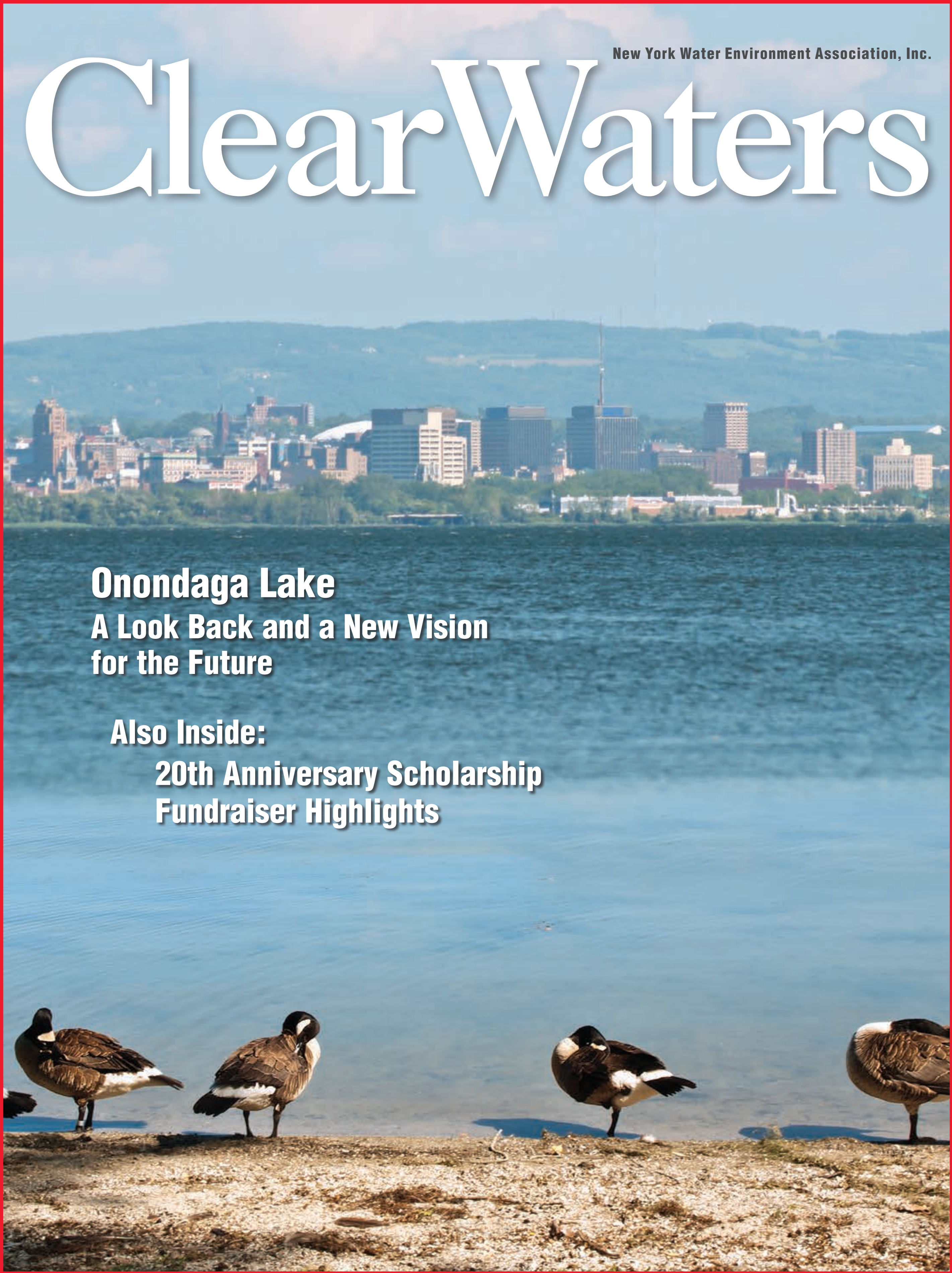
Winter 2017, Vol. 47, No. 4

New York Water Environment Association, Inc.

ClearWaters



Onondaga Lake
A Look Back and a New Vision for the Future

Also Inside:

20th Anniversary Scholarship Fundraiser Highlights

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Clear Waters

New York Water Environment Association, Inc.

Cover: Geese take a moment to enjoy the sunshine on the shores of Onondaga Lake in Syracuse, New York. Once known as the most polluted lake in the country, Onondaga Lake is on the road to recovery.
istockphoto.com, DebraMillet

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President's Message | Winter 2017

I hope this issue of *Clear Waters* finds you and your family well. The holiday season is upon us, with opportunities to visit with friends and family and reflect on what is truly important. At NYWEA, fall and winter bring a busy time of the year with many state and chapter activities. I am gratified that NYWEA is able to bring together water quality professionals to exchange knowledge, share experiences and network.

2017 WEFTEC

WEFTEC provides a national stage for water quality professionals. WEFTEC 2017 took place in Chicago, Illinois, the first week of October. Over 30,000 water quality professionals from around the globe converged in the "windy city" for networking and knowledge exchange. NYWEA hosted a reception Sunday night at Sweetwater Tavern that provided a great venue to socialize with our New York colleagues and properly kickoff the conference. Thank you to all that were able to attend. I hope you had as much fun as I did.

20th Anniversary Scholarship Gala

I was honored to be part of the celebration of NYWEA's twentieth anniversary of its Scholarship Program, on October 19th at the Hall of Springs in Saratoga Springs, New York. Co-chaired by longtime scholarship event organizers Bob Butterworth and Fotios Papamichael, this event honored U.S. Rep. Paul Tonko, Onondaga County Executive Joanie Mahoney and NYCDEP Commissioner Vincent Sapienza, P.E. Over 130 people gathered in a magnificent location during a picturesque time of the year to recognize these leaders for their contributions to the water environment. This single event raised over $84,000! In addition to the co-chairs, I'd like to thank the members of the Fundraising Team: Mark Koester, Dick Pope, Joe Husband, Al Lopez and Jamie Howard. Many thanks also to our Executive Director Patricia Cerro-Reehil, and her staff members Maggie Hoose and Theresa Baker for their roles in organizing this event. Most importantly, I'd like to recognize the sponsors for this event, without their generous support this program would not be possible. See pags 6 for photos from this great evening. To date, NYWEA has granted $417,000 in scholarships to 177 students.

Catastrophes and Opportunities to Do Good

Our nation and the Caribbean were hit with multiple strong hurricanes this fall, resulting in severe damage, loss of life, flooding, power outages and great humanitarian need. Our thoughts and prayers go out to the people impacted by these record-setting events. Most of us heard stories on the news about the devastation and the lack of sanitation and clean water. Events like these highlight the importance of clean water that you, the members of NYWEA, make possible every day in the communities you serve. For that, I thank you. With these tragedies, there are opportunities for those with our expertise in water systems to help. I know many from NYWEA have helped those affected by these storms in many ways and the need for more help persists. I know we will all continue to support the recovery efforts in our own way.

Upcoming Events

After another successful Watershed Conference in September, the volunteers and staff of NYWEA have turned their full efforts to planning and organizing the Annual Meeting scheduled for February 5-7, 2018. During this meeting, we will celebrate NYWEA's 90th anniversary by acknowledging the many advancements made in water quality over the last 90 years, while looking forward to ongoing and future challenges. We, the professionals of NYWEA, are well positioned to take on these challenges and continue to protect the water environment. Please join us in New York City to celebrate NYWEA's 90th anniversary.

Onondaga Lake

This issue of *Clear Waters* highlights Onondaga Lake in Central New York. The lake has made a remarkable recovery in a relatively short period. The 4.1 square-mile lake in the City of Syracuse faced two primary threats to its environmental quality: legacy industrial contamination; and municipal wastewater and combined sewer overflow discharges. Under the supervision of the New York State Department of Environmental Conservation and the U.S. Environmental Protection Agency, Honeywell worked with national and local experts to devise and implement a cleanup plan to address the legacy industrial contamination (see the article on page 17 by Honeywell's Syracuse Program Director John McAuliffe). Onondaga County, for its part, has implemented significant wastewater infrastructure upgrades that contributed to improved water quality in the lake, including the creative use of green infrastructure (see the article on page 14 by Onondaga County Executive Joanie Mahoney). Other articles in this issue look at aspects of the lake's recovery from several angles: the phosphorus Total Maximum Daily Load; the control of methylmercury using nitrate addition; the trends in mercury concentrations in fish flesh; and phytoplankton dynamics and harmful algal blooms.

Please read on about the remarkable accomplishments made in Onondaga Lake with articles about the lake's history, updates on efforts undertaken by those taking a lead cleaning up the lake, how the lake fishery is responding, ongoing lake research, and ways the community is engaging and how they are now able to enjoy the lake.

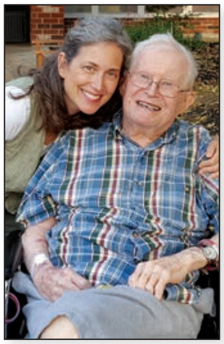
On a sad note, this year the Central New York community lost two of its Onondaga Lake champions: Robert D. Hennigan and Steven W. Effler. NYWEA honors the water legacy of these well-respected individuals in this issue of *Clear Waters*.

The Clear Waters App

Please remember that *Clear Waters* is now available on a mobile app, allowing our members to read the magazine on their smart phones and tablets. For more information on how to log-in, see the ad on page 5.

I wish you and your family a happy holiday season and joyous New Year.

Paul J. McGarvey, PE, NYWEA President



Taking Stock

Whether intentionally or unconsciously, at the end of every year we tend to take stock. How did the year go? What positive experiences stayed with us, and what sorrows touched our hearts? How do we make things better and improve in the new year? Inevitably, life becomes a blend of happy and sad times. We recently experienced this with the passing of my predecessor, Robert D. Hennigan, on October 12th. Bob lived a productive, long life and, as he used to say, was in his 93rd "natal year" when he passed. I am so very grateful that we stayed in touch over the years, and that I got to see him on his birthday just a few weeks before he died. So that is the sad part of the story. The flipside is that on the same day as his calling hours, we were holding the 20th Anniversary Scholarship Fundraiser in Saratoga Springs, an event that raised over $84,000! Bob would have been elated and as proud as we were by the success of this event and the scholarship program he initiated.

It is also serendipitous that this issue of *Clear Waters* magazine carries the theme of Onondaga Lake, a topic near and dear to Bob's heart, and one that he worked on with Steve Effler for many years. Steve also passed away earlier this year. It is with these losses in mind that we dedicate this issue to our water legacy partners and friends who both left us in 2017, Robert D. Hennigan and Steve Effler. *(See stories on pages 58-59.)* A special appreciation goes out to Peter Moffa, who by penning his historical article gave us the idea to dedicate another issue of the magazine to Onondaga Lake.

Business Plan – An Important Driver

I am so pleased to report that the Board of Directors has unanimously approved NYWEA's Business Plan that will carry our organization into the future. This plan has been insightfully created to set up specific objectives and share strategies for growth. It supports the initiatives outlined in the Strategic Plan and creates a tangible framework for making decisions. The Business Plan will be a great tool for all volunteers and the NYWEA leadership to follow moving forward.

Engagement with Advocacy Organizations and Elected Officials

In late October, NYWEA leaders participated in a Water Summit coordinated by Adrienne Esposito, Executive Director from Citizen's Campaign for the Environment. Over 25 different environmental organizations were present and shared their ideas and insights on water protection in New York. I was pleased to be present at the meeting with fellow NYWEA officers and volunteers, as well as leaders from our sister organizations, NYSAWWA and NY Rural Water Association.

Engagement with elected officials is a top priority, and NYWEA's Vice President-Elect, William J. Nylic, III, testified in early December at the state Assembly's Public Hearing on Water Quality, putting before the committee leaders the critical need for a dedicated funding stream for water infrastructure. This same message was delivered to state Senator John DeFrancisco, and will be shared with other elected officials in the coming months. We must remain vigilant and make sure everyone understands how critically important clean water is to the protection of public health and the environment.

Happy Holidays and Thank You!

Most importantly, the end of the year is a time for sharing our gratitude to everyone who has helped to shape the success for this organization! On behalf of NYWEA, many thanks to each one of you. Here's wishing you a happy and healthy holiday season and all the best in 2018!

Patricia Cerro-Reehil, pcr@nywea.org

Saratoga Springs, New York

NYWEA's 20th Anniversary Scholarship Fundraiser – a Huge Success with over $84,000 Raised!

NYWEA honored Congressman Paul Tonko, Onondaga County Executive Joanie Mahoney and NYC DEP Commissioner Vincent Sapienza at the October 19th event held in the Hall of Springs in Saratoga Springs, NY.

Our heartfelt appreciation goes out to the following individuals and companies who gave support to this event!

Benefactors: Koester Associates, Inc. and Siewert Equipment

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Many thanks also to the individuals and companies who made donations to this event! Our appreciation goes out to Jamie Howard who coordinated the wine tasting, and Theresa Baker who coordinated the wine-grab!

The evening-long celebration included a welcome from Scholarship Chair Robert Butterworth, and an Invocation from NYWEA's Treasurer Tom Lauro who was able to weave in a few of Robert Hennigan's Invocations from the past, as well as words of advice. The timing of this event was fitting and poignant as Robert Hennigan passed away on October 12th, and this scholarship program was kicked off under his initiative and leadership.

In addition to celebrating the scholarship honorees, contributors and supporters, 2016 Scholarship Winner Makenzi Herbst from RPI was also recognized for her environmental leadership.

Many thanks to everyone who made this event such a wonderful and huge success!

NYWEA President Paul McGarvey shares his appreciation.

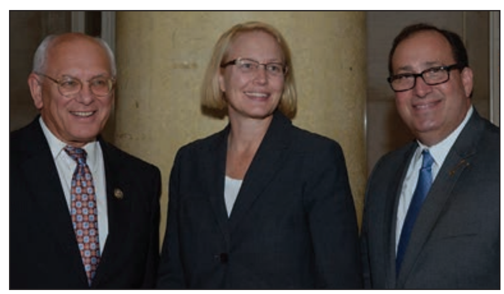
President Paul McGarvey presents Congressman Paul Tonko with a plaque recognizing his commitment to improved water quality.

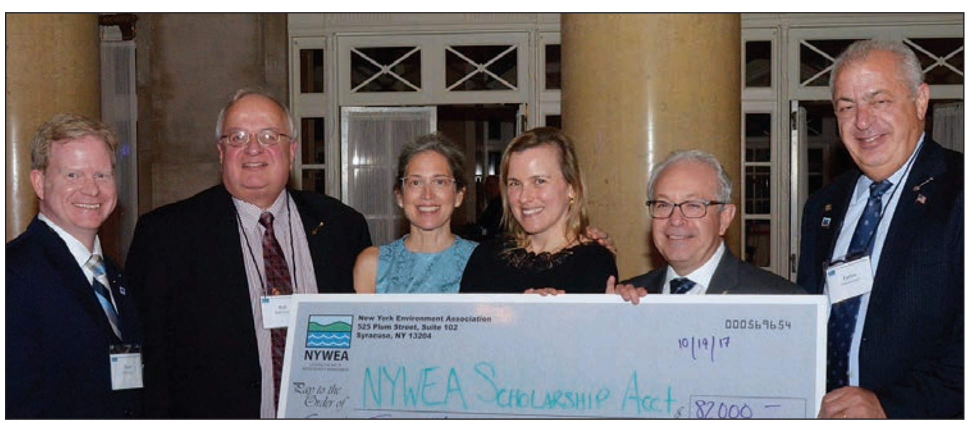
Onondaga County Executive Joanie Mahoney accepts the recognition and thanks everyone in the room for their work on water quality issues.

Scholarship winner Makenzi Herbst talks about how much being a scholarship winner meant to her.

President Paul McGarvey and Honoree, NYCDEP Commissioner Vincent Sapienza

Right: The evening's honorees: Congressman Paul Tonko, Onondaga County Executive Joanie Mahoney and NYCDEP Commissioner Vincent Sapienza





Over $84,000 was raised for scholarships, shown with the "big" check are (l-r): NYWEA President Paul McGarvey, 20th Anniversary Scholarship Fundraiser Chair Robert Butterworth, Executive Director Patricia Cerro-Reehil, Scholarship Committee Co-chairs Diane Hammerman and Al Lopez, and 20th Anniversary Scholarship Fundraiser Chair Fotios Papamichael.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Water Views | Winter 2017

Onondaga County's Save the Rain Program

Onondaga Lake, once widely referred to as the most polluted lake in North America, is now vastly improved. Hard work and fiscal investment transformed the lake from a noxious stew to a place where people fish, boat and picnic. Bass fishing tournaments are held on the lake. In 2015, NYSDEC's then-commissioner Joe Martens even went for a swim to commemorate very publicly the lake's comeback.

Standard Superfund and wastewater treatment practices have been a highly effective part of the restoration of Onondaga Lake. Collaborative efforts also produced Onondaga County's award-winning Save the Rain green infrastructure program to reduce combined sewer overflow (CSOs) discharges.

In many older urbanized areas with combined sewers, excessive storm waters frequently overwhelm the collection system, resulting in under-treated waste discharging into our waterways. The usual approach to CSOs has been "gray infrastructure" – highly effective tunnels, tanks, pumps and treatment systems. Onondaga County, however, embarked on an ambitious program to re-deploy hundreds of millions of dollars targeted for massive gray infrastructure toward community-beautifying "green infrastructure".

In January 2008, County Executive Mahoney suspended plans to construct large treatment facilities required by a federal consent judgment. These facilities would have loomed over Onondaga Creek and were unwelcomed by the local community and the Onondaga Nation. In 2009, a federal judge signed a much-revamped plan that relied on limited gray and extensive green infrastructure to achieve the aggressive 95 percent CSO capture goal. Onondaga County became the first community in the United States to enter into this type of legally-binding green program.

The initiative is an enormous success, from the 66,000-square foot green roof that covers the OnCenter Convention Center, to permeable basketball courts, to the water reuse cistern system at the War Memorial Arena. Rain barrels, tree pits, bio-retention filter-strips, underground infiltration systems and porous pavements abound. Onondaga County has made all its designs available on the web – there for you to use.

The success of the Save the Rain program has inspired other communities. For example, in 2011, New York City agreed to a $2.4 billion green infrastructure program as part of its long-term efforts to abate CSO discharges.

Installing green infrastructure is effective and makes sense due to its many co-benefits. Managing stormwater through green infrastructure saves energy, beautifies neighborhoods, abates localized flooding and basement backups and provides green space. In Syracuse, neighborhoods opposed to the treatment facilities welcomed the planting of trees and renovated parking lots. Communities interested in green infrastructure can explore Onondaga County's website, *http://savetherain.us*.

The State of New York provides funding for green infrastructure projects through the Water Quality Improvement Project program, the Green Innovative Grants Program and some NYSDEC watershed programs. I encourage all communities with CSOs to follow Onondaga County's lead and explore green infrastructure solutions to reduce sewage overflows into New York's waters.

– James Tierney, Deputy Commissioner for Water Resources
NYS Department of Environmental Conservation

Focus on Safety | Winter 2017

Health and Safety Plan Framework: An Adaptive Approach

I have lived in Central New York nearly all my life. From as far back as I remember, Onondaga Lake suffered from bad image and bad jokes. Old timers spoke fondly of swimming and fishing in its waters and I couldn't relate. Our joke back then was if we ever caught a fish in the lake, we would just nail it to the side of the barn and use it as a thermometer. Fortunately, those days are over, due greatly to the efforts of many and a massive cleanup project.

Looking at the cleanup project as an uninvolved geographical-area resident – and with the safety spectacles firmly in place – health and safety plans were crucial elements of the Onondaga Lake clean up project. The Community Health and Safety Plan (CHASP), submitted by the major contractor, addressed the safety and health issues likely to be encountered during the duration of the project that may affect the community. The project phases had individual project safety plans to ensure the health and safety of workers and contractors. The worker project safety plans helped the clean up project achieve a safety record that was recognized in 2014 by the Western Dredging Association. Not surprisingly, these health and safety plans would be immediately recognizable to many of us. Worker safety plans are a norm, not an anomaly, and are not just for large projects funded by governmental agencies and with a big budget. These may be called a HASP (health and safety plan), a safety program, a safety book, or by another name, but they perform the same function: they identify the anticipated hazards and control measures to minimize or eliminate those risks.

One of the necessary cultural aspects of the safety plans related to the lake cleanup is that the primary safety document stayed essentially the same for all the phases of the project. However, each individual plan was then enhanced by the hazards specific to the location or activity, passage of time, specific contractor or subcontractor, or any other identified condition not in the original plan. Essentially, the framework of the plan was a known entity but could morph as needed to address the specifics of the changing environment. These changes could be the ones known in advance as the project progressed, such as geography, contractors or season of year. These changes could also be real-time adaptations that are addressed in the field in a Job Safety Analysis.

For those of the readership not on a major construction or environmental project, an approach like that employed by the Onondaga Lake cleanup project can help put a safety program on track and keep it there. The safety policy book sitting dusty on a shelf is of no real help to anyone, but an organized strategy that is current, contextual and comprehensive may be a lifesaver.

– Eileen M. Reynolds, Certified Safety Professional
Owner, Coracle Safety Management

Onondaga Lake and Wet Weather Abatement: A Look Back

by Peter E. Moffa

Onondaga Lake, a jewel in the Syracuse, New York, metropolitan area, is in the process of recovery from years of misuse. It serves as an example of a once bountiful resource that has suffered the consequences of industrial and urban development. While a complex and unique water quality challenge, it is also a good example of the multi-faceted effort it takes to recover a polluted water body. The cleanup of Onondaga Lake has been a saga of the interplay of public concern and outcry, scientific knowledge and the coming together of political will, regulatory oversight and financial support. Over fifty years, it has taken the "perfect storm" of these components to come together at key times to provide the necessary actions to address pollution of the lake

Industrial and Urban Development

One of the earliest written accounts of Onondaga Lake was composed by Father Simon LeMoyne. In 1653, this Jesuit missionary wrote about the lake's salt springs along the southeastern shores: "We arrive at the entrance of a small lake in a large half-dried basin; we taste the water of a spring that they (the Indians) durst not drink." It was Father LeMoyne who showed the Onondagas how salt could be produced from the salt springs on the southeastern shore "as natural as that from the sea" *(Onondaga County 1971)*.

Salt was the first industrial resource of the Syracuse area. Salt was referred to as "white gold" because of its importance and increase in cost as it was transported westward. While the price of salt in Syracuse could be pennies per pound, in the far west (Pittsburgh, Pennsylvania) the price could be dollars per pound *(Onondaga County 1971)*. Transport of this highly valued commodity was a major factor in the development of the Erie Canal, the construction of which began in 1817.

In 1822, the Canal Commissioners were authorized $4,500 to cut a channel that would lower the waters of Onondaga Lake to the level of the Seneca River. While this greatly reduced the risks of malaria, it took away the buffering and protective wetlands bordering the southern end of the lake *(Onondaga County 1971)*.

The Erie Canal changed the Syracuse area from a sleepy town of 250 in 1820 to 22,000 in 1850. Syracuse was referred to as the "American Venice." *(Kurlansky 2003)*.

Onondaga Lake became a resort area known for its numerous amusement parks. Travelers from as far away as New York City came for recreational opportunities that included swimming, fishing and waterfowl hunting *(Thompson 2002)*. "Onondaga Lake whitefish," a member of the salmonid family thought to be *Coregonus* species *(Tango and Ringler 1996)*, was bountiful and a prized delicacy sold throughout New York.

In 1881, Alfred and Ernest Solvay opened the first – and what was to become the country's largest – plant that artificially produced bicarbonate of soda from the locally abundant supply of salt and limestone, using a process called the Solvay Process *(Solvay n.d.)*. Once again salt was to play a major factor in the area's development. Onondaga Lake was the source of the necessary cooling water and served as a convenient waterbody for the discharge of the thermal and process wastewater from the Solvay Process. Rapid industrialization was spurred by product demand and provided employment opportunities in the Syracuse area. Owing to the area's development as a transportation hub, several other types of industries eventually settled in the area, including air conditioning, general appliances, pharmaceuticals, steel and vehicular accessories. Onondaga Lake was the ultimate receptacle of the process waste waters of many of the major industries of the time.

The first recorded concern for the water quality of Onondaga Lake was in 1896, when the highly-regarded Onondaga Lake whitefish disappeared. Just two years earlier, in 1894 the Syracuse Post Standard had reported that "there are whitefish in our Lake without number" *(Onondaga County 1971)*. The cause for the loss of Onondaga Lake whitefish, as well as Atlantic salmon *(Salmo salar)* and American eel (*Anguilla rostrate*) during this time, has been attributed to degradation of the lake and adjacent tributary environments *(Tango and Ringler 1996)*.

By 1907 other communities, such as Solvay and Liverpool, developed and contributed to Onondaga Lake's pollution. Syracuse had grown to a population of 120,000 and concerns were expressed about the water quality of the lake's two major tributaries: Onondaga Creek and Harbor Brook. These two tributaries – and to a lesser extent, Ley Creek – received combined sewer discharges from the city's sewer system. These combined sewer discharges contained human wastes and posed a great risk to public health. In response to these concerns, the Intercepting Sewer Board was formed in 1907, which led to the construction of an Interceptor Sewer. The Interceptor Sewer conveyed the 90 separate points of combined sewer discharge from Onondaga Creek and Harbor Brook into one discharge point at the southern end of the lake. It was believed that Onondaga Lake would dilute the municipal sewage to "unnoticeable" levels. This was not to be the case. To further address the issue, in 1922 a 1,700-foot outfall pipe was constructed to further disperse and dilute the combined sewage into the lake *(Pitts 1948)*.

The First Steps toward Municipal Water Treatment

In 1925, owing to public concern, a municipal sewage treatment plant was built in Syracuse at the southern end of Onondaga Lake. The plant removed wastewater solids and employed chlorine disinfection prior to discharging through the outfall. This was the first recognition of the limitation of the lake to dilute wastewaters. Over the next forty years, improvements were made to what became known as the Syracuse Metropolitan Sewage Treatment Plant (Metro). Another treatment plant was built on Ley Creek in 1940 to address the city's continuing industrial and municipal growth in that area *(Pitts 1948)*.

In 1948, the City of Syracuse Department of Engineering conducted, for the first time, a water-quality survey which focused primarily on Onondaga Lake's tributaries. This was in response to concerns over the water quality of Onondaga Lake by the New York State Department of Health (NYSDOH). In 1957, the NYSDOH again raised the concern that recent improvements to Metro did not address the inadequacy of the sewer system; it was estimated that one-third to one-half of the dry-weather flow never reached the site of the treatment plant *(Pitts 1948)*.

The 1960s brought the dawn of a new era, largely influenced by Rachael Carson's ground-breaking book "Silent Spring." Through documenting the environmental hazards posed by DDT, Carson's book raised public awareness of human influence on the environment *(Natural Resources Defense Council 2015*). This elevated public awareness, combined with the creation of the environmental regulatory framework, resulted in new state and federal funding opportunities to address pollution control. In 1966, Onondaga County received a federal grant from the Water Pollution Control Administration, a predecessor to U.S. Environmental Protection Agency (USEPA), to determine the impact of industrial wastes on Onondaga Lake. As part of the grant, the county's Department of Drainage and Sanitation developed a wish list to clean up the lake. The list was developed in 1966 and included: a survey of the industrial wastewaters entering the sewer system; pilot-testing the treatment of the Metro discharge with the Solvay Process wastewaters; a baseline study of the lake; and an evaluation and proposed abatement of the combined sewer system.

The baseline survey was to become known as the Onondaga Lake Study and involved extensive monitoring of the lake at its two deep-basin locations starting in 1967. Thirty-two parameters were measured over a two-year period. Parameters were selected that represented the industrial discharges and algae that were in "suffocating" abundance. Also included in the study were thermal transects to identify the influence of the Solvay Process plant's cooling water discharge *(Onondaga County 1971)*.

During the second year of the monitoring program that followed the study, mercury was added to the list of heavy metals that were measured. Mercury was one of the Solvay Process waste products, used in the electrolytic cells that produced chlorine from calcium chloride.

The Onondaga Lake Study was arguably the most intense of its kind in the country at that time. A team of nationally-renowned advisors was formed to direct the study, led by an advisor specializing in overall limnology. The other advisors specialized in biology, chemistry, fisheries and mineral stability. The study identified the industrial and municipal pollutant sources and set the basis for prioritizing abatement actions ongoing to this day *(Onondaga County 1971)*.

Some of the surprising findings of the Onondaga Lake Study were:

- The sediments were dominated by calcite with only 10 percent organic material, and contained large populations of diatoms (a calcium-based algae). Before the study the sediments were thought by many to be devoid of life.
- The lake water had unusually high concentrations of calcium and salt resulting from the Solvay Process waste discharge.
- The lake's fish population was unexpectedly diverse, with over 50 species of fish.

The complex chemistry of the open waters, in conjunction with the sediments, reflected how the calcium discharged from the Solvay Process was causing both sediment buildup and entrapment of much of the phosphorus loading to the lake. The sources of phosphorus were two-fold: transported to the lake via the tributaries from the active farming industry in the watershed; and the discharge from the Metro plant. The high phosphorus concentration was identified as the major factor in the lake's eutrophic status. Based on the findings of the study, the advisors recommended that water quality measurements be continued through an annual monitoring program, which is ongoing to this day *(Onondaga County 1971)*. The monitoring program has served as an invaluable record of tracking water quality improvements resulting from a wide range of abatement steps.

Feasibility Studies and CSO Abatement

The 1960s was the beginning of significant steps toward cleaning up Onondaga Lake. Grants for feasibility studies and construction of abatement facilities were awarded, with 75 percent from federal, 12.5 percent from the state and a local commitment of the remaining 12.5 percent. The feasibility studies were conducted through the newly-created (July 1, 1970) New York State Department of Environmental Conservation (NYSDEC) and the federal USEPA formed on December 2, 1970.

In 1971, the City of Syracuse enacted a limit on detergent phosphorus, which was followed in 1972 by a statewide limit. Also in 1971, the County initiated an intense maintenance program of the overflow control structures along Onondaga Creek and Harbor Brook, which increased the capacity and reduced the frequency of overflows.

During Onondaga County's feasibility studies, a major improvement to Onondaga Lake's water quality was observed that was attributed to both the phosphorus detergent limit and to improved sewer maintenance. Phosphorus in the lake had been reduced by over 50 percent, and because of reduced algae growth and subsequent die-off the dissolved oxygen in the lake improved by 20 percent *(Murphy and Moffa 1973)*.

In 1972, amendments to the federal Water Pollution Control Act of 1948 ushered in the most sweeping water quality requirements applicable to navigable waters. The goal of the 1972 Amendments, referred to as the Clean Water Act (CWA), had as the goal the achievement of "fishable, swimmable" water quality in navigable and tributary waters of the nation. Many of the components of Onondaga County's 1966 wish list, interestingly, became requirements of the CWA, including: an industrial wastewater and pretreatment survey; secondary treatment at Publicly-Owned Treatment Works (POTW); and abatement of the combined sewer overflows (CSOs). The latter was to focus on the public health concerns related to bacteria in raw sewage from the CSOs.

The CSO abatement plan sparked a USEPA Research & Demonstration (R&D) Program for Onondaga County that was to become one of the largest in the country. The R&D program started with a concern expressed by the county's Department of Drainage and Sanitation that a proposed interceptor-overflow conduit, estimated at $60 million (in 1967 dollars) was prohibitive and that "satellite" treatment at select CSO locations might avoid the costly tunnel-size pipe. A 75 percent federal grant was offered to the county to demonstrate CSO satellite control and treatment technologies. Full-scale units were tested at two Syracuse CSO sites: Newell Street and Maltbie Street. The first USEPA vortex device, termed a "swirl concentrator/regulator," was located at Newell Street. Three different high-rate screening devices with high-rate mixing were located at Maltbie Street. High-rate mixing was designed to accomplish disinfection with a contact time of less than five minutes; conventional treatment plants required contact times in excess of 30 minutes for disinfection *(USEPA 1979)*. The USEPA vortex device that was demonstrated in Syracuse was followed by the development of British and German versions. Vortex and the high-rate disinfection technologies initially demonstrated in Syracuse were eventually implemented for CSO control and treatment throughout the United States, Canada, and Europe. A list of installations was later provided as part of the Consent Order described later in this article.

In 1976, Onondaga County received a USEPA R&D grant to measure the actual impact on receiving waters from CSOs; this was the first such study in the country to do so. The "Storms Impact Study" involved monitoring of the water quality of the tributaries and Onondaga Lake before and after six storms of varying duration and intensity *(Stearns & Wheler Engineers 1979)*. A mathematical model of the lake was developed and verified as part of this study. The Storms Impact Model was used to select the most cost-effective

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storm for CSO abatement, commonly referred to as the "knee of the curve" solution. The storm selected through a consensus of local and state authorities was a one-year return frequency intensity/duration storm. This procedure was an approach commonly employed by many municipalities.

In 1979, Onondaga County submitted their first CSO Abatement Plan to NYSDEC. This plan proposed Best Management Practices (BMP) improvements to the combined sewer system and control/treatment facilities comprised of vortex devices and high-rate disinfection at six regional sites throughout the city *(O'Brien & Gere Engineers 1979)*.

In the early 1980s the BMP improvements were completed at a cost of $10 million dollars. In 1986, the County updated the CSO abatement plan and verified through CSO monitoring, (with NYSDEC oversight), and Storm Water Management Model (SWMM), the effectiveness of the BMPs. The BMPs resulted in 85 percent capture of the annual CSO volume and a reduction of the number of overflows per year from 165 (pre-BMP) to 56 (post-BMP) *(Moffa 1997)*.

In 1979 the Metro plant was expanded to secondary treatment that included phosphorus removal using the calcium carbonate Solvay Process waste slurry as a precipitant. Consequently, the dissolved oxygen in the lake was markedly improved, particularly in the lower waters (hypolimnion). The algal community composition changed from predominantly blue-green algae – typically indicative of organic wastes – to that of green algae, which was verified and reported in the Onondaga Lake Monitoring Reports following 1979.

Consent Orders and TMDL

In 1989, Onondaga County entered into a legal Consent Order referred to as the Judgement on Consent (1989 Consent Judgement). The Atlantic States Legal Foundation (ASLF) brought suit against Onondaga County for violating water pollution control laws relative to the discharge of sewage to Onondaga Lake from Metro and the CSOs. Under this Consent Judgment, the County was required to develop and implement a Municipal Compliance Plan to address the discharges *(Onondaga County 1996)*.

Facilities planning was completed by 1992, which separately addressed the improvements to Metro and the CSO abatement. The improvements to Metro were focused on further phosphorus reductions to increase dissolved oxygen (DO) and nitrification to eliminate toxicity in the lake. The phosphorus reductions would reduce algae, which was found through lake modeling to be the major cause of poor DO in the lower waters. The ammonia discharged by Metro caused toxicity to fish and biota, as well as contributing to DO demand in the lake.

The main objective of CSO abatement was for the protection of public health from the attendant raw sewage and bacteria entering the lake. Since the main source of phosphorus was the Metro discharge, while the second greatest phosphorus load originated from nonpoint sources in the upper watershed related to farming, phosphorus from CSOs was considered a relatively small proportion of the total load. This was later verified through watershed modeling. Upon completion of the eight satellite Regional Control Facilities (RCFs), the annual phosphorus emanating from CSOs was projected to be on the order of 4 percent *(Moffa 1997); (Onondaga County 1996)*.

In 1995, over a dozen meetings were held by the parties to the 1989 Consent Judgment to come to agreement on the technical solutions needed to meet the directives of the judgement. These meetings were followed in 1996 by more meetings to develop the legal language of what would become the Amended Consent Judgement (ACJ). In January 1998, Judge McAvoy "entered" the ACJ, which superseded the 1989 Consent Judgement and resolved the claims asserted by the ASLF against Onondaga County under the CWA and the NYSDEC regulations. The three major components of the ACJ were: improvements to Metro; control and disinfection of the CSOs; and an Ambient Monitoring Program (AMP) *(Amended Consent Judgment 1998)*. Design of the facilities began in 1998. The stage was set for completion of all CSO and Metro projects by 2012 to achieve the CWA goal of a "fishable, swimmable" lake. The only exception to this goal was at the extreme southern end of the lake, adjacent to the Metro plant outfalls, which was recognized and accepted by all the ACJ signatories as an area not suitable for swimming *(Moffa 1997); (Onondaga County 1996)*.

Also in 1998, phosphorus Total Maximum Daily Load (TMDL) was developed for Onondaga Lake by NYSDEC. The TMDL assigned waste load allocations for point and nonpoint source contributions of phosphorus to Onondaga Lake.

Implementation of Municipal Treatment and CSOs

In October 2006, Onondaga County had all but completed the Metro improvements. For the CSOs, two of the eight planned Regional Treatment Facilities (RTFs) had been completed, the first on Ley Creek and the largest on Onondaga Creek. The largest floatables control facility (FCF) was also built at a CSO to Onondaga Creek. For Harbor Brook, a FCF was placed in-stream to be operated temporarily until two more RTFs were completed *(Moffa 1997); (Onondaga County 1996)*.

Significant improvement in the water quality of the tributaries and the lake were becoming apparent. Phosphorus and ammonia concentrations in the lake were the lowest measured over the 36 years of monitoring. Phosphorus concentrations have approached the New York State Ambient Water Quality Standards, while ammonia concentrations have met the standards. While bacteria concentrations at the northern shore – the furthest location from the Metro and CSO discharges – met standards for contact recreation for the entire summer recreational period, continued progress with CSOs, storm water and nonpoint sources of pollution was still needed. Blue-green algae, as a proportion of the algal community, had dropped from dominance to less than 2 percent. Improvement in the lake's fishery was notable, as both smallmouth and largemouth bass were becoming more common, particularly in the northern end *(OCDWEP 2006)*. This was a marked improvement to the fishery dominated by white perch that was reported in the 1971 Onondaga Lake Study.

Extension of the ACJ and Green Solutions for Stormwater

In 2009, the Onondaga County Executive and the ASLF petitioned for and were granted an extension of the ACJ deadline (2009 Extension) from 2012 to 2018 to allow more time to determine whether additional phosphorus reduction measures would be needed. These additional measures included possible diversion of the effluent from the Metro plant, and evaluation of using both gray and green infrastructures to capture an additional 10 percent (an increase from 85 percent to 95 percent) of the annual CSO volume. Gray infrastructure such as the RTFs, provide storage of runoff, that allows for delayed conveyance to Metro for treatment including phosphorus removal. Green infrastructure – including green rooftops, porous pavement and wetlands, among others – are intended to prevent runoff from entering the combined sewer system at all, and instead allow alternate routes for capturing and redirecting runoff. The intent of using the green infrastructure options was to eliminate or limit the need for constructing the remaining planned RTFs, which had become a contentious environmental justice issue within the communities where these facilities were to have been located *(Fourth Stipulation and Order Amending the Amended Consent Judgment 2009)*.

This was an essential and significant departure from the ACJ and original intent of the RTFs, which was to assure disinfection of the CSOs for public health protection. During the technical meetings held in 1995, storage alone had been shown to be not as effective and less feasible for the purpose of disinfection, particularly for the extremely intense and back-to-back storms. Phosphorous associated with CSOs and stormwater had been determined through watershed modeling to be less than 4 percent upon build out of all the RTFs. In particular, this was noted in the 2012 update to the phosphorus TMDL, which indicated that CSOs were still a contributor of phosphorus.

The 1997 original ACJ plan was designed to meet both the "Presumptive" and "Demonstration" Approaches of the CSO Policy. The ACJ Demonstration Approach was based on actual measurement/modeling of CSO discharges and water-quality impacts on the lake for intense storms up to a one-year frequency storm *(Moffa 1997)*. A major objective of the 2009 Extension was to increase the capture of CSOs beyond the Presumptive requirement of 85 percent. However, the additional storage and the green projects implemented do not yet meet or assure the Demonstration Approach of the swimmable goal for the lake.

The Work is Not Yet Done

Although the water quality and habitat of Onondaga Lake has improved measurably and significantly since the early 20th century, there are still challenges to be overcome. The very first source of pollution prompting public concern – the combined sewer system discharging sewage into the lake and its tributaries – has not yet been fully abated. Presently, there are CSOs still remaining that discharge raw sewage to Onondaga Lake under intense storm conditions, which increase the risk of bacteria in the water and results in partial achievement of the swimmable goal of the CWA. During intense storms and for two to three days thereafter, the lake may only be safe to swim at certain locations in the northern end – and at certain times – only if there were no intense storms two to three days prior. In general, during dry weather, water quality conditions for bacteria and water clarity have been suitable for swimming in the northern two-thirds of the lake. This portion of the lake is Class B, for which the best usages are primary and secondary contact recreation and fishing. The southern end of the lake is Class C for which the best usage is fishing. The signatories to the ACJ recognized that this Class C portion of the lake would not be suitable for swimming *(Amended Consent Judgment 1998)*. While the RTFs that were not constructed would have addressed the remaining CSO discharges, the green infrastructure implementation is on-going. Time will tell the extent to which the full build-out of the green infrastructure will increase the capture of runoff before it reaches the combined sewer system and thereby further reduce the remaining CSOs.

The ongoing cleanup of Onondaga Lake can serve as an excellent example of the interplay of public concern, scientific knowledge, political will and sources of public and private funding. The success has been the result of the work of hundreds of individuals, including researchers, engineers, political leaders, government employees and volunteers who have contributed tirelessly to the goal. We can only hope that government agencies, corporations, nonprofit organizations and other entities will continue to work together toward a cleaner Onondaga Lake.

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Onondaga County Save the Rain and Onondaga Lake's Remarkable Recovery

by Joanie Mahoney

Onondaga Lake is experiencing a rebirth. The old story of public sewers overflowing into its tributaries and industrial waste being piled on its shores is no longer. Today, the water is clean, the shoreline is being restored and people have rediscovered our urban lake. The combination of public and private investment turned what was once a liability into one of the county's biggest assets. People now flock to the lake to bike and walk on the miles of new trails, and they come by the thousands to watch concerts at the new Lakeview Amphitheater on the shore. There is a real renaissance occurring for this once neglected waterbody.

Several years ago, Onondaga County began to imagine what a clean Onondaga Lake could do for the region. We began to see the potential in our publicly owned shoreline and imagined what a bustling inner harbor connected to the heart of our downtown could mean. We knew pedestrians would enjoy a trail system that made it possible to safely loop the lake without having to dodge traffic.

After many years of work, a billion dollars of public and private investment and a lot of public input, we are now realizing that potential. In addition to the national acts taking the stage at the Lakeview Amphitheater, the lake now hosts boating, fishing and running events, cycling, a dog park, a skate park and many year-round activities. Future plans include a public beach, more trails and dredging of the harbor to welcome travelers who come by boat.

After 20 years of infrastructure improvements intended to satisfy a consent decree to clean the lake, we decided in 2008 to find a more environmentally friendly way to meet water quality requirements. Instead of building three more regional treatment facilities, we looked for a better way. The treatment facilities were expensive to build and operate, and caused real harm to neighborhoods when they were constructed. In addition, the hulking plants consumed massive amounts of energy and didn't clean the water as well as nature could. When a site was being prepared for a treatment facility in the heart of downtown Syracuse, we stopped what we were doing and looked instead at green infrastructure. We knew our combined sewer system overflowed when it rained. So instead of paying to capture, clean and pump all that water, we decided to keep the rainwater out of the sewer system in the first place. We invested in parks, created green streets and put green roofs on our buildings. We built basketball courts using porous pavement and planted trees to soak up the rainwater; we used rain barrels and cisterns to capture the stormwater; and we are making the ice for our hockey team out of recycled rainwater. We also built two underground facilities to store millions of gallons of combined sewer overflow during heavy rain and we direct those overflows to our existing wastewater treatment plant once the storm has passed.

We are very proud that Onondaga County was the first municipality to convince a federal court to amend a consent order to require green infrastructure to address combined sewer overflows. As a result, we developed what we call Save the Rain, a program now

The Lakeview Amphitheater, lower right in the photograph, is located on the shore of Onondaga Lake near the New York State Fairgrounds. Country singer Miranda Lambert was the first act to perform at the Amphitheater when it opened in 2015. *Honeywell*

The sport of rowing has a long history on Onondaga Lake. A local rowing club, CHARGERS, keeps a boathouse on the lake, and works with community groups, high schools and area colleges to teach and promote the sport. Regional and national regattas have also been held on the lake. *Onondaga County Save the Rain*

nationally recognized for its innovative use of green infrastructure to capture rain and snow melt to return it to the ground for natural filtration.

Approximately 200 green infrastructure projects have been completed to complement the more traditional gray infrastructure improvements. This more balanced approach resulted in our ability to capture over 97 percent of our overflows by 2016, exceeding the consent decree requirements and doing so years ahead of schedule *(OCDWEP 2017)*. We continue to work hard implementing even more green infrastructure projects because our intention is to run through the finish line. We know we are able to improve water quality as we continue to further reduce overflows.

We are also planning for the next phase once the consent order is lifted. We are working to reduce the litter that makes its way into Onondaga Lake and its tributaries. Approximately 98 percent of the litter that reaches the lake started out on the streets in Syracuse. Food and beverage containers, plastic bags and other items discarded improperly are carried by water or wind either into our sewer system or directly into the lake and creeks. The litter detracts from the great gains in improved water quality that we're seeing through the Save the Rain program. In 2016, we introduced "Connect the Drops," our newest outreach effort to educate the public to make the connection between street litter and water quality.

As part of our "Connect the Drops" campaign we are working with the Onondaga County Resource Recovery Agency (OCRRA), our regional recycling partner, to encourage residents to support our Block Litter initiative. *(See Madison Quinn's story, page 52.)* When neighbors pick up the litter on their own block and encourage their neighbors to do the same, we are working together to improve water quality.

We know that the investments in our infrastructure and the effort to get the public involved have already improved the water quality in Onondaga Lake. The northern two-thirds of the lake are even meeting swimmable standards every day of the year *(Upstate Freshwater Institute 2015)*.

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Fishing is an enjoyable pastime on Onondaga Lake, and it has become a very popular location for black bass and carp anglers. As with some other lakes in New York, there are currently health advisories for eating fish from the lake; however, the catch-and-release sport fishing opportunities are abundant. *Onondaga County Save the Rain*

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The Onondaga Lake fishery is thriving now as well – with 66 different species identified recently in sampling efforts. Sport fishing has become popular again on Onondaga Lake and we were proud to welcome Bassmaster Elite pros in 2016 when they came to fish on the lake *(Figura 2016)*.

All the new activity on the lake is making an impact on the local economy. When we built the Lakeview Amphitheater on the western shore of Onondaga Lake, we immediately welcomed visitors from all 50 states, as well as Washington D.C., Puerto Rico, and the U.S. Virgin Islands. People from all 62 counties in New York purchased tickets as well. Over 62 percent of tickets purchased were from zip codes outside of Onondaga County and over 30 percent were from outside the State of New York. We had hundreds of thousands of people come to the shores of a lake that only a few short years ago people went out of their way to avoid. Onondaga Lake is now an extraordinary asset to our community, bringing tourism and sales tax revenue from outside of the county.

The Loop the Lake Trail, when complete, will be 14 miles of continuous trail fully looping the lake. The project has been talked about for years and is now becoming a reality, thanks to the newly cleaned lake and a commitment from Onondaga County to keep the land accessible to the public. The Loop the Lake Trail will also connect to downtown Syracuse via the existing creek walk that follows Onondaga Creek to the heart of downtown Syracuse. This creek walk is an attractive feature for residents and tourists alike. People want to live in places where they can experience a variety of recreational opportunities. While the trails and parks on the lake already provide many different options, once the Loop the Lake Trail is completed, it will connect residents and visitors to the Erie Canal Towpath and ultimately the Empire State Trail that Governor Cuomo announced in January of 2017.

A newly revitalized Onondaga Lake is also an attractive feature for businesses near the lake and in surrounding areas. Restaurants, hotels and other businesses in the hospitality industry benefit as we attract visitors from outside of Onondaga County to visit the lake *(Beach 2016)*. Additionally, more commercialized development is happening at the Inner Harbor, where an Aloft Hotel recently opened. Further development is underway on other mixed-use buildings for offices, housing and more places to dock boats. Attracting businesses to this previously under-used area will create jobs and further satisfy the growing demand from people to be on our urban lakeshore.

Another economic benefit of a clean Onondaga Lake is attracting and retaining the young professionals that businesses need. Young people are attracted to communities that protect our natural resources, offer recreational opportunities, and offer entertainment opportunities like those now available on our lake.

Onondaga Lake has become a real source of pride in our community. Our clean lake is welcoming visitors and making our economy more vibrant. The investments we have made are paying dividends that the whole region will enjoy for generations to come.

Joanne M. "Joanie" Mahoney serves as the Onondaga County Executive. For inquiries about this article, contact savetherain@ongov.net.

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Onondaga Lake is Back

by John McAuliffe

Onondaga Lake in Central New York has undergone a transformation few thought possible as a result of one of the largest lake cleanup projects in North America. The remarkable progress is due in large measure to the talent, creativity and dedication of many who reside and work in the local community.

The restoration project, led by Honeywell, was completed through an unwavering focus on sound science, technical excellence, habitat enhancements, sustainable practices, a commitment to health and safety and community engagement. Careful planning and execution by a passionate team of scientists, engineers and skilled craft laborers led to groundbreaking collaborative work with regulators, elected officials, academics, nonprofits and the business community.

The cleanup, together with upgrades made by Onondaga County to its water resource recovery facility and the county's Save the Rain program, has resulted in the best water quality in Onondaga Lake in more than 100 years.

Sound Science and Technical Excellence

Under the supervision of the New York State Department of Environmental Conservation (NYSDEC) and the U.S. Environmental Protection Agency (USEPA), Honeywell worked on the restoration project with national and local experts including the State University of New York College of Environmental Science and Forestry (SUNY-ESF), Syracuse University and Upstate Freshwater Institute, among others. Decades of investigations led to the design and implementation of the dredging and capping remedy of legacy pollutants. About 500 Central New York workers have been an integral part of the cleanup.

A green heron rests in the restored Geddes Brook wetlands. *Honeywell*

The cleanup combined dredging and capping designs with long-term habitat restoration, leading to an environmentally protective solution. Lake dredging was completed in November 2014, a year ahead of schedule. About 2.2 million cubic yards of material was removed from the bottom of the lake using hydraulic dredges. Capping was completed in December 2016. More than 3 million cubic yards of material consisting primarily of sand, activated carbon and stone was used to cap 475 acres of the lake bottom, providing a new habitat layer. Habitat restoration is a major focus of the remedy and restoration.

In 2015, USEPA, in its five-year report on Onondaga Lake, stated that the cleanup is progressing as expected.

Habitat Enhancements

The Onondaga Lake Habitat Restoration Plan set the stage for how improved habitat conditions could revitalize the lake. Habitat enhancements were focused on diversification, the reintroduction of native species and connectivity. The work included new and enhanced wetlands, shoreline improvements and the robust habitat layer for the lake bottom. The Habitat Restoration Plan included input from Onondaga Audubon Society, Onondaga County Federation of Sportsmen's Clubs, Salt City Bassmasters, Sierra Club, F.O.C.U.S. Greater Syracuse and a host of other nonprofit organizations.

As a result of habitat enhancements in the restored wetlands and tributaries, Geddes Brook and Ninemile Creek are now part of a thriving ecosystem and green corridor connecting Onondaga Lake to upland areas. Habitat structures help ensure ideal conditions for various species. To improve the fishery, native vegetation was planted in shallow-water areas of the lake, and over a thousand fish habitat structures are being added to the lake bottom to attract game fish for anglers.

Plants with cultural or historical significance were carefully chosen. Many native species were selected to re-establish specific natural plant communities that once dominated the area, including floodplain forest, hardwood swamp and emergent wetlands. Native plants, well-adapted to local conditions, produce a beautiful progression of flowers, textures and colors, as well as attract wildlife including many pollinating insects. They can control and filter stormwater runoff better and more sustainably than many mechanical systems.

About 90 acres of wetlands along the lakeshore and the lake's tributaries have been improved, and about 1.1 million native plants, shrubs and trees are being planted. More than 250 species of fish, birds and other wildlife have returned to restored areas. Threatened bird species in the State of New York, including the bald eagle, pied-billed grebe and northern harrier, have been observed in restored areas near the lake.

In November 2015, Honeywell received Audubon New York's Thomas W. Keesee, Jr. Conservation Award for its leadership in the cleanup, which it called "one of the most ambitious environmental reclamation projects in the United States."

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Sustainable Practices

The cleanup featured traditional remediation practices and engineering, and smart ecological restoration. Hydraulic dredging helped minimize impacts to the lake and surrounding areas. Lake sediment was pumped to a consolidation area using a 4-mile-long, double-walled pipeline, eliminating the need for trucks to transport the material. Four electric-powered booster pumps were positioned along the pipeline route, and biodiesel was used to power equipment. This approach minimized greenhouse gas generation.

For its innovative work incorporating technologies into an environmentally sustainable remedy, the Onondaga Lake cleanup team received the Western Dredging Association Environmental Excellence Award for Environmental Dredging in 2017.

Commitment to Health and Safety

Health and safety measures were incorporated at every level of planning and operations to protect workers and public health. An experienced team of engineers, health and safety professionals, construction managers and quality-control personnel collaborated throughout the project.

A Community Health and Safety Plan was reviewed by the New York State Department of Health and approved by NYSDEC. A daily commitment to a safe workplace resulted in a safety record 80 percent better than industry standards.

In 2014, the Western Dredging Association awarded the Onondaga Lake cleanup team with its annual safety award for the project's outstanding safety record and performance.

Community Engagement

The Central New York community has played a key role in the efforts to restore Onondaga Lake. Community engagement and dialogue were critical to the success of the restoration. More than 1,200 meetings have been held to inform the public and gather feedback.

Starting in 2004, Honeywell and NYSDEC held a series of public meetings to outline the restoration and remediation plans. Public input was incorporated into the remediation and restoration design. Honeywell, in partnership with NYSDEC, created a habitat community working group with local habitat, conservation and community organizations to gather opinions and perspectives throughout the development of the Habitat Restoration Plan.

To keep the public informed and involved in the cleanup, NYSDEC established the Onondaga Lake Community Participation Working Group, which has offered opportunities for community input and ways for the public to receive information.

Up-to-date information about the cleanup's progress and community health and safety commitments is available to the public through fact sheets, electronic newsletters, NYSDEC's website and Honeywell's Onondaga Lake website.

Throughout the project Honeywell sought ways to educate and involve the community in activities that promote environmental stewardship and stimulate learning. Two avenues to accomplish this are through the Onondaga Lake Visitors Center and the Onondaga Lake Conservation Corps.

Onondaga Lake Visitors Center

The Onondaga Lake Visitors Center, which was designed and built by Honeywell, provides the public with access to the considerable progress achieved by hundreds of scientists, engineers and skilled craft laborers from this region. From significant improvements in water quality, to the return of native plants and animals, the center offers an opportunity to see the progress being made to restore the natural beauty and value of Onondaga Lake and adjacent habitats.

The Central New York community is returning to Onondaga Lake for outdoor recreation, including fishing. *Honeywell*

Since its opening in 2012, more than 15,000 people, including school groups, professional organizations and members of the Central New York community have learned about the cleanup at the Onondaga Lake Visitors Center.

Onondaga Lake Conservation Corps

Citizen participation and environmental stewardship have been an integral part of the habitat restoration. In July 2012, the Onondaga Lake Conservation Corps was founded with the goal of inspiring future stewards of Onondaga Lake and its watershed.

The experience-based program offers citizens and organizations the opportunity to participate in activities that help restore and sustain the Onondaga Lake watershed and its value as an Important Bird Area.

More than 650 community volunteers have become environmental stewards of Onondaga Lake and continue to participate in habitat restoration efforts. In recognition of their work, USEPA recognized the Onondaga Lake Conservation Corps, co-founded by Honeywell, with a 2015 Environmental Champion Award.

Conservation Corps partners include Audubon New York, Montezuma Audubon Center, Onondaga Audubon Society, Parsons, O"Brien & Gere, Anchor QEA, Bond Schoeneck & King, SUNY-ESF, Habitat Gardening in Central New York and Honeywell.

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Lakeview Amphitheater

The Central New York community has embraced Onondaga Lake's change by returning to the lake's shoreline to attend events at the Lakeview Amphitheater.

In 2014, Onondaga County announced plans to build an outdoor lakeside amphitheater. The Lakeview Amphitheater was built within a year and hosted its inaugural concert in 2015. More than 40 other concerts have taken place since then. Amphitheater concerts are estimated to attract up to 300,000 visitors annually to the lakeshore during the summer months, according to Onondaga County.

Onondaga Lake Cleanup Monitoring and Maintenance

Honeywell is implementing a comprehensive Onondaga Lake monitoring and maintenance program to ensure the remedy meets the long-term objectives outlined in the state and federal cleanup plan.

Source of Pride and Economic Driver

Onondaga Lake is now a source of pride and optimism for residents, and an economic driver for the region. The Onondaga Lake cleanup and restoration represents a successful collaboration between private and public entities to create and execute an innovative and sustainable project.

The restoration of Onondaga Lake, its lakeshore and nearby wetlands has progressed faster than expected. The lake is now being returned to the community as a healthy, sustainable asset, and the community is once again opening its eyes toward the recreational and economic potential of Onondaga Lake.

About 90 acres of wetlands on the lakeshore and along the lake's tributaries were improved as part of the cleanup. *Honeywell*

John McAuliffe is Honeywell's Syracuse Program Director with responsibility for the company's remediation and restoration of Onondaga Lake, and former Allied Signal properties. McAuliffe led hundreds of world-class scientists, engineers and skilled craft laborers from the Central New York region in one of the largest remediation projects in the country. He can be reached at John.McAuliffe@Honeywell.com.

Onondaga Lake and its Watershed: Recovery in Sight!

by Neil H. Ringler and Stephanie J. Johnson

Onondaga Lake is a remarkable jewel that is a vibrant part of the Syracuse, New York area. Most of us are aware of its checkered history of pollution, but few perhaps have witnessed the phenomenal success of its restoration. Faculty and students with the State University of New York College of Environmental Science and Forestry (SUNY-ESF) have helped with the restoration, working as partners with Honeywell and Parsons, to provide recommendations for habitat structures and to monitor the biological responses of this lake ecosystem.

Onondaga Lake Fishery

Long-time residents of the Syracuse area are often surprised that the lake has always had a fish community, which is documented in records dating from the 1700s, 1927, 1969 and the 1980s and 1990s through the present day. Sixty-four fish species have been recorded in the lake since 1986, with at least 40 found in any one sampling year. Even visitors from many countries attending the World Canal Conference in Syracuse on September 24, 2017, were surprised at the size and diversity of fish in the lake ***(Photograph 1)***.

Historically, the watershed held abundant populations of species such as Atlantic salmon *(Salmo salar),* brook trout *(Salvelinus fontinalis),* and American eel *(Anguilla rostrata)*. An unpreserved species described as the Onondaga Lake whitefish was served in top restaurants in New York City until its extinction near the turn of the 20th century. Today, American eel have been extirpated from the system, but brook trout are still present and landlocked Atlantic salmon have been stocked successfully in Nine Mile Creek annually since 2014. Based on the presence and survival of large brown trout in the lake, it should be only a matter of time before the salmon also reach the lake and achieve large size. In fact, the first record of an Atlantic salmon in the lake, near the mouth of Nine Mile Creek, occurred in September 2017.

The lake has become a center of aquatic education in Central New York since closure of the Allied Solvay plant in 1986. Studies of the fish in the lake have entailed sampling with trap nets, gill nets, seines and nighttime boat-mounted electro-shockers. Sampling occurs from ice-out to Thanksgiving each year. Plastic Floy tags and sonic tags have been used to follow fish movements, particularly walleye (*Kirby et al. 2016*). Some of these fish have been found as far away at Sylvan Beach, at the eastern end of Oneida Lake.

Photograph 1. Deborah Hummel demonstrating bowfin. *Neil Ringler*

Extensive work is now underway to assess the fish community responses to physical habitat structures installed in the lake since 2016 by Honeywell. These include rock piles and wooden "porcupine cribs" intended to attract fish food, fish and probably anglers to the new sites. In addition, the 425 acres of substrate that are capping the dredged areas in the southern basin of the lake show promise as new sites for plant growth, epiphytic invertebrate survival and fish spawning. Techniques to assess specific habitats include short-term gill netting and longer-term underwater photography. These data are just coming in and will be analyzed at about the time this article appears.

A very bright future for this ecosystem is potentially within reach. Reduced levels of mercury in young fish have been reported, and remarkably large numbers of young-of-the-year sunfish have been found in the remediated shoreline areas. While we hope to have a systematic survey of anglers utilizing the expanded fish community, it is already clear that many anglers have been successful. At the weigh-in at the New York State Fair in September 2017, for example, bass of nearly seven pounds were reported taken by experienced fishermen.

Tributary Studies

By comparison with the lake proper, the physical and biological conditions of the tributaries had been less understood. Recognizing that the successful restoration of the lake is vitally linked to the upland habitats, particularly for cold water fish restoration, recent studies and restoration efforts have begun to place emphasis on the tributaries. For example, Johnson and Ringler (2014) documented the significance of water chemistry and canopy cover on fish community structure in the tributaries to Onondaga Lake.

In 2008, the Onondaga Environmental Institute (OEI) and Onondaga County Department of Water Environment Protection (OCDWEP) began a Microbial Trackdown Study (MTS) to identify and monitor potential bacterial sources unrelated to Combined Sewer Overflow (CSO) events, and to monitor spatial and seasonal variability in Harbor Brook and Onondaga Creek under dry-weather conditions. The MTS is currently in its third phase. To date, over one dozen infrastructure corrections have been made in the Onondaga Creek, Harbor Brook and Ley Creek. Sources of bacteria have included collapsed pipes, cross connections, and illicit discharges and connections.

Collaborative efforts have been made to restore brook trout in the upper Onondaga Creek watershed. Partnerships between the OEI and Onondaga County Soil & Water Conservation District (OCSWCD) have led to the restoration of three sites in upper Onondaga Creek for the improvement of in-stream and riparian habitat necessary to support sustainable populations of wild brook trout. Efforts are ongoing, and they will collectively contribute to the restoration of approximately half a mile of linear riparian

Canopy cover over a tributary, such as this location on Onondaga Creek, provides shade to keep the water cool and comfortable for the fish and other animals that live in this habitat.

Stephanie L. Johnson, Onondaga Environmental Institute

habitat, the restoration and re-naturalization of one acre of riparian zone, the removal of two fish barriers, and the installation of three in-stream cross-vane structures.

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Tracking the Recovery of Onondaga Lake in the Context of the Phosphorus TMDL Numerical Water Quality Target

by Janaki Suryadevara and David A. Matthews

Background

Onondaga Lake is a small urban lake on the northern edge of Syracuse, New York. The lake was historically subjected to industrial and municipal discharges, as well as runoff from agricultural and developed areas, for over a century. These inputs to Onondaga Lake caused severe degradation of water quality and loss of uses, including swimming and fishing. The lake exhibited classical symptoms of extreme cultural eutrophication through the 1990s *(Effler 1996, Matthews et al. 2015)*, including:

- High levels of phytoplankton biomass with severe blooms of cyanobacteria (blue-green algae), which can have harmful effects on water quality.
- Low transparency.
- Rapid loss of dissolved oxygen (DO) from the hypolimnion.
- Severe depletion of DO in the upper waters during fall mixing.

By 1998, Onondaga Lake was at the top of state and federal priority lists of impaired waters due to nutrient enrichment, habitat degradation and mercury contamination. The lake's impairment due to elevated concentrations of phosphorus – the nutrient that controls algal growth – was addressed by the approved phosphorus Total Maximum Daily Load (TMDL; *NYSDEC 2012*).

Amended Consent Judgment

The 1998 Amended Consent Judgment (ACJ) between Onondaga County, the State of New York and Atlantic States Legal Foundation (ASLF) required upgrades to the county's wastewater collection and treatment infrastructure, as well as an extensive ambient monitoring program (AMP) to document related environmental improvements. Onondaga County's Save the Rain program was created in response to the Fourth Stipulation of the ACJ, which specifically identified green infrastructure as an acceptable technology for combined sewer overflow (CSO) control. The ACJ Fourth Stipulation includes a phased schedule for CSO compliance, with a goal of capturing, for treatment or elimination, no less than 95 percent by volume of CSO by 2018, using a combination of gray and multiple green infrastructure approaches. The county's major infrastructure investments in wastewater collection and treatment, coupled with an innovative focus on managing stormwater and Honeywell's on-going remediation of legacy industrial contamination, have brought about a remarkable recovery of the Onondaga Lake ecosystem.

Development of the Phosphorus TMDL

New York uses a narrative standard to regulate 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, *NYSDEC, 2008*). For ponded waters, the narrative standard is interpreted using a guidance value of 20 micrograms/L (µg/L), calculated as the average total phosphorus concentration in the lake's upper waters between June 1 and September 30 *(NYSDEC, 1993)*.

In 1998, the New York State Department of Environmental Conservation (NYSDEC) promulgated a Phase I Phosphorus TMDL for Onondaga Lake. The TMDL established a total phosphorus concentration of 20 µg/L as the water quality endpoint and focused primarily on load reductions from the Metropolitan Syracuse Wastewater Treatment Plant (Metro), which contributed approximately 65 percent of the total phosphorus load to the lake. The ACJ provided NYSDEC with discretion to revise the TMDL as needed to modify the Metro effluent limitations set forth in Phase I.

In 2012, the U.S. Environmental Protection Agency (USEPA) approved NYSDEC's Phase II Phosphorus TMDL *(NYSDEC 2012)*, which was a culmination of over a decade of water quality monitoring and modeling. NYSDEC used an ensemble modeling approach to evaluate the environmental benefits associated with additional phosphorus removal from Metro combined with reductions from other sources. The Onondaga Lake Water Quality Model (OLWQM), a mechanistic and predictive model, was a key component of this evaluation. OLWQM was calibrated and validated using 16 years of monitoring data and was subject to outside expert peer review. The OLWQM was used to simulate water quality conditions under various management scenarios.

The TMDL target is a numeric endpoint that protects the designated best uses of a waterbody. A TMDL allocation for phosphorus inputs to Onondaga Lake was developed to meet the water quality goal for the protection of primary and secondary contact recreational best uses. The annual phosphorus load allocations in the TMDL include a Waste Load Allocation for point sources, Load Allocation for non-point sources and a Margin of Safety to account for uncertainty. The Phase II TMDL incorporates the use of green infrastructure, in combination with other strategies, to meet loading targets and the NYSDEC phosphorus guidance value of 20 µg/L in the lake waters. Two pollutant load allocation scenarios – average and maximum – were developed for the TMDL ***(Table 1)***. The average pollutant load allocation (77,668 pounds per year for

Table 1. Annual Total Phosphorus TMDL Loading Allocations and Loading Estimates to Onondaga Lake for 2013-2016

	Waste Load Allocation (Metro only)		Other Watershed Allocation (point and non-point sourced)		Total Load Allocation (Metro and Watershed)	
Year	TMDL[1] (lbs/yr)	Estimated[2] (lbs/yr)	TMDL[1] (lbs/yr)	Estimated[2] (lbs/yr)	TMDL[1] (lbs/yr)	Estimated[2] (lbs/yr)
2013	27,684 – 29,113	15,931	45,404 – 74,302	74,111	77,668 – 114,975	90,042
2014	27,684 – 29,113	16,541	45,404 – 74,302	78,175	77,668 – 114,975	94,716
2015	27,684 – 29,113	17,020	45,404 – 74,302	67,388	77,668 – 114,975	84,408
2016	27,684 – 29,113	14,854	45,404 – 74,302	49,957	77,668 – 114,975	64,811

[1] TMDL ranges represent the average annual load allocation and the maximum annual load allocation.
[2] Estimated represents the estimated annual loading of phosphorus to Onondaga Lake for the period as reported in the AMP Annual Reports *(OCDWEP 2015, 2016, 2017a, 2017b)*.

all watershed sources) was intended to protect the lake in the long term. The maximum pollutant load allocation (114,975 pounds per year for all watershed sources) was used to develop State Pollutant Discharge Elimination System (SPDES) permit discharge limits, which recognized inter-annual variability in tributary loads to the lake.

additional phosphorus loading reductions into the future. These are the recently completed Metro Secondary Bypass Treatment Improvement project and the on-going Metro Phosphorus Optimization project.

The Metro Secondary Bypass Treatment Improvement project was completed due to NYSDEC's modification of the Metro SPDES

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Phosphorus Loading Reductions

A high-rate flocculated settling (HRFS) system was brought on-line at Metro in 2005. The HRFS, which uses coagulation, flocculation and sedimentation processes to convert phosphorus to the particulate form, dramatically reduced the total phosphorus (TP) concentration of the Metro effluent. Subsequently, concentrations of TP in the Metro effluent have remained consistently below 0.10 mg/L since 2009 and below 0.08 mg/L since 2014 ***(Figure 1)***. Both TP and total dissolved phosphorus (TDP) concentrations in the Metro effluent and associated loading to the lake have been reduced substantially since the early 1990s ***(Figure 2)***. The AMP tracks both the TDP and the soluble reactive (SRP) fractions of phosphorus. These forms are a better representation of bioavailable phosphorus than is TP alone, as a large portion of particulate phosphorus is typically unavailable to support algal growth in the lake.

Loading trends of TP and TDP for Metro and the tributaries show long-term decreases over the 1991 through 2016 period ***(Figure 2)***. These long-term decreases have been driven mostly by reductions in the Metro contribution. Year-to-year variations in phosphorus loading from the watershed are regulated by differences in the timing and magnitude of runoff. Since 2013, the Metro effluent load has been well below the TMDL average annual load allocation for the facility of 27,684 pounds and the maximum annual load allocation of 29,113 pounds ***(Table 1)***.

The predominant source of TP to Onondaga Lake in 2016 was Onondaga Creek, contributing 35 percent of the total load ***(Figure 3)***. Ninemile Creek, Metro (including the 002 Bypass) and Ley Creek each contributed 29 percent, 23 percent and 11 percent of the TP load, respectively. This stands out in contrast to phosphorus loading in the 1990s, during which Metro's contribution often exceeded 60 percent of the total load.

On-going and Future Phosphorus Loading Reductions

Two projects at Metro will contribute importantly to upgraded treatment and

Figure 1. Metro effluent TP concentrations compared to permit limits for the 2006-2016 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 was a 12 month rolling average and has been in place since June 2012.* *OCDWEP*

Figure 2. Annual Loads of total phosphorus (TP) and total dissolved phosphorus (TDP) to Onondaga Lake from Metro and watershed sources, 1991-2016. *OCDWEP*

2016 Percent Contribution to Total TP Load (%)

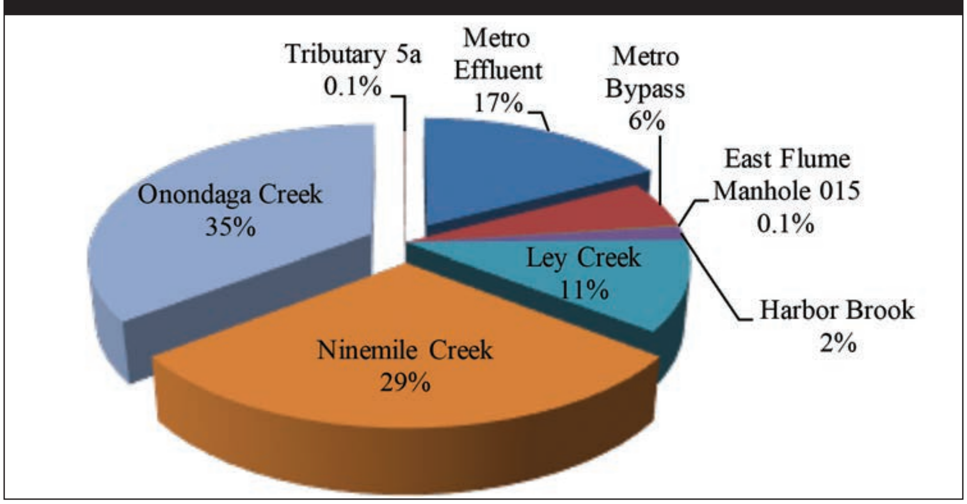

Figure 3. Percent contributions to 2016 total load to Onondaga Lake for total phosphorus. *OCDWEP*


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permit. The modified permit sets more stringent fecal coliform (200 cells/100 mL) and total residual chlorine (0.1 mg/L) limits for the plant's secondary treatment bypass discharged to the lake. Compliance with these limits was achieved by April 1, 2017. Two million gallons (MG) of new process tankage was constructed and connected in series with the existing bypass chlorine contact tank to achieve the required disinfection and dechlorination compliance. This project upgrade will provide treatment for approximately 2.8 MG of secondary bypass volume. This project will also capture additional phosphorus contained in secondary bypass wastewater, reducing on average an additional 670 lbs/year of phosphorus loading to the lake from Metro.

Construction for the Metro Phosphorus Optimization Improvements Project started in October 2017 and is expected to be completed in June 2019. This project will ensure consistent high-level phosphorus treatment at Metro, further helping to achieve the water quality goals in Onondaga Lake. During the construction phase of this project, two tertiary treatment processes (Biological Aerated Filter [BAF] and HRFS) will be off-line seasonally from October to April (2017-2018 and 2018-2019), which will affect the ammonia and phosphorus removals from Metro during these periods. Beginning January 1, 2019, the SPDES permit for Metro's treated effluent will be replaced with a bubble permit limit that includes phosphorus load from both treated and untreated (i.e., bypass) outfalls. The county remains on track to achieve compliance with the new bubble permit limit for phosphorus, an aggregate 12-month rolling average of 27,212 lbs/year for all Metro's outfalls.

The phosphorus TMDL for Onondaga Lake has a phased schedule, and has not yet been fully implemented. Phosphorus loading reductions were implemented for other SPDES permits by January 1, 2016. Implementation of CSO reductions is to be achieved by December 31, 2018, following the completion of the required green and gray infrastructure projects, as part of the county's Save the Rain program. Loading reductions from other sources within the Onondaga Lake watershed are targeted as well. Reductions from agricultural lands are to be met by December 31, 2022, and for Municipal Separate Storm Sewer System (MS4) areas by December 31, 2025. Phosphorus loading reductions from small farms are voluntary and incentive based. NYSDEC uses an adaptive approach for implementing TMDLs, which means that new data and information will be evaluated to make any adjustments to the TMDL designated phosphorus load allocations.

Remarkable Water Quality Improvements

Long-term trends in concentrations of TP in the upper waters depict major decreases since the early 1990s. Since 2006, summer average concentrations of both TDP and SRP have been consistently low and summer average TP concentrations in the upper waters of Onondaga Lake have been close to the guidance value of 20 µg/L ***(Figure 4)***. The summer average TP concentration was below the guidance value during 2008 and 2009. Total phosphorus concentrations in the upper waters of the lake averaged 20 µg/L during the summer (June-September) of 2016, equal to the NYSDEC guidance value of 20 µg/L, and lower than the summer average of 23 µg/L measured in 2015.

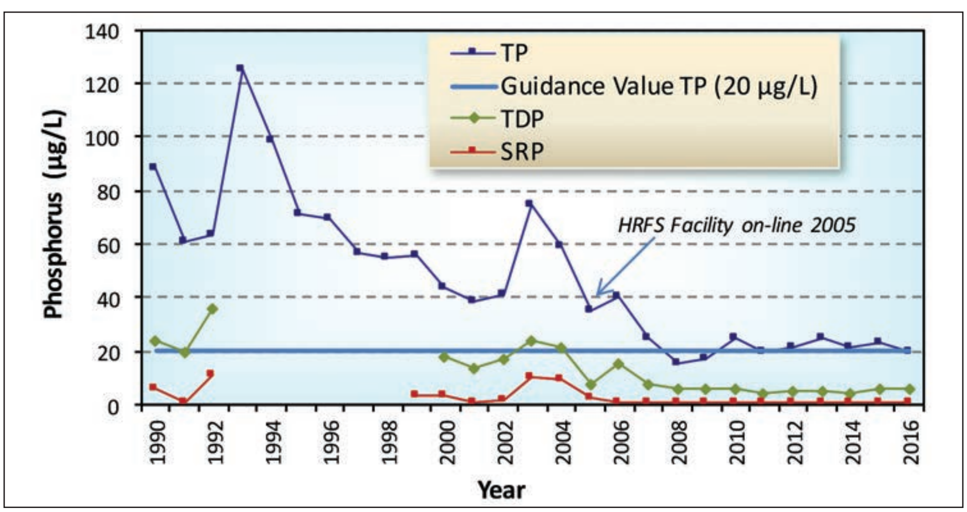

Figure 4. Summer (June-September) average total phosphorus, total dissolved phosphorus and soluble reactive phosphorus concentrations in the upper waters (0-3m) of Onondaga Lake 1990-2016. *Note: TDP and SRP data not collected during 1993-1998.* *OCDWEP*

With the advanced treatment system at Metro producing effluent consistently low in total phosphorus, the year-to-year variability in lake phosphorus levels largely reflects changes in precipitation, resultant watershed loading and food web structure. 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 the resulting influx of inorganic particles to the lake.

Reduced phosphorus levels in Onondaga Lake have resulted in tangible water quality benefits. Algal biomass has decreased by more than 80 percent, major algal blooms have not occurred since 2004, and cyanobacteria are no longer a significant proportion of the algal community. Since 2007, levels of these important water quality indicators have been similar to those measured in Otisco Lake and Oneida Lake. Water clarity in the lake has improved and depletion of dissolved oxygen during the fall is no longer a problem. The lake now supports a robust and diverse fish community, including both warmwater and coolwater species. The county's large investment in state-of-the-art wastewater treatment upgrades, with an innovative and comprehensive approach to stormwater management, have successfully brought Metro's discharges into full compliance with the regulatory requirements for phosphorus.

For more information on the remarkable improvements in Onondaga Lake's water quality, please visit the county's Save the Rain website *(http://savetherain.us)* and the Department of Water Environment Protection's website *(http://www.ongov.net/wep/we15.html)*.

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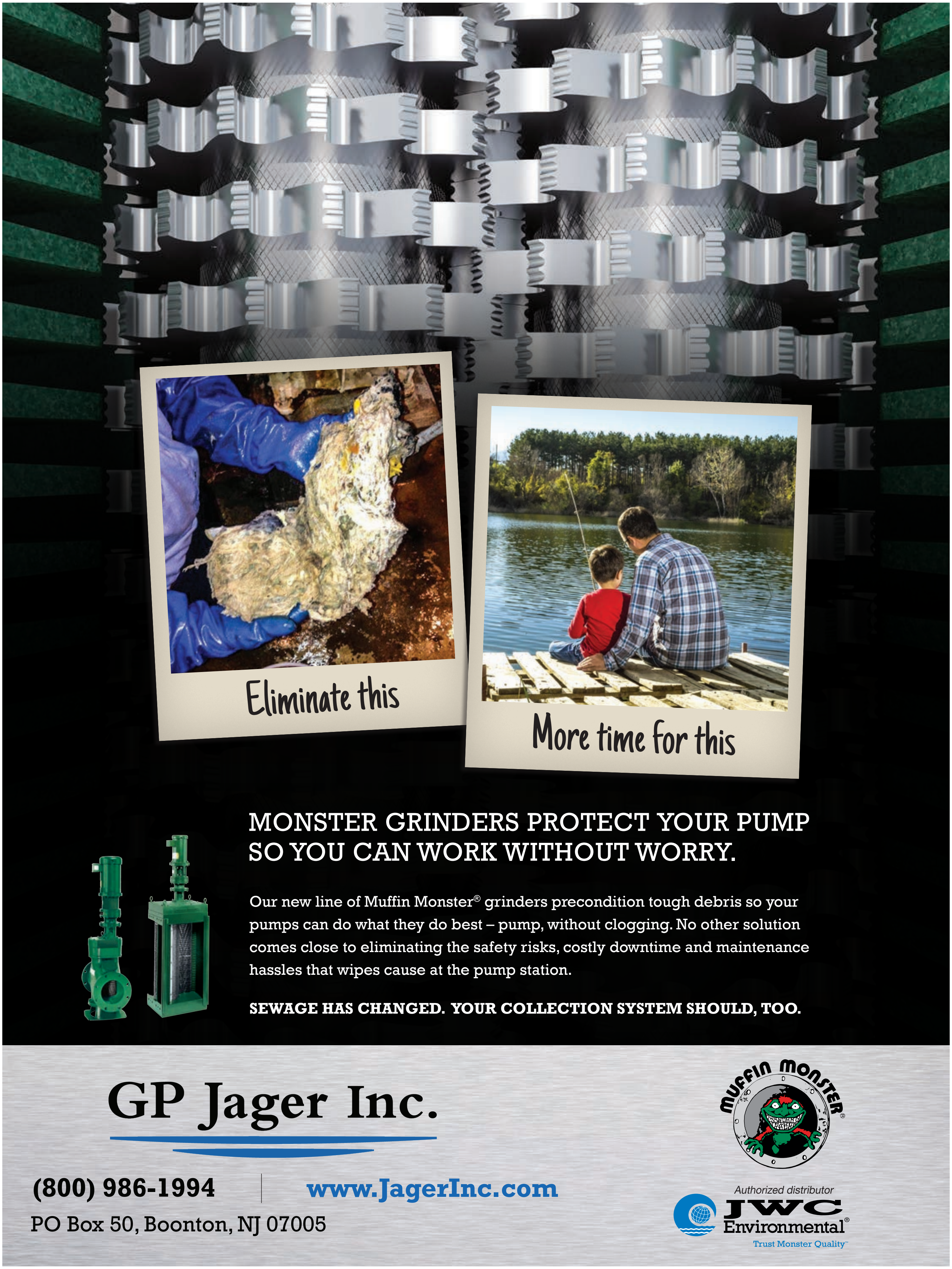
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Fish Community Response to Water Quality Improvements in Onondaga Lake

by Danielle Hurley and Christopher Gandino

Technicians seine for larval fish on the western shore of Onondaga Lake. *OCDWEP*

The Onondaga Lake fish community has changed dramatically since colonial times. During the 1800s Onondaga Lake supported an important commercial and recreational coldwater fishery of Atlantic salmon, American eel and Onondaga Lake "whitefish" *(Tango and Ringler 1996)*. In addition to the coldwater fish community, the lake also supported populations of pike, perch, bass and bullheads *(Nemerow 1964)*. Due to urban development, watershed control measures and inputs of industrial and municipal waste, the coldwater fishery in the lake disappeared by 1898 *(Tango and Ringler 1996)*. Surveys of Onondaga Lake fishes conducted by state and federal agencies from 1927 through 1981 documented a fishery dominated by pollution-tolerant species including common carp, gizzard shad and white perch, with reproduction being limited or nonexistent *(Greeley 1928, Stone and Pasko 1946, Noble and Forney 1971)*.

Facility Upgrades

Like many older cities, Syracuse has a combined sewer system where stormwater and wastewater are transported using the same pipes. Onondaga County completed construction of a large primary treatment plant in 1960 (the Metropolitan Syracuse Wastewater Treatment Plant, or "Metro"), which discharged treated water to Onondaga Lake. While most of the wastewater was treated by this facility, sewage was still discharged to the lake and its tributaries via combined sewer overflows (CSOs). In 1978, the Metro plant was upgraded to secondary treatment to reduce pollutant loading, followed by another upgrade to tertiary treatment in 1981. Even after these improvements, Onondaga Lake was still exhibiting substantial degradation due to nutrient loading from the treatment plant and the continuing CSO discharges.

In 1998, an Amended Consent Judgment (ACJ) between Onondaga County, the State of New York and Atlantic States Legal Foundation was signed to resolve a lawsuit filed against Onondaga County. The lawsuit alleged that the discharges from Metro and the CSOs prevented Onondaga Lake from meeting its designated best use, and therefore violated the Clean Water Act. The ACJ required further upgrades to the wastewater collection and treatment infrastructure, as well as an extensive Ambient Monitoring Program (AMP) to document environmental improvements. The biological monitoring component of the AMP tracks the response of phytoplankton, zooplankton, macrophytes, macro-benthos and fish in Onondaga Lake to infrastructure improvements.

Utilizing Advanced Treatment Combined with Gray and Green Infrastructure to Improve Water Quality in Onondaga Lake

The Metro treatment plant upgrades required by the ACJ included the construction of a Biologically Aerated Filter (BAF) in 2004, which resulted in a 98 percent reduction in ammonia discharged from the plant ***(Figure 1)***. Phosphorus loading from Metro was reduced by 80 percent since the High Rate Flocculation Settling (HRFS) process was installed in 2005 ***(Figure 2)***. Since 2007, summer average total phosphorus concentrations in Onondaga Lake's upper waters have been close to the state guidance value of 20 micrograms per liter *(OCDWEP 2017)*.

In addition to treatment plant upgrades, the County has completed a combination of gray and green infrastructure projects to reduce wet weather discharges from CSOs. Gray infrastructure projects have included sewer separation, capture of floatable materials, and the addition of regional treatment and storage facilities. Through 2016, 51 of the County's 72 CSOs have been closed or abated. Two hundred individual green infrastructure projects have been completed to date through the County's Save the Rain program. Green infrastructure prevents approximately 131 million

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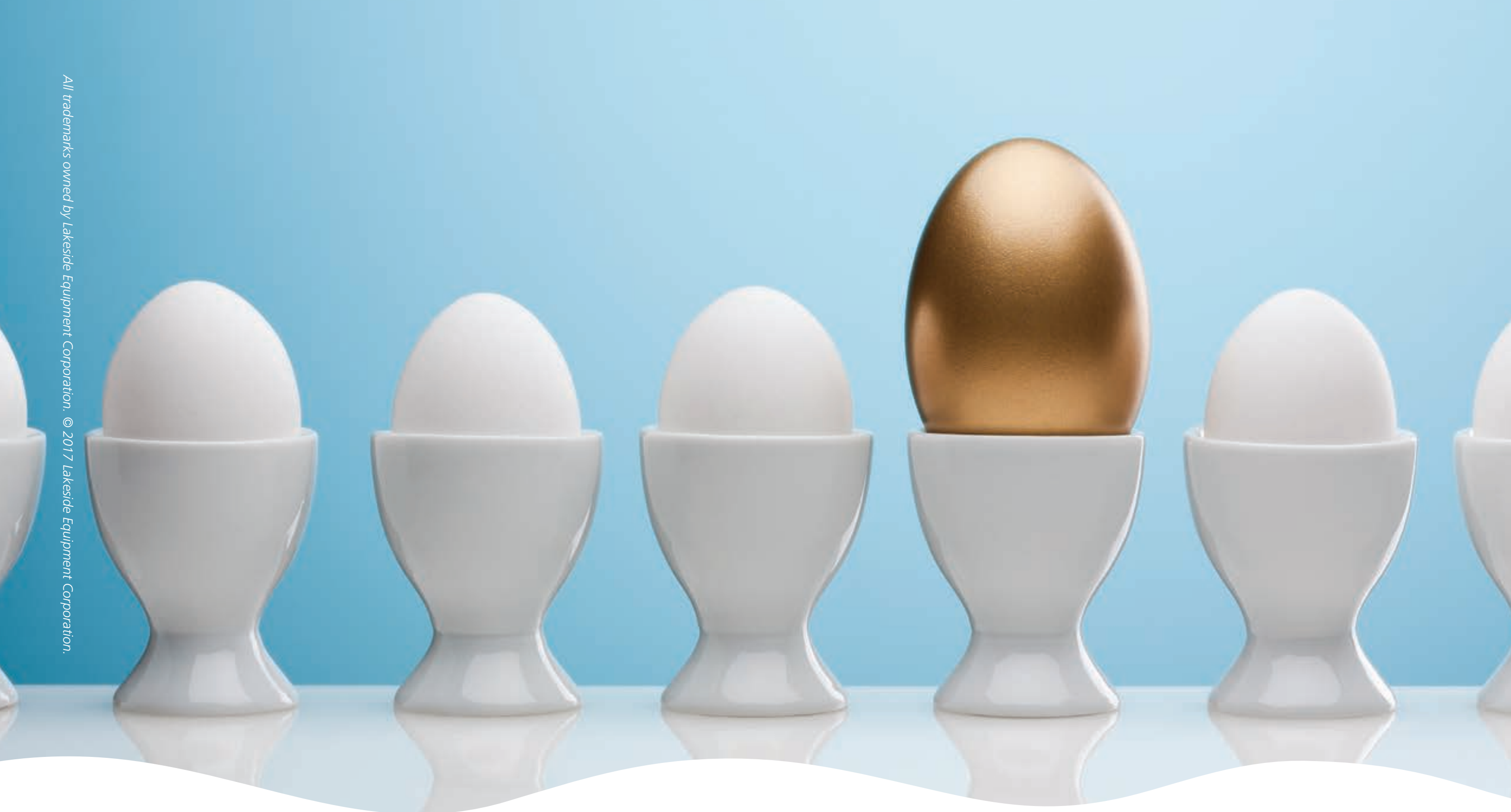

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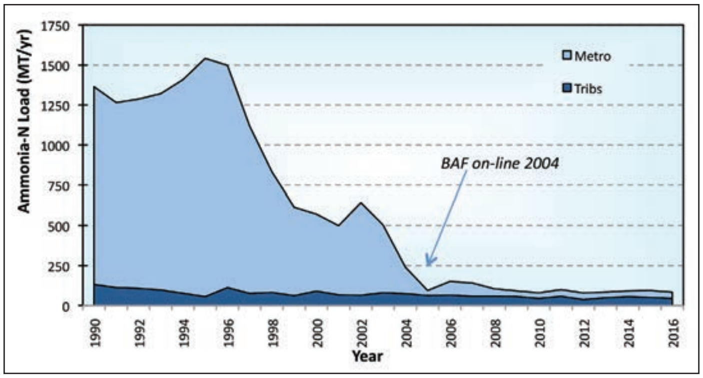

Figure 1. Daily average discharge of ammonia-N, in metric tons per year, to Onondaga Lake from Metro and tributaries, 1990-2016. *OCDWEP*

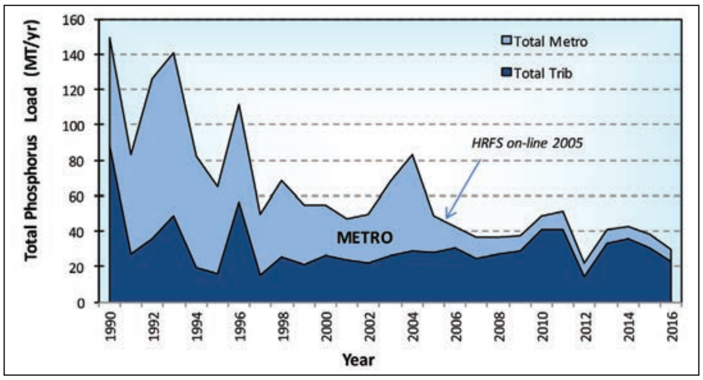

Figure 2. Daily average discharge of total phosphorus, in metric tons per year, to Onondaga Lake from Metro and tributaries, 1990-2016. *OCDWEP*

gallons of runoff from entering the sewer system annually.

Responses of the Biological Communities in Onondaga Lake to Facility Upgrades

The results of the AMP show that the upgrades to the treatment facilities and collection system, in combination with the Save the Rain program, have had profound positive impacts on the biological communities in Onondaga Lake. Recent fish surveys conducted through the AMP, as well as surveys performed by the State University of New York College of Environmental Science and Forestry (SUNY-ESF), have documented a diverse warmwater fish community. Since 1986, 66 native and exotic species of fish have been identified in Onondaga Lake.

Reductions in nutrient loading have eliminated major algal blooms and increased water clarity, allowing for deeper light penetration through the water column. In response, the area of littoral zone that is covered with rooted aquatic plants increased from 85 acres in 2000 to a high of 505 acres in 2012 ***(Figure 3)***. The increase in plant abundance aids in stabilizing sediments and provides vital habitat to many fish and other aquatic species. Reductions in algal growth also resulted in increased dissolved oxygen concentrations, further improving habitat quality. The fish community, once dominated by gizzard shad and white perch, now includes healthy populations of many game species, such as largemouth bass, brown bullhead, yellow perch, pumpkinseed, bluegill, walleye, bowfin and northern pike, making it a popular catch and release fishery.

Habitat plays a significant role in structuring the Onondaga Lake biological community. Under current conditions, the lake supports a reproducing warmwater fish community supplemented by fish migrating from the Seneca River and surrounding tributaries. However, over the entire annual cycle, there is no stratum of the lake's water column that continually provides both suitable temperature and adequate dissolved oxygen for coldwater fishes such as salmonids.

Fish migration between Onondaga Lake and other waterbodies, including Cross Lake and Oneida Lake, occurs via Onondaga Lake's only outlet, the Seneca River. As the Seneca River flows north it combines with the Oneida River forming the Oswego River which ultimately drains into Lake Ontario. These connections allow for migration of many fish species, including coldwater fishes. Fish migrations can also occur between Onondaga Lake and its tributaries, such as Ninemile Creek, which is annually stocked with brown trout. The AMP biological sampling program includes marking fish with tags containing contact information. Fish migrations between lakes have been documented when anglers report catching tagged fish from Onondaga Lake in other rivers and lakes. This connectivity between systems has in recent years allowed for well-documented catches of large brown trout and lake sturgeon in Onondaga Lake when temperature and dissolved oxygen conditions are suitable.

One of the methods used in the AMP to assess fish reproduction

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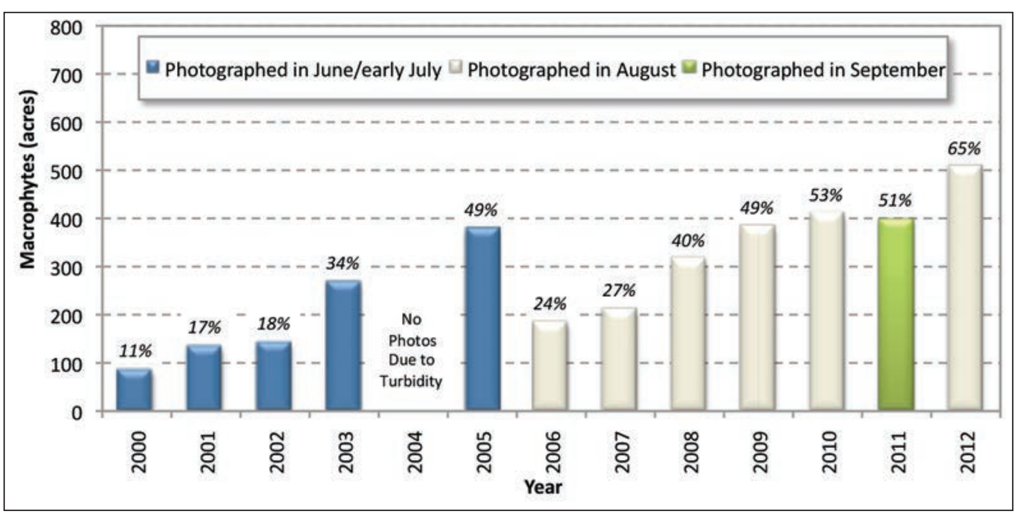

Figure 3. Total acreage of macrophytes in Onondaga Lake from 2000-2012, based on areas delineated as macrophytes from digitized aerial photographs*. Percent represents the percent of the littoral zone (defined as the zero to 6-meter depth, approximately 777 acres) that is occupied by macrophytes.

**Photographs were taken in different months, which adds an unknown level of variability to the analysis. Therefore, the June/July, August and September data are depicted separately.* *OCDWEP*

Adult walleye captured during boat electrofishing in Onondaga Lake in 2017. *OCDWEP*

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Largemouth bass caught during 2017 sampling on Onondaga Lake.
OCDWEP

is nesting surveys. Centrarchid species (largemouth and smallmouth bass, pumpkinseed, bluegill and rock bass) and brown bullhead construct and guard nests in the littoral zone. Since 2000, most of the nests have been documented in the north basin due to better habitat conditions ***(Figure 4)***. Nesting sites have become more evenly distributed in the lake starting in 2008, presumably because of the increase in aquatic plants in the southern basin providing improved habitat conditions ***(Figure 4)***.

Largemouth and smallmouth bass are two of the most popular sport fish in Onondaga Lake. As macrophyte coverage has expanded, largemouth bass catch rates have increased ***(Figure 5)***. The catch rates of smallmouth bass have declined, likely due to the changing conditions in the littoral zone, as increased macrophyte coverage is more suitable for largemouth bass *(Stuber et al. 1982, Edwards et al. 1983)*. Smallmouth bass prefer rock and gravel substrate *(Robbins and MacCrimmon 1974)*. A similar trend in largemouth bass and smallmouth bass abundance also occurred in Oneida Lake and Canadarago Lake as macrophyte coverage increased *(Jackson et al. 2012, Brooking et al. 2012)*. Sport fishing continues to gain popularity in response to the thriving largemouth bass population. A modest tournament fishery has developed in addition to non-competitive angling. Local bass organizations compete several

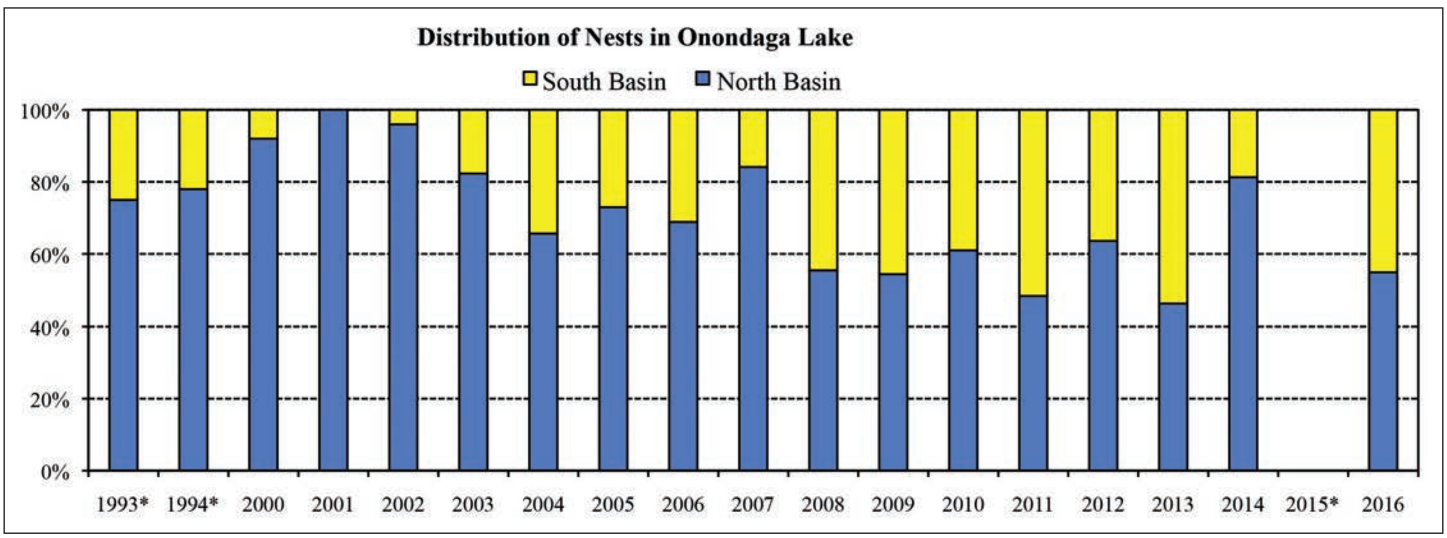

Figure 4. Distribution of nests in Onondaga Lake. *Historic nest distribution. 1993 and 1994 data from Arrigo (1998). Nesting Survey not completed in 2015 due to extended period of poor visibility.
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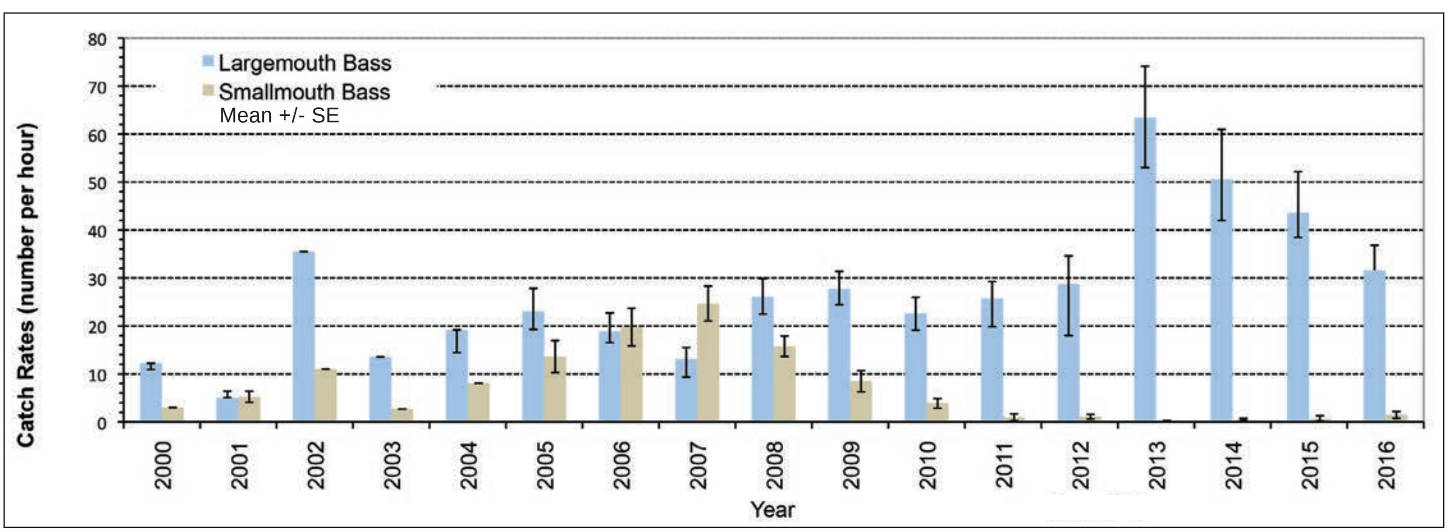

Figure 5. Annual average catch rates (number per hour) from fall electrofishing events of largemouth and smallmouth bass in Onondaga Lake from 2000-2016.
OCDWEP

weekends throughout the summer, and several large-scale fishing tournaments have been held on Onondaga Lake including the Bassmaster Memorial in 2007 and the Junior Bassmaster World Championship in 2008.

Impacts of Invasive Species

The Onondaga Lake ecosystem continues to change even after the stabilization of nutrient status. Food web interactions are changing in response to species composition. Over the course of the AMP several invasive species, including alewife, dreissenid mussels and round goby have become established in the lake. Alewife have had several successful year classes which have reduced the abundance of large *Daphnia,* a genus of zooplankton that grazes on phytoplankton more efficiently than the smaller bosminids. This has had some negative impacts on water clarity, as large concentrations of phytoplankton increase turbidity. The round goby have rapidly increased in abundance since they were first observed in Onondaga Lake in 2010. Round goby can be an important food resource for game fish, but they are also nest predators that could have negative impacts on fish reproduction in the lake. Additionally, round goby have the potential to outcompete native species for resources. The impact of round goby in Onondaga Lake is yet to be fully understood.

Summary

The biotic community in Onondaga Lake has improved greatly since upgrading Metro and the collection system. Lower total phosphorus and ammonia concentrations in Onondaga Lake have reduced algal productivity and eliminated major algal blooms. Increased macrophyte coverage has expanded nearshore habitat for many fish and presumably other aquatic animal species. Lake improvements continue to increase angling and recreational opportunities, restoring Onondaga Lake to a tremendous community asset.

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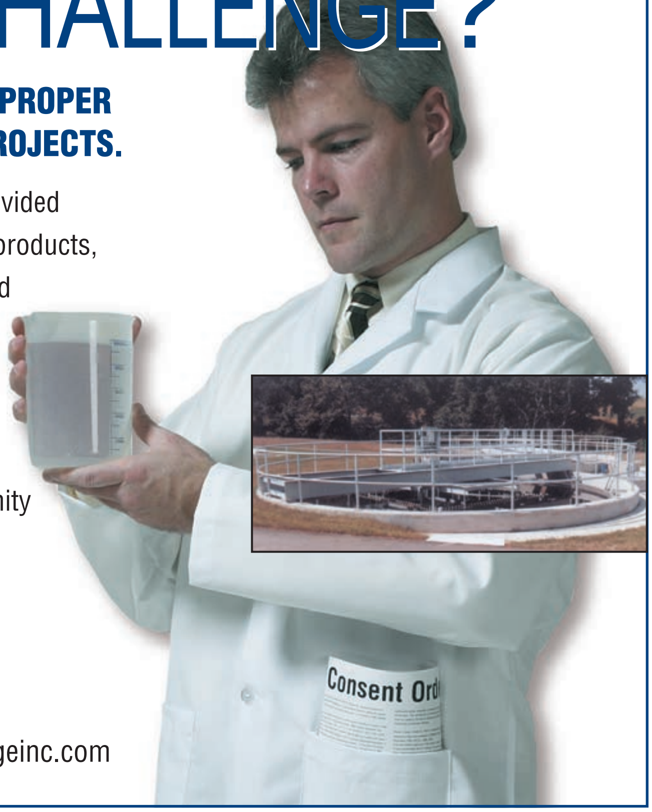

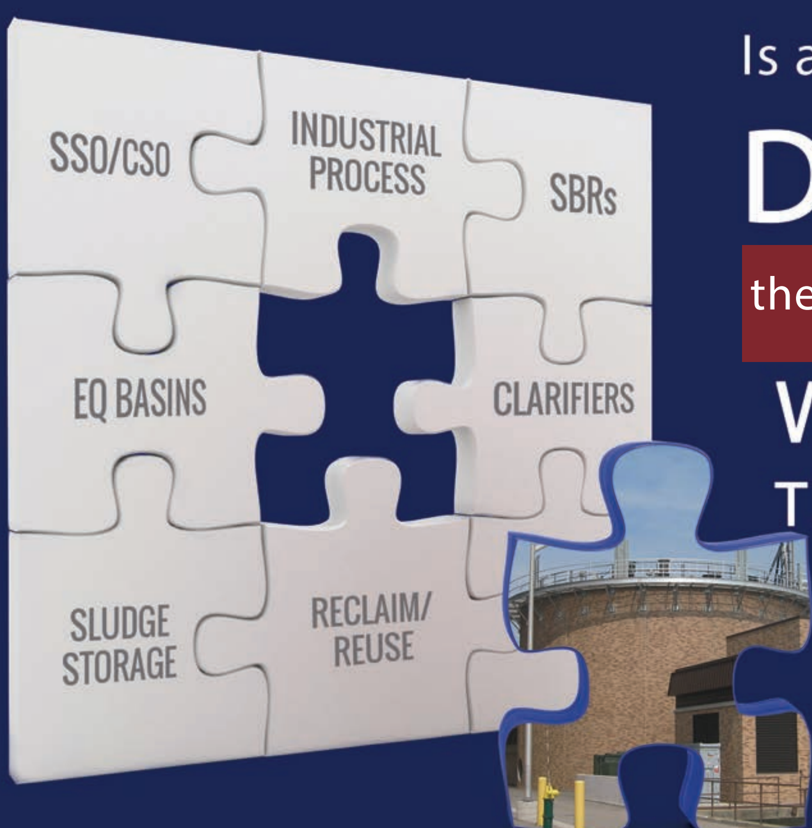
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Whole-lake Nitrate Addition for Control of Methylmercury in Onondaga Lake

by David A. Matthews

Background

An important objective of the Onondaga Lake cleanup is to control release of methylmercury from the deep water sediments to the water column. Methylmercury (MeHg) is of particular concern because it is the organic form of mercury that bioaccumulates strongly in aquatic food webs, resulting in toxic effects at upper trophic levels when concentrations are high *(Sandheinrich and Wiener 2011)*. Sulfate-reducing bacteria are the principal methylators of inorganic mercury *(Benoit et al. 2003)*. Production of MeHg is promoted by anaerobic conditions and the supply of inorganic mercury, sulfate and labile organic carbon to sulfate-reducing bacteria. The anaerobic sediments of stratified lakes are particularly active zones for production of MeHg and can be an important source of MeHg to the water column during summer anoxia and fall turnover *(Herrin et al. 1998, Wollenberg and Peters 2009)*. Phytoplankton actively uptake MeHg from the water column and represent the primary entry point for MeHg in aquatic food webs *(Pickhardt and Fisher 2007)*. Therefore, controlling the MeHg concentration in the water column is a key component in limiting concentrations in aquatic biota *(Morel et al. 1998, Rolfhus et al. 2011)*.

Commonly applied methods for remediation of mercury-contaminated sediments include dredging, *in situ* capping and monitored natural recovery *(Wang et al. 2004)*. However, dredging and *in situ* capping may be impractical in systems where the areal extent of contamination is very large, while the time required for natural recovery may be considered unacceptable in some cases. A novel approach for control of MeHg mobilization from Onondaga Lake sediments was proposed by researchers at Upstate Freshwater Institute and Syracuse University. This approach relies on regulation of oxidation-reduction (redox) conditions in surficial sediments through addition of nitrate to the lower waters of the lake *(Effler and Matthews 2008, Todorova et al. 2009)*. A whole-lake nitrate addition program, conducted annually during summer since 2011, has dramatically reduced MeHg concentrations in the water column of Onondaga Lake.

System Description

Onondaga Lake is an alkaline, sulfate-rich, dimictic lake located in Syracuse, New York. The lake has a surface area of 12 square kilometers (4.6 square miles), a volume of 131 million cubic meters (34.6 billion gallons), and a maximum depth of 20 meters (65.6 feet). Domestic and industrial waste inputs accompanied development of the watershed that resulted in deterioration and loss of uses of the lake *(Effler 1996)*. An estimated 75,000 kilograms (82.7 tons) of mercury, discharged to the lake in association with chlor-alkali manufacture *(USEPA 1973)* has resulted in contamination of the lake's biota *(Effler 1996)*, water column *(Bloom and Effler 1990)*, and sediments *(NYSDEC 2004)*. Dissolved oxygen (DO) is depleted rapidly from the hypolimnion following summer stratification, with anoxic conditions typically prevailing from July through fall turnover in October. Onondaga Lake is naturally enriched with sulfate due to the abundance of gypsum ($CaSO_4$) in the watershed.

Internal loading of MeHg from profundal sediments during summer anoxia resulted in hypolimnetic concentrations greater than 15 nanograms per liter (ng/L) *(Bloom and Effler 1990, PTI Environmental Services 1994, Sharpe 2004)*. In 1994, Onondaga Lake sediments were added to the U.S. Environmental Protection Agency (USEPA) Superfund National Priorities List due to industrial inputs of mercury, aromatic volatiles, chlorinated benzenes, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls. Under state and federal oversight, Honeywell is implementing the lake bottom remedy, which includes source control, dredging, *in situ* capping, habitat restoration, monitored natural recovery, and nitrate addition to control accumulation of MeHg in the hypolimnion during summer anoxia.

Wastewater Treatment Upgrades

Municipal wastewater effluent, representing nearly 20 percent of the total hydrologic loading to the lake, caused severe cultural eutrophication and routine violations of receiving water quality standards through the mid-2000s *(Effler 1996, Effler and O'Donnell 2010, Effler et al. 2010)*. The lake has responded positively to rehabilitation efforts targeting improvements in effluent quality at the contributing wastewater facility, the Metropolitan Syracuse Wastewater Treatment Plant (Metro). Treatment upgrades at Metro in 2005 caused major decrease in epilimnetic summer average total phosphorus concentrations and transformed the lake from a condition of severe eutrophy to upper mesotrophy since 2007 *(Matthews et al. 2015)*.

Efficient year-round nitrification of wastewater at Metro was initiated in 2004, resulting in a marked decrease in ammonia levels and a two-fold increase in water column nitrate concentrations at spring turnover, from approximately 1 milligram nitrogen per liter (mgN/L) to 2 mgN/L *(Effler and Matthews 2008, Todorova et al. 2009)*. The presence of nitrate in the hypolimnion was extended by nearly two months and the onset of sulfate reduction was shifted later in the summer or eliminated *(Effler and Matthews 2008)*. The enhanced supply of nitrate also exerted strong regulation on MeHg concentrations, resulting in a greater than 50 percent decrease in hypolimnetic accumulations of MeHg *(Todorova et al. 2009)*. However, MeHg continued to be released from profundal sediments in late summer following depletion of the hypolimnetic pool of nitrate. The initial decision to maintain high concentrations of nitrate in the Metro discharge (i.e., no denitrification) was in order to abate the occurrence of nuisance nitrogen-fixing cyanobacteria through maintenance of a high nitrogen-to-phosphorus ratio (N:P). The potential benefit of increased nitrate loading for control of MeHg was not foreseen.

Methylmercury Dynamics Prior to Nitrate Addition

The presence of nitrate at the sediment-water interface inhibits sulfate-reducing bacteria and keeps MeHg bound to iron oxyhydroxides in the sediments. In the absence of nitrate addition, the pool of nitrate in the lower waters was progressively depleted during summer and exhausted by September ***(Figure 1)***. MeHg concentrations increased dramatically when nitrate levels decreased below 1 mgN/L in late summer and decreased to background concentrations in October when nitrate was replenished during fall turnover.

MeHg that accumulated in the lower waters during late summer was transported to the upper waters during fall turnover ***(Figure 2)***, where it provided an exposure pathway for aquatic biota. It was hypothesized that addition of nitrate to the lower waters during the summer stratification period could eliminate nitrate depletion, control MeHg accumulation and limit exposure of aquatic biota to elevated concentrations of MeHg during fall turnover.

Nitrate Application

A three-year pilot test was initiated in 2011 to supplement the existing hypolimnetic nitrate pool and demonstrate the feasibility of maintaining nitrate concentrations at levels sufficient to further limit release of MeHg from profundal sediments. Following a successful pilot test *(Matthews et al. 2013)*, full-scale nitrate addition continued in 2014, 2015 and 2016. Nitrate, in the form of a calcium nitrate ($Ca(NO_3)_2$) solution (8.5 percent N), was pumped from a motorized barge ***(Figure 3)*** to the lower portion of the hypolimnion of Onondaga Lake, approximately three days per week from July to early October. Calcium nitrate was added as a neutrally buoyant plume at three deepwater sites ***(Figure 4)***, with each location receiving an 18,000-liter application approximately once per week. These targeted applications totaled to less than 10 percent of the annual nitrate loading to the lake from Metro.

Nitrate was applied three days per week with a goal of maintaining nitrate concentrations greater than 1 mgN/L throughout summer stratification. The rate of nitrate addition was 1.0 metric tons per day (MT/d), somewhat higher than the measured rate of hypolimnetic nitrate depletion (0.8 MT/d). The $Ca(NO_3)_2$ solution had a specific gravity of 1.48 and was diluted with water from the epilimnion at a ratio of approximately 250:1 to achieve neutral buoyancy in the lower hypolimnion. The locations, frequency and rate of nitrate addition were determined from supporting studies, including: five dye tracer studies conducted to measure hypolimnetic dispersion; two full-scale field trials; and mass transport analyses *(Parsons and UFI 2011)*. These studies indicated that nitrate added at three locations would be spread reasonably uniformly across the

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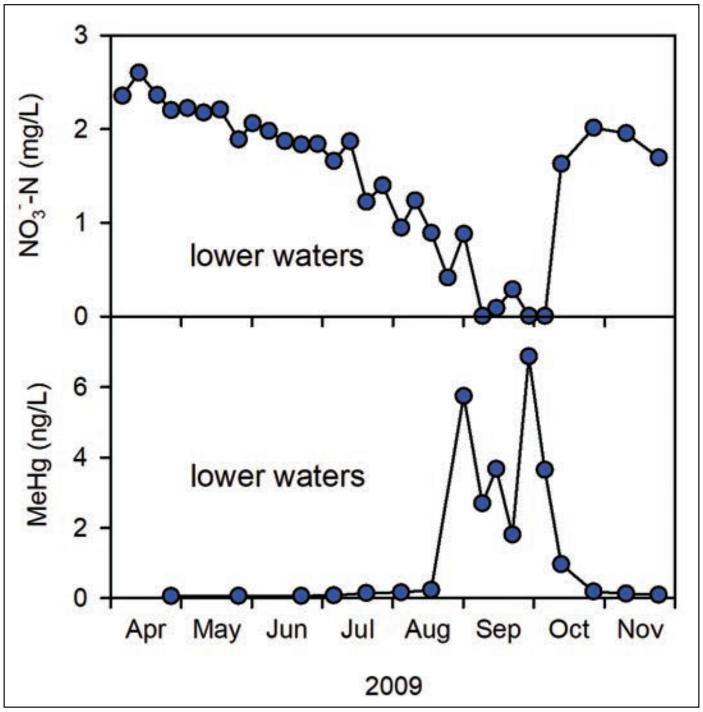

Figure 1. Time series of nitrate and methylmercury concentrations in the lower waters of Onondaga Lake, 2009. *Upstate Freshwater Institute*

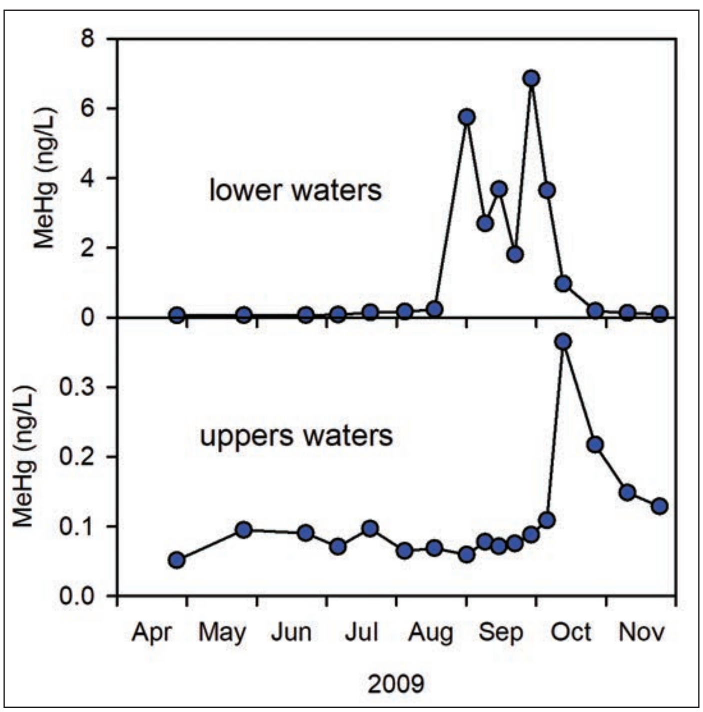

Figure 2. Time series of methylmercury concentrations in the lower and upper waters of Onondaga Lake, 2009. *Upstate Freshwater Institute*

Figure 3. Nitrate addition barge on Onondaga Lake. *Parsons*

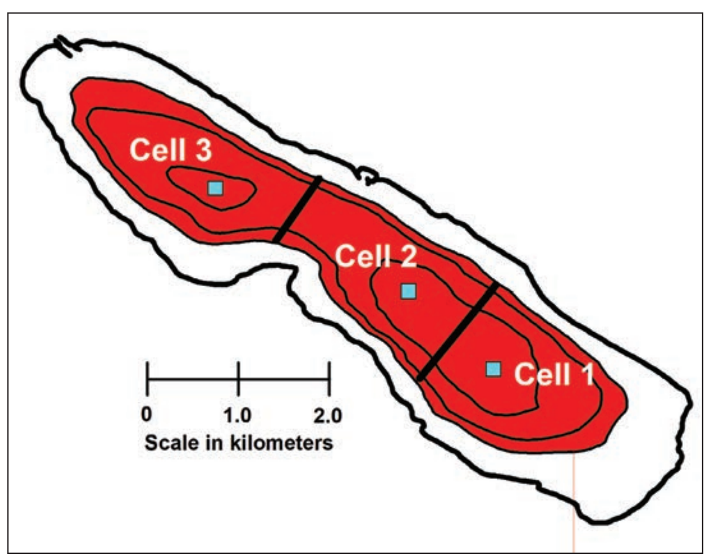

Figure 4. Onondaga Lake, with the hypolimnion (in red) and three nitrate addition locations identified. *Upstate Freshwater Institute*

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hypolimnion by ambient horizontal mixing processes.

Monitoring Program

An intensive monitoring program was conducted annually to guide rates and locations for nitrate addition, to track the fate of the chemical addition, and to assess nitrate addition as a means of abating accumulation of MeHg in the hypolimnion. An important component of the monitoring program was near-real-time measurements of the three-dimensional distribution of the nitrate pool in the hypolimnion to assess fate and transport of the added nitrate and to guide the addition program. This was accomplished through rapid profiling with an *in situ* ultraviolet spectrophotometer (ISUS) that utilizes the characteristic absorption spectra within UV wavelengths and spectral deconvolution techniques to quantify concentrations of nitrate and other inorganic constituents *(Johnson and Coletti 2002)*. Vertical profiling with ISUS was conducted at least once per week at more than 30 sites, which provided vertically detailed (0.25-meter resolution) nitrate data in real time. The ISUS technology has been used successfully to identify spatial patterns of nitrate and sulfide in Onondaga Lake, and its performance has been verified with laboratory measurements *(Prestigiacomo et al. 2009)*.

Control of MeHg Accumulation by Nitrate Addition

Comparisons of temporally detailed seasonal MeHg patterns in years with (2011) and without (2006) nitrate addition clearly isolate the effects of this program at the whole-lake scale ***(Figure 5)***. In 2006, MeHg accumulated to concentrations exceeding 10 nanograms per liter (ng/L) in the lower waters during summer. Entrainment of the lower layers during fall turnover resulted in increased levels of MeHg in the upper waters of the lake during October and November. Targeted addition of nitrate during summer eliminated both accumulation of MeHg in the lower waters during summer and transport of MeHg to the upper waters during fall ***(Figure 5)***. Maintenance of high nitrate levels has also eliminated phosphorus release from profundal sediments *(Matthews et al. 2013)*, limiting the availability of this critical nutrient for algal growth.

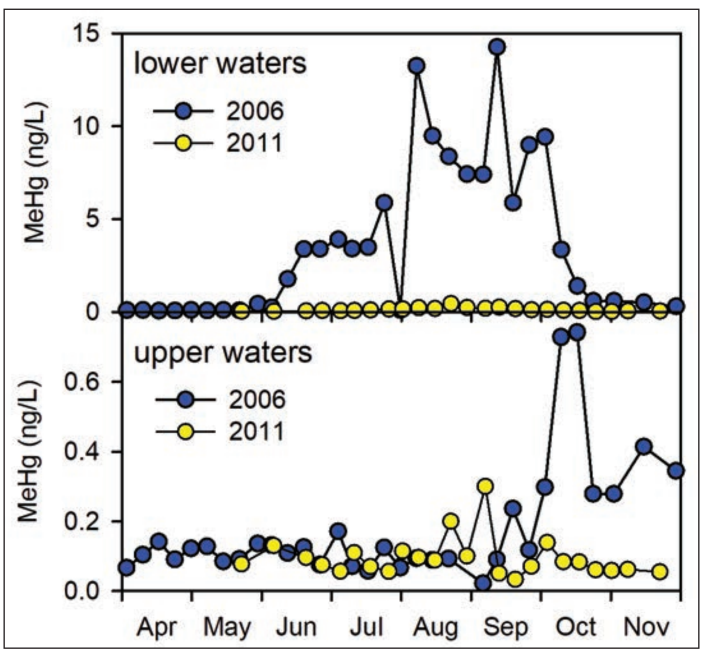

Figure 5. Time series of methylmercury concentrations in the lower and upper waters of Onondaga Lake, 2006 and 2011. *Upstate Freshwater Institute*

The maximum mass of MeHg in the hypolimnion during summer stratification is a particularly useful metric because it integrates the rate of MeHg accumulation and the time over which the accumulation occurred. Accumulation of MeHg in the lower waters of the lake has been effectively controlled by nitrate addition as illustrated by the consistently low levels maintained during the 2011-2016 period ***(Figure 6)***. The maximum mass of MeHg in the hypolimnion decreased more than 95 percent from 2006 levels as a result of treatment upgrades at Metro – which decreased algal productivity and increased nitrate levels – and targeted nitrate addition. Elevated MeHg concentrations in zooplankton during fall turnover was a recurring feature that has been eliminated since nitrate addition was initiated in 2011. Recent decreases in MeHg concentrations in smallmouth bass and walleye suggest that nitrate addition, in conjunction with the other components of the remediation, is having a positive impact at higher trophic levels.

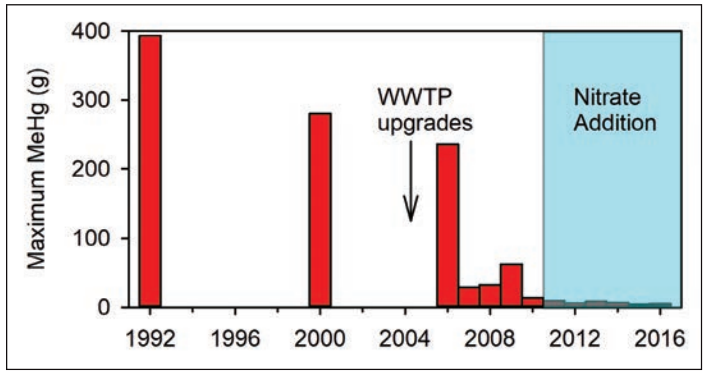

Figure 6. Maximum mass of methylmercury in the lower waters of Onondaga Lake, 1992–2016. *Upstate Freshwater Institute*

Summary

A whole-lake nitrate addition program undertaken to control mobilization of MeHg from the sediments of Onondaga Lake has provided a rare opportunity to further our understanding of mercury cycling in lakes and advance management and remediation of mercury-contaminated ecosystems. Results from this whole-lake program clearly demonstrate control of MeHg mobilization by nitrate at both seasonal and long-term time scales. Maintenance of nitrate-N at greater than 1.0 mg N/L throughout the summer stratification period resulted in a 95 percent decrease in the maximum mass of MeHg accumulated in the hypolimnion during summer. Phosphorus release from the profundal sediments decreased by a similar percentage *(Matthews et al. 2013)*, providing trophic state benefits through control of the nutrient that limits primary production in Onondaga Lake.

From the perspectives of biological exposure and human health risks, it is perhaps most important to decrease MeHg levels in the upper productive layers where it enters the food web through active uptake by phytoplankton. Therefore, accumulation of MeHg in the anoxic hypolimnia of lakes is of particular concern when it is mixed into the upper layers during fall turnover. Nitrate addition eliminated accumulation of MeHg in the hypolimnion during summer stratification and the occurrence of elevated MeHg concentrations in the upper waters during fall, thereby limiting entry of MeHg into the food web.

Nitrate addition was a particularly attractive management alternative for control of MeHg mobilization in Onondaga Lake because it represented an extension of the high nitrate loads delivered to the lake from Metro. Moreover, the benefits of an increased supply of nitrate to the hypolimnion from Metro were well established *(Todorova et al. 2009)*. Hypolimnetic oxygenation also has the potential to result in similar decreases in sediment release of MeHg, as suggested by Beutel and Horne (1999). Higher costs, the necessity for substantial in-lake infrastructure, and the potential for increased exposure of aquatic biota to contaminated sediments have been identified as disadvantages of implementing hypolimnetic oxygenation in Onondaga Lake *(Effler and Matthews 2008)*. Nitrate addition may represent a viable remediation alternative to dredging, capping, and oxygenation at other mercury-contaminated sites.

Acknowledgments

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Analysis of Phytoplankton Community Dynamics: Is Onondaga Lake at Risk for Cyanobacterial Blooms?

by A. Thomas Vawter

Introduction

Cyanobacterial blooms, also known as blue-green algal blooms or harmful algal blooms (HABs), have become increasingly common in freshwater systems globally, including in many New York lakes. Nutrient enrichment, warming waters, invasive species and changing food webs have all been implicated as potential factors affecting cyanobacterial abundance. In New York, HABs have been documented in lakes with a wide range of phosphorus concentrations; many lakes experiencing cyanobacterial blooms have summer average total phosphorus (TP) concentrations well below the New York State Department of Environmental Conservation (NYSDEC) guidance value of 20 micrograms per liter (µg/L). All eleven of New York's Finger Lakes, as well as Oneida Lake, experienced cyanobacterial blooms during the summer of 2017. Onondaga Lake, in contrast, has not had cyanobacterial blooms in recent years, despite summer TP concentrations in the range of 17 to 25 µg/L. This article examines the detailed water chemistry and phytoplankton data from decades of monitoring and research to explore why Onondaga Lake differs, and evaluate the risk of future HABs in this recovering ecosystem.

Onondaga Lake Phytoplankton Community: History and Recent Changes

As part of its long-term ambient monitoring program, Onondaga County Department of Environment Protection (OCDWEP) has sampled and analyzed the phytoplankton community, in addition to monitoring the algal pigment chlorophyll-a. Cyanobacterial blooms were common in Onondaga Lake until 2005, when advanced phosphorus removal came on-line at the Metropolitan Syracuse Wastewater Treatment Plant (Metro), a water resource recovery facility discharging to Onondaga Lake. Between 1998 and 2004, cyanobacteria comprised a significant component of the phytoplankton community during the June to September recreational period ***(Figure 1)***. Implementation of advanced phosphorus treatment has led to a substantial decrease in both phytoplankton biomass and the proportional contribution of cyanobacteria to the community *(Baker 2013)*.

The Onondaga County Ambient Monitoring Program uses chlorophyll-a concentration to indicate bloom conditions; 15 µg/L is the threshold for a "minor" bloom and 30 µg/L indicates a "major" bloom. There have been only minor blooms measured since 2005 ***(Figure 2)***, and none has been dominated by cyanobacteria. Some of these minor blooms have occurred in the spring when diatoms and green algae dominate the phytoplankton community.

Cyanobacteria are often present in the phytoplankton assemblage. The species detected in Onondaga Lake include the potentially toxic genera *Anabaena, Dolichospermum* (formerly *Anabaena* in part), *Aphanizomenon, Microcystis* and *Cylindrospermopsis*. Although cyanobacteria have not dominated the phytoplankton assembly in recent years, there has been an increase in their total biomass and their proportional contribution to the community since 2012. On 18 sampling days between April 6 and December 5, 2016, the proportional contribution of cyanobacteria to the phytoplankton biomass varied from less than one percent to 39 percent ***(Figure 3)***. On average for the period, cyanobacteria constituted 9.5 percent of the open water phytoplankton biomass. A large biomass of *Pseudoanabena* (reaching 302 µg/L) was measured on September 27, 2016, which comprised 82 percent of the cyanobacteria community for that date. During the two dates on which minor blooms occurred (September 13 and 27), the contribution of cyanobacteria to the phytoplankton community was relatively high (11 percent and 18 percent, respectively). But the proportion of cyanobacteria was as high or higher on several other dates on which chlorophyll-a concentrations were lower than the bloom thresholds.

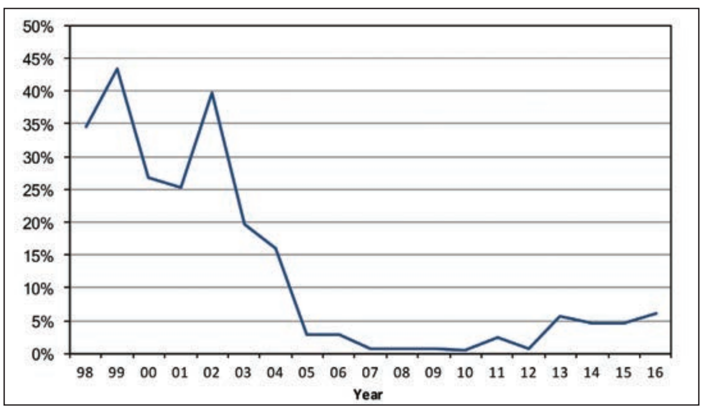

Figure 1. Percent of phytoplankton community composed of cyanobacteria, June-Sept. Onondaga Lake NY, 1998-2016.
Data courtesy of OCDWEP and Cornell University Biological Field Station

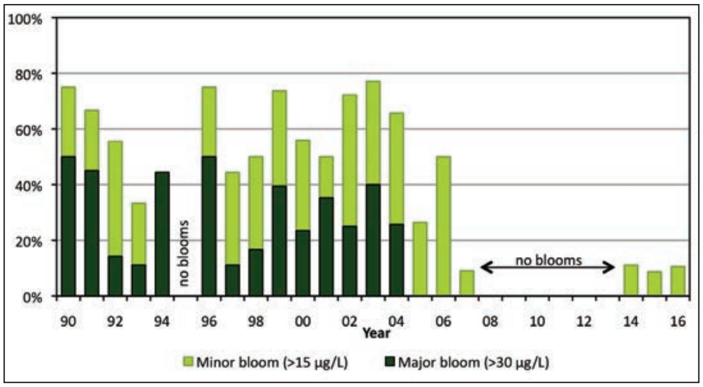

Figure 2. Summer algal bloom frequency, measured as chlorophyll-a, in Onondaga Lake from 1990 through 2016. *Data courtesy of OCDWEP*

Environmental Conditions That Encourage Cyanobacteria Growth

Nutrient Stoichiometry

The absolute or relative concentrations of nutrient elements other than phosphorus may contribute to the growth of cyanbacteria. For example, the ratio of nitrogen to phosphorus (N:P) may determine whether or not HABs occur, and HABs are thought to be rare in lakes where N:P ratios exceed 29:1 (by weight) *(Filstrup et al. 2016, Smith 1983)*. This is partly because cyanobacteria can take up and use nitrogen more efficiently than true (eukaryotic) algae, thus potentially giving cyanobacteria a competitive advantage in conditions where the concentration of nitrogen becomes limiting. In fact, some cyanobacteria, unlike eukaryotic algae and plants, can "fix" atmospheric molecular nitrogen (N_2) dissolved in the water. Nitrogen-fixing ability, however, is not the only attribute

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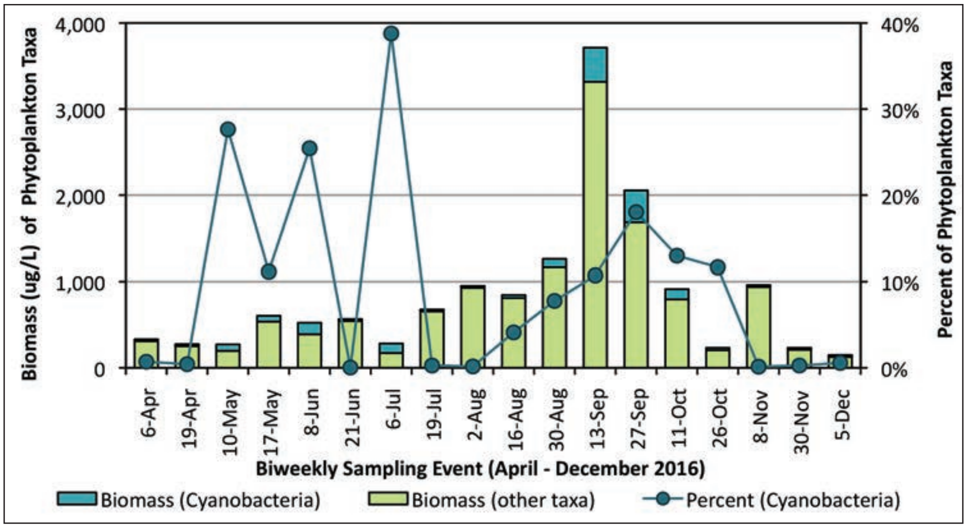

Figure 3. Seasonal phytoplankton biomass and cyanobacteria as percent of phytoplankton taxa, April to December 2016. *Data courtesy of OCDWEP*

of cyanobacteria that can increase their competitive ability over other phytoplankton. Many non-N-fixing cyanobacteria species have superior nitrogen storage capacity, and Ferber *et al. (2004)* found that cyanobacteria had a small proportion of "fixed" N_2, accumulating N in inorganic form, principally as ammonia but also as nitrate.

A review by Beutel *et al. (2016)* demonstrated that addition of nitrate to surface waters affects water-quality improvements by several routes, including the suppression of cyanobacteria in favor of eukaryotic algae, mostly greens *(Chlorophyte* and *Charophyte algae)*. In an early Swedish study *(Ripl and Lindmark 1979)*, addition of nitrate to a group of small quarry lakes converted the plankton community from one dominated by cyanobacteria and small-bodied zooplankton to one dominated by green algae and large-bodied zooplankton.

In Onondaga Lake, nitrification of the Metro effluent began in 2004, greatly reducing the loading of ammonia to the lake and increasing the water column concentration of nitrate by a factor of two. This brought about several salutary effects on the lake's water quality, including a late summer reduction in the mobilization of phosphorus from the sediments. Since 2011, concentrations of nitrate have been augmented by the addition of hypolimnetic calcium nitrate to prolong these effects *(OCDWEP 2017*). It is difficult to distinguish between the effects of phosphorus reduction on the phytoplankton community from the effects of increased nitrogen; however, nitrate additions have reduced internal phosphorus loading, further curtailing eutrophication and the concomitant encouragement of HABs. It has also reduced the methylation of mercury in the sediments and its entrance into the food chain, and has improved water quality in several other ways.

Light

In any given nutrient environment, cyanobacteria may realize a competitive advantage over other types of phytoplankton because of their more efficient use of light *(Ferber et al. 2004, Kosten et al. 2012, Smith 1983, Smith 1986)*. Not only do cyanobacteria grow more rapidly, especially under low-light conditions, but because they have buoyancy-regulating gas vacuoles, they rise to the surface and shade out other species. Because their buoyancy also reduces their sinking rate, cyanobacteria remain in the well-lighted, upper level of the water column. As surface scums, cyanobacteria are also moved by wind-driven currents and may accumulate on leeward shores or in protected embayments.

Climate Change

There are several reasons to predict that global climate change will favor the growth of cyanobacteria in surface waters, leading to an increase in the frequency of HABs. The increased frequency of HABs worldwide is likely not due solely to increased eutrophication *(Mantzouki et al. 2016, Paerl and Otten 2016)*. The direct and indirect effects of warming may play an important role in changing the properties of aquatic ecosystems *(Elliott 2012; Kosten et al. 2012; Paerl and Huisman 2008)*.

Global warming directly favors cyanobacteria over eukaryotic algae because the optimal temperature for the growth of many cyanobacteria is greater than that for most algal species *(Butterwick et al. 2005)*. Warmer surface water temperatures are also associated with more stable thermal stratification and less turbulent mixing. In addition, the thermocline in these warmed lakes will be shallower and more stable for a longer time, which can encourage the growth of certain cyanobacteria taxa *(Paerl and Huisman 2008)*. Under stable water column conditions, positively buoyant cyanobacteria will be able to regulate their position in the water column and remain in the euphotic zone, while negatively buoyant algae will sink in the absence of turbulent mixing. The concentration of cyanobacteria in surface layers will shade levels beneath the surface, further enhancing the growth advantage of the cyanobacteria on the surface. Furthermore, dense light-absorbing aggregations of cyanobacteria near the surface will further warm the water, enhancing the dominance of the cyanobacteria.

Dense phytoplankton growth can outstrip the supply of carbon, but buoyant cyanobacteria, closer to the surface will have better access to both carbon dioxide (CO_2) diffusing from the surface and to atmospheric CO_2 that is continuing to increase.

Other attributes of a changing climate may affect the occurrence of HABs. Intensified precipitation will lead to higher terrestrial nutrient-laden runoff, exacerbating eutrophication and further encouraging blooms. Other extreme events associated with global climate change may increase the likelihood of HABs. Heat waves, for example, especially those accompanied by sunny calm weather conditions, have been associated with local cyanobacteria blooms *(Pearl and Huisman 2016)*.

Comparison to Oneida Lake

Average summer values of chlorophyll-a concentrations along with inferred phytoplankton densities in Oneida Lake are lower than those in Onondaga Lake, although TP concentrations in the two lakes are similar *(OCDWEP 2017*). Oneida Lake is shallower than Onondaga Lake and more of its bottom is suitable for dreissenid mussel grazing. Nonetheless, large summer blooms of cyanobacteria and concentrations of cyanobacterial toxins exceeding current health guidelines occur during the summer in Oneida Lake *(Idrisi et al. 2016, Greg Boyer, pers. comm. 2017)*.

One relevant difference between the two lakes with regard to cyanobacteria blooms is their different N:P ratios. It is well-documented that cyanobacteria dominate primarily in lakes with N:P ratios (by weight) below 29 *(Smith 1983)*. The low proportion of cyanobacteria in Onondaga Lake is consistent with its elevated summer N:P ratio, which has been well above the 29:1 threshold since before 1998. This ratio has been very high, over 100:1 since 2007 ***(Figure 4)*** *(OCDWEP 2017)*. This is not the case in Oneida Lake, where summer N:P ratios are substantially lower. Between 2011 and 2016, the N:P ratio varies between 14:1 and 26:1 ***(Figure 4)*** with summer minima between 6:1 and 15:1 *(Rudstam 2017)*. Thus, N is more limiting in Oneida Lake giving cyanobacteria a competitive advantage. Other attributes potentially promoting cyanobacteria (TP concentrations, warmer temperatures, more stable water column, and increased phosphorus release from sediments) do not appear to be dramatically different in the two lakes.

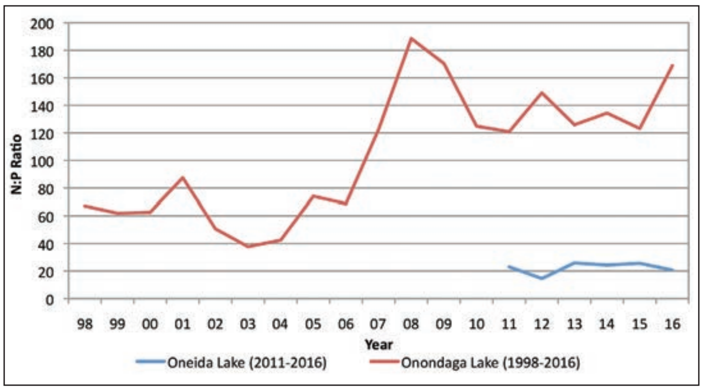

Figure 4. Average N:P ratio in Onondaga Lake (1998-2016) and Oneida Lake (2011-2016).

Data courtesy of OCDWEP and Cornell University Biological Field Station

Lessons from Other Regional Lakes

All the Finger Lakes have experienced cyanobacterial blooms, even oligotrophic ones (e.g., Skaneateles), but HABs have become more common in Conesus, Honeoye, Canandaigua, Seneca, Owasco and Otisco (*Halfman 2017*). Although Honeoye is eutrophic, with TP between 30 and 45 µg/L, Cayuga, Seneca, Owasco and Otisco are mesotrophic (TP between 10 and 20 µg/L). The HABs in Canandaigua, Honeoye, Owasco, Skaneateles and Seneca Lakes have been associated with cyanobacterial toxins in the water *(NYSDEC 2017)*. Cayuga and Owasco have experienced HABs in mid- to late-summer in 2016 and 2017, and – in the case of Owasco Lake – cyanobacteria toxins were detected in Auburn, New York's, municipal water supply.

Classification of the trophic status of these lakes is typically made from mid-lake sites, while the HABs typically occur in nearshore locations; cyanobacterial concentrations in nearshore blooms far exceed those of open water. In certain areas, nutrient-laden terrestrial run-off augments the ambient nearshore phosphorus concentrations, although that is not a general pattern. Nearshore concentrations of nutrients in Onondaga, Cayuga and Owasco Lakes have been similar to pelagic values *(Dave Matthews, pers. com. 2017)*. Furthermore, the buoyancy-control of many cyanobacteria concentrates them in surface scums carried to nearshore locations by wind-driven currents. In Owasco Lake, the HABs occurred in mid-summer, when air and water temperatures were at their highest and abated when water temperatures decreased. The most intense blooms are typically associated with calm, sunny days, with maximum thermal stratification of the surface and little wind-induced mixing.

Conclusion

Clearly, the causes of cyanobacterial blooms are complex. While high concentrations of limiting nutrients, such as phosphorus, have been the principal culprit in hypertrophic and eutrophic bodies of freshwater, it is now clear that less productive waterbodies are not immune from HABs. Onondaga Lake is now less productive than it was before remediation was undertaken, and major algal blooms and the abundance of cyanobacteria has greatly declined. The N:P ratio of the upper waters appears to be a key indicator of risk of HABs, likely exacerbated by warming and more quiescent conditions.

While the evidence from Onondaga Lake reviewed here does not suggest an imminent threat of cyanobacterial blooms, the recent increase in the importance of cyanobacteria in the lake's phytoplankton community, the presence of toxic genera of cyanobacteria in Onondaga Lake, and the experience of HABs in nearby mesotrophic lakes suggest watchfulness.

Acknowledgements

This analysis was made possible by OCDWEP, who shared their long-term data set, and Dr. Lars Rudstam of Cornell Biological Field Station. This paper benefitted from thoughtful reviews by Dr. David A. Matthews of the Upstate Freshwater Institute and my EcoLogic colleague, Dr. Liz Moran.

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Declining Mercury Concentrations in Prey Fish in Onondaga Lake, Following Sediment Remediation

by Betsy Henry and Charles Driscoll

Onondaga Lake in Syracuse, New York ***(Figure 1)***, is a 4.6-square-mile lake that has a long history of being impacted by local municipal and industrial activity, including two mercury cell chlor-alkali plants. Since at least the 1970s, mercury concentrations in fish have been elevated because of historical discharges of mercury to the lake. Significant cleanup efforts by both Onondaga County and Honeywell have improved the water quality, sediment quality and fish community of the lake ecosystem in recent years. Since 2004, the lake has experienced significant improvements in water quality, including reductions in phosphorus, ammonia and chlorophyll concentrations, as well as increases in dissolved oxygen concentrations and water column transparency *(Matthews et al. 2015)*, following upgrades to Onondaga County's Metropolitan Syracuse Wastewater Treatment Plant (Metro).

Figure 1. Location of Onondaga Lake. *Anchor QEA, LLC*

In addition, Honeywell is completing the Onondaga Lake Superfund Site remedy under the direction of the New York State Department of Environmental Conservation (NYSDEC) and U.S. Environmental Protection Agency (USEPA). Key components of the remedy include:

- The dredging and capping of contaminated sediment primarily in the nearshore zone at less than 9 meters water depth (completed in 2016).
- Monitoring of natural recovery in deepwater sediment (i.e., sediment below 9 meters water depth).
- The annual addition of nitrate to the hypolimnion to limit methylmercury production and mercury release from profundal sediment starting in 2011 *(Matthews et al. 2013)*.

Dredging and capping have been completed. Honeywell has also restored or created nearly 90 acres of wetlands along the lakeshore and Ninemile Creek, a major tributary to the lake, following remediation.

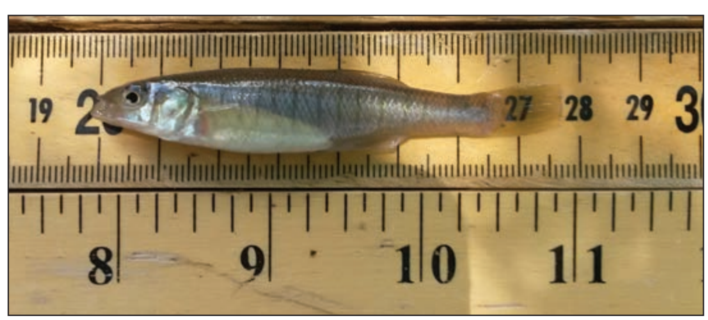
The overall purpose of the remedy is to control contaminants in the lake and, by doing so, protect human health and the environment. While the purpose of nitrate addition is to eliminate or reduce mercury methylation in the hypolimnion and mercury releases from deepwater sediment, the dredging, capping, and monitored natural recovery were designed to eliminate or reduce adverse ecological effects on fish and wildlife and potential risks to humans. Dredging and capping in nearshore sediment were done to address toxicity to benthic macroinvertebrates from a variety of contaminants, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and mercury. Natural recovery in deepwater sediment is an ongoing process that occurs when cleaner suspended particles (e.g., from tributaries, nearshore sediment and the water column) are deposited to the bottom of the lake, resulting in lower and lower contaminant concentrations in surface sediment. Together, the remedial activities decrease concentrations of bioaccumulative contaminants like mercury and PCBs that pose risk to wildlife and humans who consume fish.

The 2005 Record of Decision established specific remediation goals in sediment, surface water and fish tissue, including a goal of 0.14 milligram per kilogram (mg/kg) wet weight for mercury in small prey fish for protection of ecological receptors. A long-term monitoring program, being designed under the direction of the NYSDEC and USEPA and to be implemented by Honeywell, will track the progress of the remedy in achieving these goals. In this article, we report on recent monitoring results for mercury in small prey fish.

Why Monitor Small Prey Fish?

Small prey fish, including species such as banded killifish *(Fundulus diaphanous)*, golden shiner *(Notemigonus crysoleucas),* and round goby *(Neogobius melanostomus)*, are abundant in Onondaga Lake. As in many lakes, they are a major forage base for a wide range of ecological receptors, including larger fish, birds such as belted kingfisher, and mammals that may consume small fish. Due to their small home ranges and low likelihood for traveling far – even as they age – contaminant concentrations observed in small prey fish are typically indicative of localized conditions. They exhibit rapid responses to changes in contaminant concentrations in their environment due to their short life cycles and rapid reproduction rates. Based on these factors, small prey fish are ideally suited to provide insight into recovery in specific portions of the lake and in a relatively short timeframe following remediation.

Prey fish monitoring, in conjunction with other long-term monitoring activities, allows for the evaluation of trends in mercury concentrations over time and within various areas of the lake. This



Banded killifish ***(Fundulus diaphanous)*** **is an abundant species of small prey fish in Onondaga Lake.** *Matt Smith, Anchor QEA, LLC* information will be used to assess achievement of the remedial action objectives and remediation goals, and to better understand the ecology of Onondaga Lake with respect to contaminant bioaccumulation.

Monitoring Approach

Baseline monitoring was conducted from 2008 through 2011 to document conditions in the lake prior to remediation. This initial monitoring helps to lay the groundwork for future evaluation of the effectiveness of the remedy. Monitoring continued from 2012 through 2016 to document lake conditions during implementation of dredging and capping. Annual post-remediation monitoring will continue for the foreseeable future, consistent with the long-term monitoring program, under the direction of the NYSDEC and USEPA.

Each year, prey fish sampling with a littoral seine net was conducted at approximately the same eight locations in the lake in late July or early August. Consistent timing is important because contaminant concentrations may change during each year due to growth of the fish. In 2012, small prey fish monitoring was conducted in early August, shortly after in-lake remediation began in late July. The eight locations were identified within sediment management units (SMUs) that had been developed during a 2005 feasibility study that evaluated remedial alternatives in different areas of the lake with different conditions. Boundaries of the SMUs are shown in ***Figure 2***, which also depicts the nearshore remediation areas. The nearshore remediation areas targeted the SMUs with elevated contaminant concentrations, which posed risk of sediment toxicity to benthic macroinvertebrates and bioaccumulation of contaminants. Following remediation, conditions in surface sediment in these SMUs are similar to other lakes in the region. Natural recovery is ongoing in SMU 8 that comprises deepwater sediment below 9 meters water depth.

Setting littoral seine nets in Onondaga Lake to collect fish samples.
Anne Burnham, Parsons

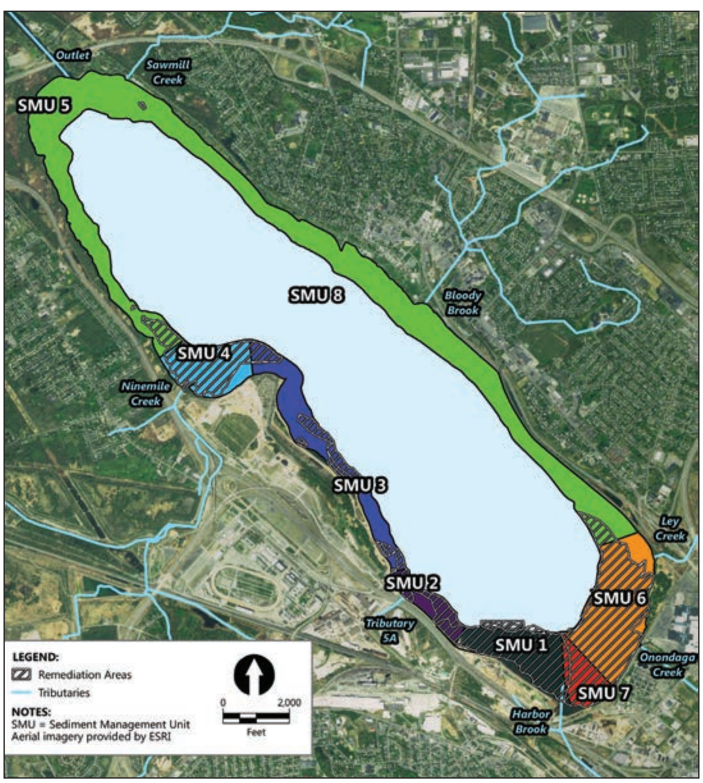


Figure 2. Boundaries of the Sediment Management Units (SMUs) and nearshore remediation areas defined during a 2005 feasibility study.
Anchor QEA, LLC

Samples were collected at specific locations within each of the nearshore SMUs. Due to the relatively large size of SMU 5, which is located on the opposite side of the lake from known mercury discharges, three locations were sampled. All other SMUs were characterized by one sample location.

Banded killifish were the primary target for small prey fish collection. When banded killifish were not observed in abundance, locally abundant surrogate species such as golden shiner were collected. The monitoring data confirmed that mercury concentrations in the small prey fish species are comparable. Three composite samples were collected from each location, and each composite sample comprised individuals of the same species and of similar size.

Monitoring Results

Mercury concentrations observed in small prey fish during baseline monitoring from 2008 to 2011 ***(Figure 3)*** were consistent with the spatial distribution of surface sediment mercury concentrations measured during the remedial investigation in 1992 and 2000. Concentrations in fish were highest in SMUs with the highest concentrations of mercury in sediment, consistent with the expectation that contaminant concentrations observed in small prey fish are indicative of existing conditions in localized sediments.

The response of small prey fish to the reduction in mercury concentrations in sediment has been rapid. Since the completion of dredging in 2014, mean concentrations of mercury in prey fish have declined, particularly in SMUs with the highest mercury concentrations prior to remediation. For example, mercury concentrations in small prey fish from SMU 2 have declined by more than 90 percent. Variability among sampling locations has also declined and mercury concentrations in all SMUs are now similar to those in SMU 5, which is furthest from the historical mercury discharges.

In 2016, mean mercury concentrations in all SMUs were below the remediation goal of 0.14 mg/kg for protection of ecological receptors that consume small prey fish ***(Figure 3)***. When the data from each SMU were averaged together to produce a lake-wide mean, annual mean mercury concentrations measured in small prey fish were below baseline concentrations from 2013 through 2016, and below the remediation goal in 2016 ***(Figure 3)***.

Looking Forward

In addition to documenting reductions in potential mercury exposure to wildlife, reductions in mercury concentrations in

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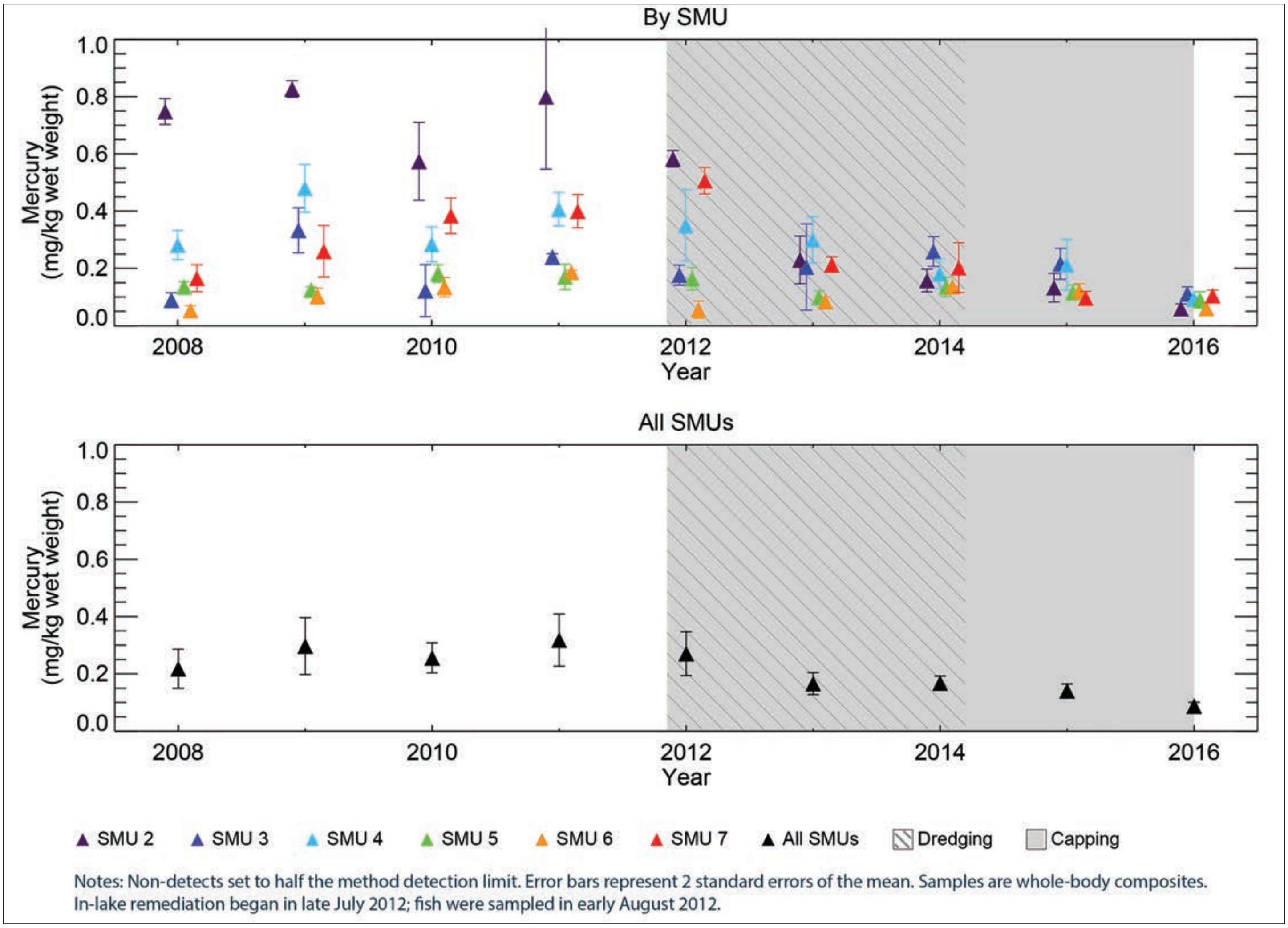

Figure 3. Trends in annual mean mercury concentrations in small prey fish, lake-wide and by SMU, 2008 through 2016. *Anchor QEA, LLC*

prey fish are a good early indicator of long-term improvements in mercury concentrations in sportfish resulting from remediation. Unlike small prey fish, sportfish are long lived and expected to take longer to respond to changes in mercury concentrations in water and sediment. In addition to small prey fish that are linked to sediment, sportfish also consume fish that consume plankton, which acquire mercury from the water column. The reductions in methylmercury in the water column due to nitrate addition – in combination with reductions in mercury in sediment due to dredging, capping and natural recovery – bode well for mercury reductions in sportfish, albeit in the context of elevated mercury concentrations in sportfish statewide due to atmospheric deposition of mercury.

Small prey fish will continue to be monitored annually, under the direction of the NYSDEC and USEPA.

Acknowledgments

The monitoring program is managed by Parsons and performed by the State University of New York College of Environmental Science and Forestry. Data analysis was performed by Anchor QEA, LLC. This program is funded by Honeywell as part of their ongoing monitoring program on Onondaga Lake.

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Public Engagement through Onondaga County's Save the Rain Program

by Madison M. Quinn

Under the leadership of County Executive Joanie Mahoney, Onondaga County's Department of Water Environment Protection (OCDWEP) has developed an award-winning program to implement green and gray infrastructure solutions to reduce combined sewer overflows (CSOs) and improve the water quality of Onondaga Lake and its tributaries. This program is known as the Save the Rain program, which has been recognized locally, regionally and nationally as a leader in innovative solutions to CSO mitigation and stormwater management. Under the Save the Rain program, OCDWEP has developed a robust education and outreach portfolio.

Outreach Initiatives

Approximately 200 green infrastructure projects have been completed to date, as well as a variety of complementary gray infrastructure improvements. An essential component of the Save the Rain program is public engagement programming. The various outreach initiatives serve several purposes, the first of which is to inform the public of ongoing infrastructure projects and progress in improving water quality. Public meetings and presentations, exhibiting at local events from festivals to farmers markets, and the third-grade educational program are examples of informing various audiences of the ongoing work that benefits the Onondaga Lake watershed.

Another purpose of outreach initiatives is to gain public support, buy-in and participation from residents and businesses for the decentralized efforts to improve water quality. OCDWEP has several programs specifically directed toward this purpose. The first is the residential rain barrel program, through which approximately 2,000 rain barrels have been distributed. Residents attend a brief instructional workshop and are taught how to install and maintain their rain barrel. Participants can then take home a free rain barrel to manage rain water from their roofs and reduce runoff into the sewer system, helping to prevent CSOs. This is a decentralized approach to stormwater capture, as well as a powerful tool in our public outreach toolkit. Having the attention of workshop attendees allows us to speak with them not only about rain barrels, but also the various other projects and programs administered under the Save the Rain program.

The county added the "Connect the Drops" component to the Save the Rain outreach programming in 2016, aiming to reduce floatable material, particularly street litter, in Onondaga Lake and its tributaries. Connect the Drops aims to communicate the connection between litter and water quality impairment. The message is that when someone "drops" litter on the street, rain "drops" carry that litter further than one might think – into the sewer system and into local waterways. Stemming from the Connect the Drops, the county launched a call to action with the Block Litter initiative, in partnership with Onondaga County Resource Recovery Agency (OCRRA). Block Litter engages community members in both supporting and participating in a decentralized approach to water quality improvement. Block Litter asks residents and businesses to take a pledge to do small, regular litter pickups on the block where they live or work. To date, over 600 people within the Onondaga County Consolidated Sanitary District have signed up to pick up litter on their block. Those participants are then encouraged to share their cleanups on social media to both show their commitment to the program and to inspire others in their social circle to take part. Further, the county is offering incentives to prompt regular cleanups and posting on social media, featuring community-submitted photos on *BlockLitter.com* and offering prizes as added incentive.

Block Litter is a collaborative initiative between OCDWEP's Connect the Drops program and OCRRA to reduce street litter reaching local waterways *(blocklitter.com)*. *Onondaga County Save the Rain*

Save the Rain employs a vast array of education and outreach programming. These efforts complement the infrastructure implementation and maintenance undertaken by the county. One example is how the public participation through the Connect the Drops and Block Litter initiatives complements the skimmer boat operations and the improved catch basin maintenance and other floatables control infrastructure used to reduce trash and debris in Onondaga Lake. Engaging the public serves to help reduce the amount of litter reaching the waterways. The goal is reducing the costly efforts needed to remove debris after it has entered the water environment.

Communication strategies and measurement of community engagement are critical to our adaptive approach to public outreach. Website and social media analytics help us discover which messaging resonates with our various audiences. We also track those that take an action, such as signing up to take the Block Litter pledge.

Partnerships

Partnerships with community-based organizations help OCDWEP to achieve our goals with green infrastructure maintenance, street tree planting, environmental education, rain barrel workshops, informational tours of green and gray infrastructure and the Save the Rain Clean Water Fair, which draws hundreds of local visitors to the county's Metropolitan Syracuse Wastewater Treatment Plant (Metro) each fall.

Onondaga Earth Corps (OEC) has been a valued community partner of Save the Rain since 2011, working on several facets of the program. OEC is a nonprofit green jobs organization that hires and trains both youth and young adults in the City of Syracuse in green infrastructure implementation and maintenance, tree planting and outreach. One OEC crew is trained specifically in green infrastructure maintenance best practices and helps to meet the county's seasonal maintenance needs on rain gardens and bioretention installations. Another OEC crew is trained in tree planting and maintenance, planting almost a thousand trees per year for the county's tree planting program. OEC crew members are essential to the Save the Rain education and outreach team, communicating the value of green infrastructure to their friends and neighbors. OEC has been very successful in securing homeowner permissions to plant street trees in front of their property.

Another element of public education and outreach is through the county's partnership with the Baltimore Woods Nature Center's "Nature in the City" program. In the 2016-2017 school year, over 1,600 students in 63 third grade classrooms received three one-hour lessons for a total of 4,818 hours of water quality education *(Baltimore Woods 2017)*. The first lesson tells the story of stormwater and Save the Rain, using a watershed model activity to demonstrate the water cycle and how land-based pollution can be picked up by stormwater. With real-time changes to the model, the students learn how green infrastructure implementation helps to reduce that pollution and the runoff into tributary waters. The second lesson includes an activity book that explains green infrastructure practices and how to soak up stormwater. The students also learn to identify macroinvertebrates and which species are found in water with or without pollution. The final lesson is a field trip in which the students visit a Save the Rain green infrastructure project to see first-hand how green infrastructure is working in their community to reduce pollution to Onondaga Creek and Harbor Brook. Then the students visit Elmwood Park to perform a stream cleanup and sample for macroinvertebrates. The instructor leads a discussion about the macroinvertebrates the students sampled and how the species they find relate to water quality. This curriculum successfully integrates with the school district's science curriculum requirements by offering hands-on science learning opportunities.

Onondaga Earth Corps demonstrate proper tree planting techniques at an Onondaga County Save the Rain community tree planting event.
Onondaga Earth Corps

Onondaga Earth Corps crew members plant street trees in the City of Syracuse for the Onondaga County Save the Rain program.
Onondaga Earth Corps

Annual Clean Water Fair

OCDWEP's largest public engagement event of the year is the annual Save the Rain Clean Water Fair, welcoming hundreds of visitors to the Metro plant *(Save the Rain 2017)*. In 2017, attractions included hourly tours of the state-of-the-art plant, viewing live fish from Onondaga Lake and updates on the county's Save the Rain and Connect the Drops programs. Informational displays from over 20 different organizations – ranging from engineering companies to environmental nonprofits to equipment vendors to government agencies – were also present. The event had an inviting, festival-style appeal with face painting and a bounce house. Other kids' activities that focus on water included a trivia scavenger hunt and a litter awareness game. In addition to the hourly walking tours conducted by operators, teams also offered tram tours and a virtual tour presentation for those with mobility limitations.

There were a variety of displays highlighting the work of various divisions within OCDWEP and how that work helps to improve water quality in the watershed. The process engineering team demonstrated how several pieces of equipment are used for the work of their division. Informative display boards showed topics such as asset management, underground storage tank removal, and capital projects, both green and gray. The county's laboratory team engaged children and families to learn about water chemistry and how the health of local water bodies is tested in the lab. OCDWEP's maintenance team showed the equipment that the department maintains, such as the pumps that help the treatment plant operate. The biological sampling technicians brought in fish caught from Onondaga Lake for visitors to view up close and even hold in their hands.

The event also included two rain barrel workshops, and distributed approximately 60 rain barrels to local residents to help them "save the rain" at their own homes. The Clean Water Fair is an incredible opportunity to welcome the public to the Metro facility and educate them on all the work progressing in the clean water sector.

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Public Appreciation of the Lake as a Resource

The many facets of public engagement programming under Onondaga County Save the Rain collectively facilitate an understanding and appreciation of the ongoing work to improve the water quality of Onondaga Lake and its watershed. Whether it is attending a workshop or public meeting, planting street trees at a community planting event, or a third grade class learning about green infrastructure, these elements come together to engage the public and foster an appreciation for the tremendous asset that Onondaga Lake has become.

Madison M. Quinn is the Project Coordinator for the Save the Rain program at Onondaga County Department of Water Environment Protection. She can be reached at MadisonQuinn@ongov.net.

"Nature in the City" educators from Baltimore Woods Nature Center's program help third grade students identify macroinvertebrates at a field trip to Elmwood Park. *Baltimore Woods Nature Center*

At the annual Save the Rain Clean Water Fair, visitors are able to interact with local wildlife – including fish from Onondaga Lake. *Onondaga County Save the Rain*

Baltimore Woods Nature Center staff, volunteers from Carrier Corporation and thirty fourth- and fifth-graders helped revitalize the rain garden at Seymour Dual Language Academy. *Baltimore Woods Nature Center*

Visitors from the public tour the Metro plant at the annual Save the Rain Clean Water Fair. *Onondaga County Save the Rain*

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Save the Rain. 2017. 2017 *Clean Water Fair.* Accessible on-line *http://savetherain.us/2017-fair/*

Izaak Walton CNY Chapter Releases Final Report on GLRI Habitat Restoration Projects

by Les Monostory

Introduction

In 2010, the Central New York Chapter of the Izaak Walton League of America (CNY Chapter) collaborated with the national Izaak Walton League of America (IWLA) to receive an $118,000 grant from the U.S. Environmental Protection Agency (USEPA) under the Great Lakes Restoration Initiative (GLRI) grant program. Titled "Restoring Degraded Tributaries of Onondaga Lake," the project was aimed at undertaking restoration measures in several habitat degraded tributaries of Onondaga Lake: Beartrap Creek in the Town of Salina; Baltimore Brook in the Town of Marcellus; and Ley Creek in the Town of DeWitt.

The principal partners in the overall GLRI grant elements were the IWLA's national office in Gaithersburg, Maryland, the CNY Chapter's Project Watershed Program, the Onondaga Environmental Institute, the Onondaga County Soil and Water Conservation District, the Ninemile Creek Conservation Council, and our consulting engineer firm of Natural Systems Engineering.

Habitat restoration work in Beartrap Creek and Baltimore Brook was conducted from 2011 to 2014. The CNY Chapter received substantial volunteer help from Chapter members, local citizens, and Project Watershed adult survey team members with stream water quality data collection, with placement of stone cobbles in several locations along Beartrap Creek and with the stocking of brown trout. The most recent habitat restoration project, on the South Branch of Ley Creek, was completed in October of 2016.

Previous reports on the Phase 1 and Phase 2 elements of the GLRI grant program dating back to 2010 were summarized in a March 2016 Interim Report *(Monostory 2016a)*. A final report on the GLRI project, covering the habitat restoration initiatives completed between 2010 to 2016, was sent to the IWLA and the USEPA in late December 2016 *(Monostory 2016b)*.

South Branch of Ley Creek Project

Having already completed the Phase 2 habitat restoration work on Beartrap Creek and Baltimore Brook by 2014, in the fall of 2015 the project team selected the final target site on which to apply the remaining Phase 2 GLRI funds. On the South Branch of Ley Creek, next to the west end of Tarbell Road in the Town of DeWitt, there was a stone dam structure which presented a two- to three-foot high impediment to the upstream migration of fish from lower Ley Creek and Onondaga Lake ***(Photograph 1)***. The history of this stone dam structure was unclear. Inquiries were made of adjacent landowners and state records, but no further information about the reason or purpose of the structure was documented. It is possible that this structure was a result of an earlier New York State Department of Transportation project, where the South Branch of Ley Creek was channelized and paved with concrete extending from the state Route 298 bridge crossing located several hundred feet upstream, down to the stone dam location adjacent to Tarbell Road.

The adjacent commercial landowners, Pemco Group (Syracuse, New York) and Westlake Development, LLC (East Syracuse, New York) agreed to allow the CNY Chapter access to the stone dam project site for the restoration project.

Pre-Construction

Before the construction could begin, several steps needed to be taken. The consultant, Kyle Thomas of Natural Systems Engineering, drew up design plans for placement of stone fill from the upper level of the stone dam structure and extending along a gradient to a point approximately 75 feet downstream from the existing top of the dam. This stone bottom slope, at the base of the existing barrier, would ease the migration route for the spawning movement of game fish such as walleyed pike and northern pike.

Photograph 1. Pre-construction view of the Tarbell Road habitat restoration site on the South Branch of Ley Creek. *Les Monostory*

Photograph 2. Heavy equipment is used to place stone fill on and downstream of the dam structure in the South Branch of Ley Creek near Tarbell Road. *Les Monostory*

In March 2016, permit applications were submitted under Section 401 of the Clean Water Act and Article 15 of New York State Department of Environmental Conservation (NYSDEC) regulations for excavation and placement of fill in navigable waters. The project site property owner, Pemco Group, gave its consent for the application.

A public notice on the permit application was published in the Syracuse *Post Standard* on July 3, 2016. The notice stated that a negative declaration under the State Environmental Quality Review (SEQR) law is on file at the NYSDEC office in Syracuse, New York, and that the project is an Unlisted Action that will not have a significant adverse effect on the environment.

With the permits in place, it was time to mobilize for the field work. A contractor, Joe Green Excavating, was hired in September 2016 for the placement of the stone fill, and the work was scheduled to take place on October 10, 2016.

Construction

The Joe Green Excavating crew arrived at the project site in early morning of October 10 with heavy equipment and 230 cubic yards of stone fill (approximately 330 tons). They completed the stone fill placement, under supervision of Kyle Thomas of Natural Systems Engineering, by mid-afternoon on October 10 ***(Photograph 2)***. The GLRI Restoration Project Coordinator for the CNY Chapter, Les Monostory, sent photographs of the pre- and post-construction project to the various partners who had contributed to the Phase 2 GLRI project, including Dave Lemon, an aquatic biologist and the regional fisheries manager for the NYSDEC's Region 7. Due to low flows in the South Branch of Ley Creek, the water below the dam was flowing underneath the stone fill placement ***(Photograph 3)***. However, Lemon anticipated that silt and mud from future high-water events would eventually fill in the voids below the stone fill, which would allow the stream to flow over the graded stone section rather than under it. This would in turn lead to accomplishment of the GLRI project goal to allow enhanced upstream migration of fish into the South Branch through Ley Creek and from Onondaga Lake.

Post-Construction

The Restoration Project Coordinator made periodic visits to the Ley Creek project site to monitor the length of time needed to establish continuous stream flows over the stone fill placement. A week following placement of the stone fill, the Syracuse area was inundated by storms that deposited over four inches of rain across the Central New York region. As a direct result, high waters at the Ley Creek South Branch project carried mud and silt, which filled in the voids between and under the stones. This had the desired effect of allowing the stream to flow over the stone fill, rather than underneath ***(Photograph 4)***.

Dr. Stephanie Johnson, a fishery biologist with the Onondaga Environmental Institute, has collected data in the past on fish populations in Ley Creek, including the South Branch tributary. Based on post-project communications with Dr. Johnson, the Onondaga Environmental Institute intends to undertake fish population monitoring again in the spring of 2018 as part of their NYSDEC grant. The CNY Chapter anticipates that Dr. Johnson's fish population monitoring will help to measure the success of this restoration project to meet the goal of improving fish migration and spawning in this reach of Ley Creek.

Les Monostory is the GLRI Restoration Project Coordinator and the Vice President of the Central New York Chapter of the Izaak Walton League. He may be reached at fishbugm5@twcny.rr.com.

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Photograph 3. The stone fill is placed in the streambed at the site of the stone dam structure and downstream. The creek's water is flowing through the voids under the stone fill. *Les Monostory*

Photograph 4. One week post-construction, heavy rainfall raised the water level of the South Branch of Ley Creek, allowing for the deposition of silt and mud in the gaps between the stones so the stream flowed across the top of the fill. *Les Monostory*

My Water Legacy –

In Memory of Steven W. Effler, Exemplary Limnologist and Onondaga Lake's Champion

by David A. Matthews

The State of New York lost one of its premier freshwater researchers and leading champions for our water resources with the passing of Steven W. Effler on April 14, 2017. Although Steve's research activities extended from the Laurentian Great Lakes to the Finger Lakes and beyond, he is best known for leading a rigorous, multidisciplinary research program on Onondaga Lake that spanned 40 years. This program documented the severely degraded condition of Onondaga Lake and contributed importantly to the remarkable water quality improvements achieved in the lake over the past 15 years. Steve's passion for the rehabilitation of Onondaga Lake began with his doctoral dissertation at Syracuse University, A Study of the Recent Paleolimnology of Onondaga Lake *(Effler 1975)*, which established cause and effect relationships associated with the lake's history of pollution.

MaryGail Perkins

Steven W. Effler

In 1981 Steve founded the Upstate Freshwater Institute (UFI), a not-for-profit organization dedicated to the advancement of freshwater research and education and the protection of the freshwater resources of New York. From humble beginnings – an office in Steve's attic, a chemistry laboratory in his basement, and a leaky boat – UFI evolved into an internationally recognized leader in freshwater research thanks to Steve's unparalleled focus and perseverance, the support of his family, and the dedication of his long-time colleagues. Researchers at UFI continue Steve's legacy through their ongoing dedication to the advancement of the Institute's vital mission.

> *"The recovery of Onondaga Lake from decades of domestic and industrial contamination is a critically important but under-appreciated turning point for Central New York and bodes well for our future. Steve was a man of intellect, perseverance and tenacity. As a community we owe him considerable thanks."*
>
> *–Charles Driscoll Jr.*

Steve's contributions to our understanding of Onondaga Lake's extreme degradation and subsequent recovery are perhaps best described through the 255 peer-reviewed manuscripts he published during his career. Even a cursory review of Steve's 144 scientific contributions on the Onondaga Lake ecosystem alone reveals the depth and breadth of his work, from mercury in sediments *(Effler, Rand and Tamayo 1979; Owens, et al. 2009)* to nutrient studies (*Effler, Wodka, et al. 1986; Effler, Brooks and Whitehead 1996)* to robotic water quality monitoring *(Effler, O'Donnell and Owen 2002; Denkenberger, et al. 2007)*. Spanning the fundamental scientific disciplines of chemistry, physics, biology, and ecology, Steve's contributions have greatly advanced our understanding of Onondaga Lake and lakes in general. In fact, when it comes to Onondaga Lake, Steve wrote the book: *Limnological and Engineering Analysis of a Polluted Urban Lake – Prelude to Environmental Management of Onondaga Lake, New York (Effler 1996)* established the scientific basis for subsequent remediation efforts.

Although the number of Steve's published papers is a truly impressive measure of his productivity, the 102 co-authors who had the privilege of working with Steve on these manuscripts may be an even more meaningful reflection of his broader impact. Steve's passion for limnology was infectious, and he had a profound impact on the people who worked with him. Steve loved working with students and young scientists. He mentored dozens of aspiring scientists at UFI and students during their graduate studies. For his lasting impacts on lakes and the people who work to protect them, Steve is a champion. Thank you, Steve. You will be missed.

David A. Matthews, PhD, is the Director of the Upstate Freshwater Institute, a not-for-profit 501(c)(3) research corporation dedicated to the improvement of water quality and the advancement of freshwater research. He may be reached at damatthews@upstatefreshwater.org.

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My Water Legacy –

In Memory of Robert D. Hennigan, Extraordinary Environmental Leader

by Patricia Cerro-Reehil

It is with a heavy heart and great personal sadness that we share the passing of Robert D. Hennigan. Bob served as NYWEA's Executive Director for over 20 years, retiring in 2000. After retirement he served as NYWEA's Director of Special Projects while working on his book, *Water for New York*. Bob's leadership in NYWEA has been an important part of the organization's success, both programmatically and financially. It is both fitting and serendipitous that the celebration of his life took place during the 20th anniversary celebration of the Scholarship Fundraiser, a NYWEA program he initiated and of which he was most proud.

Robert D. Hennigan

Throughout his career his work made a difference, and he was truly a remarkable man. It was a privilege to work with him and witness his passion for NYWEA and its mission. I valued his guidance and advice immensely and his presence enriched my life.

Bob served in the U.S. Army as an infantry staff sergeant from 1943 to 1946. He received a Combat Infantry Badge, Purple Heart, Bronze Star, Certificate of Merit and Theater Ribbons, European Theater of Operations. In 1949. Bob received his bachelor's degree in civil engineering from Manhattan College, and began his career with the state Department of Health (NYSDOH) in the Syracuse district and regional offices, dealing mainly with water supply and water pollution issues in a time of growth and expansion (1949-57).

He moved to Albany, New York, in 1958 to head up the water pollution control section of NYSDOH. In 1960 he took a position as principal engineer with the state Office for Local Government to deal with local environmental problems. Governor Rockefeller then authorized the special study of the "Needs for Sewage Works" by the office, which Bob led from 1961 through 1962. The study defined and quantified the requirements and the estimated costs for needed wastewater facilities, and evaluated the existing water pollution control program. The findings and recommendations were accepted and endorsed by the Governor and the state Legislature. Governor Rockefeller used the study's findings as the basis for initiating and developing his "Pure Waters Program."

Bob's work experience prompted him earn his master's degree in public health from Syracuse University's Maxwell School in 1964. He was both a registered professional engineer and a certified 4A wastewater treatment plant operator. Bob returned to the NYSDOH in 1965 to direct implementation of the Pure Waters Program. The program was overwhelmingly endorsed by voters in the election of 1965 by approval of the Pure Water Bond Issue, which provided funds to support the program. When the startup phase was completed in late 1967, Bob took on a new role as the Executive Director of the Water Resource Center at the SUNY College of Environmental Science and Forestry. Later, he became the Director of the Graduate Program in Environmental Studies and Chair of the Environmental Studies faculty.

Bob also left his mark on the Onondaga Lake community, serving as chair of the county Environmental Management Council, chair of the county Water Quality Management Agency, chair of the Onondaga Lake Advisory Committee and as trustee for the Tripoli Landfill. He was a member of the Skaneateles Town Planning Board, Past President of the Onondaga Citizen's League, County Representative on the Technical Committee of the Onondaga Lake Management Conference, and a past member of the Thursday Morning Roundtable. In 1996, he was named Engineer of the Year by the Central New York Chapter of the New York State Society of Professional Engineers. Bob was a good friend and mentor to Steve Effler, and served on the boards of the Upstate Freshwater Institute and the Onondaga Environmental Institute. Bob was a local celebrity and champion for the clean-up of Onondaga Lake, appearing on the news in several videos about the lake's water quality. In 2006, he published his book, *Water for New York I – The History of the Development and Management of the Waters of New York – 1789 to 1970*.

Outside of work, Bob was active with his church, St. Mary's of the Lake in Skaneateles, where he served as a parish council member, lector and extraordinary minister of holy Communion. His son Peter put it very well at the funeral – Bob had four communities in life – his work community; his family community; his civic community and his church community.

When interviewed in 2004 by Donna Busby, a former student, Bob was asked what he considered his life's best professional work. He responded, "It is two-fold, the one work that had the greatest immediate and long-range impact was my role in developing public policy in water quality management in my role as Director of the Study on Sewage Needs in the Office for Local Government and in implementing these policies as Assistant Commissioner of NYSDOH. This work became the basis for the state's Pure Waters Program and later for much of the 1972 Federal Clean Water Act. The other major work was in educating students in my roles of academic leader and professor, in developing and administering programs and instructing and mentoring individual students in the holistic nature of environmental management. It is not so easily measured and assessed."

Bob mentored many of us. He was a dedicated leader, a valued colleague and a trusted friend who inspired all who crossed his path. Here's to you, Bob! How perfect that we have dedicated another issue of *Clear Waters* to your beloved Onondaga Lake. We hope we have made you proud!

Resources

To advertise or to become a member, contact Rebecca Martin at 315-422-7811 ext. 5 or e-mail her at rebecca@nywea.org.
Visit www.nywea.org for information or see us on Facebook.

Operator Quiz

Test No. 118 – Pumps

The following questions are designed for trainees as they prepare to take the ABC wastewater operator test. It is also designed for existing operators to test their knowledge. Each issue of *Clear Waters* will have more questions from a different section of wastewater treatment. Good luck!

1. This type of pump, commonly used to pump wastewater, may contain open or closed impellers supported on a shaft. When liquid enters this pump, mechanical forces convey flow through the discharge:
   a. Peristaltic
   b. Progressive Cavity
   c. Impeller Driven
   d. Centrifugal

2. This type of pump, commonly used to pump sludges, consists of a screw-shaped rotor which rotates within a rubber-lined stator:
   a. Reciprocating
   b. Peristaltic
   c. Progressive Cavity
   d. Centrifugal

3. This type of positive displacement pump consists of a piston that moves back and forth:
   a. Reciprocating
   b. Inline Screw
   c. Peristaltic
   d. Inline Sump

4. This type of pump injects compressed air into a discharge line, which mixes and raises solids through the line due to sludge density differential:
   a. Diaphragm
   b. Air Lift
   c. Peristaltic
   d. Centrifugal

5. This type of pump uses rollers, sometimes called shoes, to compress a flexible hose. As the shoes rotate around the hose, it fills with material which is squeezed through to the discharge:
   a. Rotary Lobe
   b. Peristaltic
   c. Progressive Cavity
   d. Centrifugal

6. This type of positive displacement pump consists of a reciprocating membrane. Material fills a chamber as the membrane flexes and gets forced out through a discharge check valve:
   a. Rotary Lobe
   b. Sump
   c. Air Lift
   d. Diaphragm

7. This type of pump uses two synchronized rotors rotating against each other to create open cavities between the rotors and pump casing. As flow enters the open spaces it is conveyed in the direction of the moving rotors to the discharge:
   a. Rotary Lobe
   b. Reciprocating
   c. Peristaltic
   d. Centrifugal

8. In this type of centrifugal pump, the motor is sealed and closed-coupled to the pump. This pump typically pushes flow from the bottom of a pit into a discharge line:
   a. Submersible
   b. Axial
   c. Rotary Lobe
   d. Diaphragm

9. This condition is the result of low pressures within a pump, which creates boiling water and vapor bubbles. Damage to the impeller can happen when these vapor bubbles pop:
   a. Air Lock
   b. Water Hammer
   c. Cavitation
   d. Plugging

10. This material can be made from Teflon or graphite and is used to prevent leakage between moving parts of a pump:
    a. Packing
    b. Stuffing
    c. Duct Tape
    d. Oil

Answers on page 62.

For those who have questions concerning operator certification requirements and scheduling, please contact Tanya May Jennings at 315-422-7811 ext. 4, tmj@nywea.org, or visit www.nywea.org/OpCert.

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Clear Waters

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Answers from page 61: 1 D, 2 C, 3 A, 4 B, 5 B, 6 D, 7 A, 8 A, 9 C, 10 A