimum macrophyte coverage for Largemouth Bass between 36 percent and 60 percent of the littoral zone (Stuber et al. 1982, Wiley et al. 1987). Based upon these relationships it appears that macrophyte coverage in Onondaga Lake in 2013 (50%) was in the ideal range for Largemouth Bass. Catch rates of Largemouth Bass in 2013 and 2014 were the highest observed since the start of the AMP possibly reflecting this relationship. Other species such as Pumpkinseed, Yellow Perch, and Brown Bullhead have increased markedly since 2008, likely benefiting from the increasing macrophyte distribution. Other species have not responded as favorably to the increase in macrophytes; Smallmouth Bass catch rates began declining in 2008 and reported catch rates in 2014 were the lowest observed since 2000. Smallmouth Bass occupies a variety of habitats throughout its native and introduced range. For the most part, the species prefers rocky and sandy areas of lakes (Werner 2004); with the increased depth and distribution of macrophytes in Onondaga Lake these areas are largely covered by macrophytes by early June.

6.5.3 Fish Community Dynamics

Changes in the biological and chemical characteristics of Onondaga Lake have been significant over the past ten years. Overall, there has been an increase in the quantity and quality of habitat available to fish species in Onondaga Lake as a result of decreases in nutrient loading. The fishes of Onondaga Lake are primarily a mixture of warm-water and cool-water forms with less abundant seasonal cold-water species composed mainly of Brown Trout (*Salmo trutta*). At least 66 species of fish have been reported from Onondaga Lake since 1987. Thirty one fish species were documented in Onondaga Lake in 2014. Since 2000, 53 species have been documented in the lake by Onondaga County.

Young of Year Longnose Gar collected in Onondaga Lake, 2014.

Alewife and Gizzard Shad continue to dominate the total catch but have yearly variations in catch rates. Abundance of these two species is highly variable because Onondaga Lake is near the northern edge of their range, and both populations periodically exhibit significant winter mortality. Largemouth Bass, Brown Bullhead, and Yellow Perch adults catches continue remain high, and Smallmouth Bass have continued to decline. This pattern is consistent with the increasing macrophyte coverage, which is not a preferred habitat for Smallmouth Bass. Additionally, Onondaga Lake lacks extensive gravel and rock shoals characteristic of ideal Smallmouth Bass waters. The limited abundance of young-of-year Bluegill and Pumpkinseed is not completely understood, but predation on the larval stage is likely a factor. The increase in Yellow Perch adults may be attributed to movement into the lake from the Seneca River. The connection to the Seneca River has served as a source of diversity to Onondaga Lake (Gandino 1996, Tango 1999, Siniscal 2009). This is supported by the documented instances of migration and the recurring presence of adult fish populations that lack juvenile year classes in Onondaga Lake.

Additionally, over the past 11 years angling primarily on a catch and release basis has increased markedly. Largemouth Bass provide important recreational and economic opportunities. In 2007, $7,447,320 was estimated for at-location fishing expenditures for Onondaga County and Largemouth Bass were the most commonly sought species at 30.5% of angler days (NYSDEC 2007). Onondaga Lake has become an increasingly popular location for catch and release Largemouth Bass fishing. It was the site for the 2007 Bass Master's Memorial

Tournament and continues to support local bass fishing tournaments each year. The improved water quality, increased plant coverage, changing plankton community, and the invasion by dreissenid mussels have altered the trophic dynamics within the lake. The fish community is still adapting to the various changes and will need to be monitored to more fully understand the trophic structure of the lake and how this may affect fishing opportunities in the future.

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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
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
CFU	Colony Forming Units
CPUE	Catch Per Unit Effort
CSO	Combined Sewer Overflow
DO	Dissolved Oxygen
DVT	Data Visualization Tool
EPA	Environmental Protection Agency
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HRFS	High Rate Flocculated Settling
METRO	Metropolitan Syracuse Wastewater Treatment Plant
MRL	Method Reporting Limit
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

NYSDOH	New York State Department of Health
OCDWEP	Onondaga County Department of Water Environment Protection
OLTAC	Onondaga Lake Technical Advisory Committee
OLWQM	Onondaga Lake Water Quality Model
PWL	Priority Waterbodies List
RSE	Relative Standard Error
SPDES	State Pollution Discharge Elimination System
SRP	Soluble Reactive Phosphorus
SSO	Sanitary Sewer Overflow
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TRWQM	Three Rivers Water Quality Model
TSS	Total Suspended Solids
UFI	Upstate Freshwater Institute
USGS	United States Geological Survey

GLOSSARY OF TERMS

Term	Abbreviation	Definition
303(d List)	--	the list of impaired and threatened waters (stream/river segments, lakes) that the Clean Water Act requires all states to submit for EPA approval every two years on even-numbered years. The states identify all waters where required pollution controls are not sufficient to attain or maintain applicable water quality standards, and establish priorities for development of TMDLs based on the severity of the pollution and the sensitivity of the uses to be made of the waters, among other factors (40C.F.R. §130.7(b)(4)).
Ambient Monitoring Program	**AMP**	Onondaga County's comprehensive program to evaluate the quality of the waterways [in Onondaga County] and track changes brought about by the improvements to the wastewater collection and treatment infrastructure and reductions in watershed sources of nutrients.
Amended Consent Judgment	**ACJ**	A legal finding or ruling. In this case, in 1998, an Amended Consent Judgment (ACJ) between Onondaga County, New York State and Atlantic States Legal Foundation was signed to resolve a lawsuit filed against Onondaga County for violations of the Clean Water Act. The lawsuit alleged that discharges from the Metropolitan Syracuse Wastewater Treatment Plant (Metro) and overflows from the combined sewer system (CSOs) precluded Onondaga Lake from meeting its designated best use. The ACJ obligates the County to undertake a phased program of wastewater collection and treatment improvements that will extend though the year 2012, monitor water quality response, and report annually on progress towards compliance.

Term	Abbreviation	Definition
Ambient Water Quality Standard	**AWQS**	Enforceable limits on the concentration of pollutants designed to protect a designated use of the waterbody. Standards are promulgated by NY State and approved by the U.S. Environmental Protection Agency.
ammonia-N	**NH_3-N**	An important form of nitrogen that is the end product of the decomposition of organic material; it is used by phytoplankton for growth.
assimilative capacity	**--**	The capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects to its designated use (e.g., without damage to aquatic life or humans who consume the water).
AUTOFLUX	**AUTOFLUX**	A customized software package developed by Dr. William Walker and used by Onondaga County WEP staff to estimate loading of water quality constituents (nutrients) to Onondaga Lake. The program uses continuous flow data and less frequent (often biweekly) tributary water quality samples to estimate annual loading rates.
biochemical oxygen demand 5 day	**BOD_5**	The amount of oxygen a water sample's chemical and biological composition will consume over a 5 day incubation period. The higher the BOD_5, the more oxygen used by the sample. Generally, the higher BOD_5 means lower water quality
Biological Aerated Filter	**BAF**	A combination standard filtration with biological treatment of wastewater. BAF usually includes a reactor filled with a filter media either in suspension or supported by a gravel layer. The dual purpose of this media is to support highly active microbes which remove dissolved nutrients from wastewater and to filter particulates.
Best Management Practices	**BMPs**	A combined group of activities designed minimize the amount of pollution that reaches a body of water. BMPs can be applied to agricultural, urban, and/or industrial areas as preventative measures to protect water quality.

Term	Abbreviation	Definition
bicarbonate	**HCO_3^-**	Serves a crucial biochemical role in the physiological pH buffering water in natural systems and thereby minimize the disturbance of biological activities in these systems
calcium	**Ca**	A nutrient required by aquatic plants and some algae for proper metabolism and growth. Calcium, normally as calcium carbonate, is also a common contributor to water hardness.
chloride	**Cl**	A halogen element usually associated with metallic elements in the form of salts.
chlorophyll-*a*	**Chl-*a***	A pigment used by plants and algae for photosynthesis. Chlorophyll concentration in lakes is used as a surrogate for estimating the amount of algae present.
combined sewer overflows	**CSOs**	A discharge of untreated sewage and stormwater to a water body; CSOs occur when the capacity of a combined storm/sanitary sewer system is exceeded by storm runoff.
conductivity	**--**	The measure of the ability of water to conduct electricity
cultural eutrophication	**--**	An increase in a water body's biological production due to human activities. Cultural eutrophication usually results in negative water quality impacts such as loss of clarity, increased algal blooms, decreased oxygen resources, and accumulation of reduced species
dissolved oxygen	**DO**	Dissolved form of oxygen, (dissolved in water) an indicator of the quality of water to support fish and aquatic organisms.
ecosystem	**--**	An interrelated and interdependent community of plants, animals, and the physical environment in which they live
Environmental Protection Agency	**EPA**	The federal agency responsible for the conservation, improvement, and protection of natural resources within the US.
eutrophic	**--**	Systems with high levels of productivity
fecal coliform bacteria	**FC**	Microscopic single-celled organisms found in the wastes of warm-blooded animals. Their presence in water is used to assess

Term	Abbreviation	Definition
		the sanitary quality of water for body-contact recreation or for consumption. Their presence indicates contamination by the wastes of warm-blooded animals and the possible presence of pathogenic (disease producing) organisms.
frustules	**--**	Silica-rich external cell walls of diatoms.
guidance value	**--**	Best professional judgment of the maximum concentration of certain pollutants that will protect a designated use.
High-Rate Flocculated Settling	**HRFS or Actiflo®,**	An advanced process used in the treatment of municipal wastewater. Actiflo™ is a compact process that operates with microsand (Actisand™) as a seed for floc formation. Actisand™ provides surface area that enhances flocculation and also acts as a ballast or weight to aid a rapid settlement.
Hilsenhoff Biological Index	**HBI**	An index that uses species-defined pollution tolerance levels to assess the overall tolerance level of a community of organisms, and is an indicator of water quality.
hypolimnion	**--**	Deep, cold waters of a stratified lake; portion of the lake volume that remains isolated from atmospheric exchange during periods of thermal stratification
hypoxia	**--**	Low dissolved oxygen conditions of a water body which is detrimental to aerobic organisms.
indicator bacteria	**--**	Bacteria used to indicate the potential presence of pathogenic (disease-causing) microorganisms in water (see also fecal coliform bacteria).
interrelatedness	**--**	The degree to which organisms in an ecosystem interact and are influenced by other organisms. Pathways of interaction between species in an ecosystem
littoral zone	**--**	Shallow water zone at the edges of lakes, where light reaches the sediment surface
magnesium	**Mg**	A metallic element required by algae for the production of chlorophyll.

Term	Abbreviation	Definition
metrics	**--**	Quantifiable physical, chemical and/or biological attributes of an ecosystem that responds to human disturbances; also, measurable attributes of the ecosystem that indicate whether a desired state has been achieved. Good metrics are cost-effective to measure, associated with low uncertainty, relevant to stakeholders and sensitive to anticipated changes.
mercury	**Hg**	A trace metal element that is toxic to aquatic life and humans.
mesotrophic	**--**	Systems with mid-levels of productivity; between eutrophic and oligotrophic
Metropolitan Syracuse Wastewater Treatment Plant	**Metro**	The wastewater treatment plant that treats the municipal waste from the City of Syracuse and large portions of Onondaga County, located in Syracuse, NY near Onondaga Lake.
New York State Department of Environmental Conservation	**NYSDEC**	The state agency responsible for the conservation, improvement, and protection of natural resources within the state of New York.
New York State Department of Health	**NYSDOH**	
nanograms per liter	**ng/L**	A concentration unit. One billionth of a gram per liter or 10^{-9} g per liter
nitrate-N	**NO_3-N**	A form of nitrogen used by phytoplankton for growth; the end product of nitrification. In addition, the final stages of wastewater treatment at Metro produces large quantities of nitrate-N that is discharged to Onondaga Lake.
nitrite-N	**NO_2-N**	A form of nitrogen formed in the intermediate step of nitrification. Accumulation of nitrite-N can be toxic to aquatic organisms.
nitrogen	**N**	A common element required by algae for growth. In aquatic ecosystems, nitrogen is usually in abundance and does not limit algal growth in most freshwater systems.
oligotrophic	**--**	Systems with low levels of productivity
Onondaga Lake Technical Advisory	**OLTAC**	

Term	Abbreviation	Definition
Committee		
particulate phosphorus	**PP**	The non-dissolved fraction of total phosphorus.
pelagic zone	**--**	Any water in the sea of a lake that is not near the bottom or the shore.
pH	**pH**	The negative log of the hydrogen ion concentration commonly used to quantify the acidity of a waterbody. pH is an important regulator of chemical reactions in ecosystems.
phosphorus	**P**	A common element required by algae for growth. In freshwater aquatic ecosystems, phosphorus is usually the nutrient limiting phytoplankton production. Increases in phosphorus can result in accelerated eutrophication.
photic zone	**--**	Upper layer of the water column where light penetration is sufficient for photosynthesis (algal growth).
phytoplankton	**--**	The community of algae and cyanobacteria present a water body.
percent model affinity	**PMA**	A measure of similarity of a sampled community to a model non-impacted community, using percent abundance of 7 major groups to quantify the community structure. The closer the similarity of the sampled community structure is to the model non-impacted community structure, the more likely that the sampled community is non-impacted.
potassium	**K**	A common alkali metal element necessary for proper growth and functioning of aquatic organisms.
profundal	**--**	The deep zone in an inland lake below the range of effective light penetration, typically below the thermocline
organic nitrogen	**--**	The total amount of nitrogen in a water sample, associated with total (particulate and dissolved) organic matter.
oxidation-reduction potential	**Redox or ORP**	A measure (in volts) of the affinity of a substance for electrons. The value is compared to that for hydrogen, which is set at zero. Substances that are more strongly

Term	Abbreviation	Definition
		oxidizing than hydrogen have positive redox potentials (oxidizing agents); substances more reducing than hydrogen have negative redox potentials (reducing agents). In Onondaga Lake's hypolimnion, ORP declines as organic material is decomposed.
Secchi disk	**SD**	A round disk, 25 cm in diameter, with alternating quadrants of black and white commonly used in limnology to quantify the clarity of surface waters. The disc is lowered through the water column on a calibrated line, and the depth at which it is no longer visible is recorded; thus indicating water clarity.
silica	**Si**	A metallic element used by phytoplankton for construction of cellular structures
soluble reactive phosphorus	**SRP**	A dissolved form of phosphorus that is most readily used by algae for growth.
sodium	**Na**	A common metallic element in aquatic ecosystems usually associated with chloride, NaCl a common form of salt
sonde	**--**	A compact monitoring device that includes one or more sensors or probes to measure water quality parameters, such as temperature, pH, salinity, oxygen content, and turbidity directly, eliminating the need to collect samples and transport them to a laboratory for analysis.
specific conductance	**SC**	Conductivity normalized to 25°C.
species diversity	**--**	A common ecological measure of the abundance and relative frequency of species in an ecosystem.
stoichiometric	**--**	The ratio of required elements needed for a chemical reaction; in this context, refers to the ratio of N and P required by phytoplankton for metabolism.
sulfate	**SO_4^{2-}**	A compound in abundance in Onondaga Lake due to the large quantities of gypsum (naturally occurring geological formation) in the lake's watershed. SO_4^{2-} can be converted to hydrogen sulfide when

Term	Abbreviation	Definition
		oxygen is depleted.
total dissolved phosphorus	**TDP**	A dissolved form of phosphorus that is used by algal for growth. TDP is not as readily available as SRP.
total dissolved solids	**TDS**	A common measure of the amount of salts in a water body.
total inorganic carbon	**TIC**	The total amount of carbon in a water sample, not associated with organic matter.
total Kjehldahl nitrogen	**TKN**	A measure of the concentration of organic nitrogen and ammonia in a water sample.
Total Maximum Daily Load	**TMDL**	An allocation of the mass of a pollutant that can be added to a water body without deleterious effects to its designated use.
total organic carbon	**TOC**	The total amount of carbon in a water sample, associated with total (particulate and dissolved) organic matter
total nitrogen	**TN**	The total amount of nitrogen in a water sample, associated with particulate and dissolved organic and inorganic matter.
total organic carbon filtered	**TOC_f**	The total amount of carbon in a water sample, associated with dissolved organic matter.
total phosphorus	**TP**	The total amount (dissolved plus particulate) of phosphorus in a water sample. TP is a common metric of water quality of aquatic ecosystems and an important water quality standard in Onondaga Lake is determined using surface water TP concentration during the summer months.
total suspended solids	**TSS**	The amount of particulate material in a water sample.
trophic state	**--**	The status of a water body with regard to its level of primary production (production of organic matter through photosynthesis)
micrograms per liter	**µg/L**	A concentration unit. One millionth of a gram per liter or 10^{-6} g per liter
milligram per liter	**mg/L**	A concentration unit. One thousandths of a gram per liter or 10^{-3} g per liter
volatile suspended solids	**VSS**	The total amount of organic particulate matter in a water sample (a fraction of TSS).
volume days of anoxia	**--**	A metric that integrates the volume of the

Term	Abbreviation	Definition
		lake water affected by low dissolved oxygen (DO) conditions over the duration of the low DO.
water year	--	The continuous 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 2010, is referred to as the 2010 water year.
watershed	--	The area of land that drains into a body of water
Water Environment Protection	**WEP**	The agency in Onondaga County, NY responsible for wastewater and storm water treatment as well as the monitoring and protection of all water resources in the county.