Fall 2018, Vol. 48, No. 3

New York Water Environment Association, Inc.

ClearWaters

Utility of the Future:

- Intelligent Water Systems
- Workforce Development
- Innovative Re-Use

Also Inside:

- NYC Watershed Meeting Highlights

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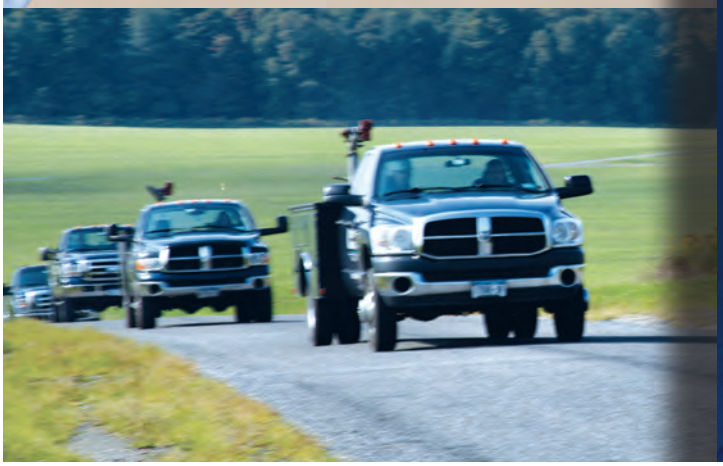

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- Screening

Clarification

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- Activated Sludge
- RBCs
- Trickling Filter
- MBBR
- MBR
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Clear Waters

New York Water Environment Association, Inc.

Cover: Workforce development and succession planning are critical considerations for the Utility of the Future. Featured on this month's cover are two operators at different places in their career paths. On the left, Mr. Rick Monroe, who was educated at Morrisville State College and has worked as an Operator for 32 years. He anticipates retirement in another two to three years. On the right, Mr. Dean Ellsworth, who received his Bachelors of Science in Environmental Biology from the State University of New York College of Environmental Science and Forestry. He has been working as an Operator for about four and a half years, and currently serves as Head Operator. He anticipates another 25 years of service ahead of him. Both operators work with the Onondaga County Department of Water Environment Protection.
Photo: Kerry A. Thurston

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President's Message | Fall 2018

As I reflect on the contents of our Fall issue of *Clear Waters,* I am struck by the leadership that our NYWEA members demonstrate in driving the clean water industry forward. As I have said repeatedly this year, you are all superheroes for waking up every day and doing what is right for the public and planet. This message was reconfirmed to me in a lovely email from one of our members, Richard Muller, who has recently retired from his position as Legislative Affairs Director for New York City Department of Environmental Protection, in which he writes:

> *"I feel privileged, as a late bloomer, to have landed in a job that manifests a basic human value: that everyone is entitled to clean water in all its varieties. I feel grateful every day of my life for the luxuries (speaking in global terms) of a hot shower, a working toilet and paddling on the Hudson."*

What I love most about this sentiment is the understanding of just how challenging it is to complete our mission. It takes a team effort, between rather loosely affiliated team members with different areas of expertise, to reach our goals. These team members all see their own role in the process and gladly accept their mission, regardless of other pressures, to see it through to the end.

The Future of Our Industry

Throughout this Fall issue, the future of our industry is explored. For example, there is a paradigm shift to "smart" utility operation. I'm not sure that "smart" is the right adjective in this case – certainly we have not been running "dumb" utilities! However, this shifting sense of priorities has been coming about for a very long time. I could not be more pleased than to witness this critical juncture in our industry. Science, technology, economics, population dynamics and political will are all coming together to allow for a real change in the way we operate, manage, design and plan the global clean water industry.

Another consideration in creating and maintaining the future of our industry is discussed in several articles about workforce culture. We have all been hearing more about the human factors involved with operations. In fact, NYWEA was a national leader in raising the discussion about succession planning with our seminal white paper on that topic in 2012. The understanding throughout the industry that we need to recruit, manage and connect to people differently to build a vibrant workforce is possibly the single biggest paradigm shift in the industry in our collective memory.

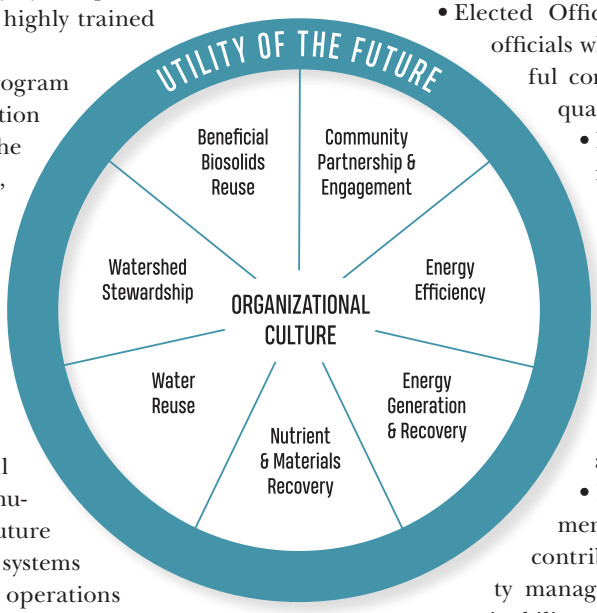
This is also an unusually geographically-dispersed *Clear Waters.* Not only do the articles address topics spanning the State of New York from Buffalo to New York City, but there are also examples from elsewhere in the United States and from as far away as Singapore. In this sense, this issue of *Clear Waters* speaks volumes not only on our membership's broad interest in the industry, but also how we are connected nationally and world-wide in creating a sustainable and smart future for our industry. All combined, the articles in this issue of *Clear Waters* make for a compelling read. I hope you all enjoy it!

Geoffrey G. Baldwin, PE BCEE
NYWEA President

Technology Moves Us Forward

As we celebrate NYWEA's 90th year, we dedicate this issue of *Clear Waters* to the Utility of the Future. Drawing upon the experiences of the past gives us strength to move confidently into the future.

Most of us want to be ahead of the curve on technology and in sync with the latest and greatest gadgets, whether it is our cell phones or assorted digital devices. With technological advances comes improved efficiency, but at the same time these advances require trained, qualified staff. As noted by my mechanic, gone are the days a mechanic could reset a service light; with newer cars a 3-4 credit college course is required to understand the computer systems. This same technological change also affects our water industry. Increasingly, utilities are becoming more automated, transforming into state-of-the-art water resource recovery facilities. At some utilities, valves formerly turned manually by an operator are now activated by computers that are run by highly trained environmental professionals.



In 2016 the *Utility of the Future Today* program was launched by the National Association of Clean Water Agencies (NACWA), the Water Environment Federation (WEF), the Water Research Foundation (WRF) and the WateReuse Association, with input from the U.S. Environmental Protection Agency (USEPA). This program recognizes and celebrates the achievements of water utilities that transform from the traditional wastewater treatment system to a resource recovery center and leader in the overall sustainability and resilience of the communities they serve. The Utility of the Future concept is being promoted as water systems around the world are transforming operations through innovation and technology.

This year, 32 water utilities are being recognized during WEFTEC for transformational work in community engagement, watershed stewardship, and recovery of resources such as water, energy and nutrients.

The Utility of the Future activity areas focus on the key building blocks of this transformation:

- Recovery and new uses of a full range of resources.
- Engagement as a leader in the full water cycle and broader social, economic and environmental sustainability of the community.
- Transformation of the internal utility culture in support of these innovations.
- Engagement in the community and formation of partnerships necessary for success when operating outside of the traditional span of control of the utility.

The *Utility of the Future Today* Recognition Program seeks to reach deeply into the water sector to form and motivate a community of like-minded water utilities engaged in advancing resource efficiency and recovery, developing proactive relationships with stakeholders, and establishing resilient, sustainable and livable communities. Think about moving your utility ahead and participating in this unique program! For more information, visit *https://www.wef.org/utility-of-the-future* or contact *UtilityRecognition@wef.org*.

Closer to Home

For the NYWEA Executive Office, this fall season ushers in good news! We are happy to have Madison Quinn join our staff as our Communications Manager and Scholarship Administrator. See page 57 for more information on Madison.

It is also the time of the year to think about recognizing our hard-working members. NYWEA's Awards Program is one way to pay tribute to those people or utilities that go above and beyond the call of duty in serving our communities. For some members, a NYWEA award is the only recognition they receive during their career! Awards are given in several categories:

- Municipal and Industrial Achievement. These awards recognize industries and municipalities that have committed to effective environmental management at their facilities.
- Elected Officials. These awards recognize elected officials who have made substantial and meaningful contribution to advancing effective water quality programs.
- Beneficial Use of Biosolids. This award recognizes significant contributions in biosolids beneficial use practices.
- Technical Papers. These awards recognize authors who have produced papers or presentations communicating research, engineering, public education or operations work.
- Safety. These awards recognize outstanding safety activities, programs and accomplishments.
- Environmental Science and Management. These awards recognize significant contributions to the fields of water quality management, environmental engineering, or sustainability.
- Wastewater Facility Operations. These awards recognize outstanding contributions and excellence in treatment plant operations and maintenance.
- Public Education. This award recognizes significant accomplishment in promoting awareness and understanding of water environment issues through public education programs.
- Association Service. These awards recognize exceptional contributions by members in support of NYWEA's activities.

Do you know someone who breaks the mold and puts in the extra effort to go beyond what is simply required for their work? Someone who is turning their utility into a *Utility of the Future*? If so, I encourage you to nominate your most deserving, hard-working colleagues by the October 31st deadline. To submit a nomination or learn more about the NYWEA Awards Program, visit NYWEA's website at *www.nywea.org/awards*.

Patricia Cerro-Reehil, pcr@nywea.org

NYC Watershed and Technical Conference

"Water Quality Issues in the NYC Watershed and Beyond"

Over 200 people attended the New York City (NYC) Watershed and Technical Conference held at the Diamond Mills Hotel in Saugerties, New York, September 12, 2018.

NYWEA President Geoff Baldwin welcomes attendees.

Lisa Melville, Chair of the NYWEA Watershed Committee

Kerri Alderisio talks about data review on Cryptosporidium.

Above: Paul Rush, Deputy Commissioner for Water Supply gives the Opening Address.

Above: Jason Siemion, USGS

Left: Karen Moore, NYCDEP

Below: Nick Sadler, NYCDEP

Patrick Palmer, Chief, NYC Watershed Section, NYSDOH

Dr. Lloyd Wilson, Director of the Bureau of Water Supply Protection, NYSDOH

Alfred Theodore Kpodonu, Research Foundation City University of New York

Glen Muckley, Stantec

David Railsback, Schnabel Engineering

Katie Friedman, NYC Department of Parks & Recreation

Anne Seeley, NYCDEP

NYWEA President-Elect Robert Wither

Lisa Melville, Chair of Watershed Committee, and Dave Warne, NYCDEP

Fernando Dongo, C3ND Enviro

Ben Wright, Hazen & Sawyer

Jordan Gass, NYCDEP

Sarah Cwikla, Stantec

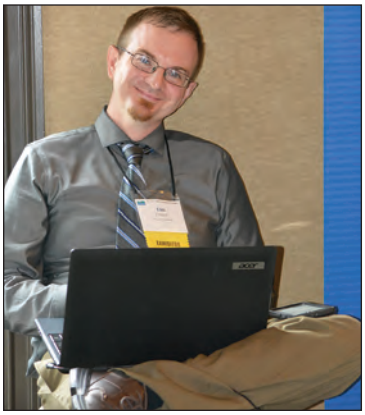
Rakesh Gelda, NYCDEP

Peter Lopez, USEPA Region II

Scott Davis, HDR

Adam Reaves, NYCDEP

Judith Hansen, City of Kingston and Robert Adamski, REA



Tim Clayton, Surpass Chemical

Jillian Cole, Stantec

Will Stradling, Siewert Equipment

Jake Scherer, left, Koester Associates

Sven Nielsen, NYCDEP

Water Views | Fall 2018

Harmful Algal Blooms

The increasing frequency and duration of harmful algal blooms (HABs) threatens drinking water quality and recreation in waterbodies essential to tourism and ecosystem health. HABs, which are not actually algae but a high concentration of cyanobacteria, can produce dangerous toxins that can harm people and animals, close economically important beaches and fisheries, and threaten drinking water supplies.

NYSDEC's HABs Program, in partnership with the Department of Health, local governments, watershed organizations, citizen volunteers, lake associations and academic experts, has worked since 2012 to identify freshwater HABs, communicate public health risks through outreach and education, and undertaken more intensive monitoring and research. New York also has many programs to reduce nutrient pollution; phosphorus and nitrogen are the most controllable factors in the formation of HABs.

To further combat HABs, Governor Cuomo unveiled a $65 million, four-point initiative to identify factors fueling HABs and implement innovative strategies to address their causes. First, the State Water Quality Rapid Response Team identified 12 priority waterbodies for HAB Action Plan development. These priority waterbodies generally are vulnerable to HABs, serve as a source of drinking water and drive tourism, and together represent a wide range of conditions and vulnerabilities. The lessons learned from these waterbodies will be applied to other impacted waterbodies.

Four regional HABs summits were held in February and March, bringing together national experts with steering committees of local stakeholders to identify causes of blooms and develop strategies to reduce bloom frequency. The HAB Action Plans derived from these summits identify potential factors contributing to HABs, and provide recommendations to minimize the frequency, intensity and duration of HABs.

New York has made available nearly $60 million in funding to support implementation projects outlined in the plans and for other waterbodies impacted by HABs. A robust research agenda is underway to learn more about the exact causes and potential treatments of HABs. Multiple pilot projects are ongoing or being formulated, including the use of alum, hydrogen peroxide, and sonic buoys to treat and abate HABs. Several advanced monitoring projects are underway to help further the scientific understanding of the conditions that trigger HABs, with all data being open-sourced. Please review the NYSDEC HABs webpage for grant funding opportunities and a wealth of additional information: *http://www.dec.ny.gov/chemical/113733.html#Funding.*

While HABs continue to occur, outreach is crucial. It can be hard to tell a harmful from a non-harmful algal bloom, so it is best to avoid recreating in or eating fish from discolored water that looks like it might have a bloom. Never drink untreated surface water, even if there is no visible bloom. If you think you see a HAB, report it to NYSDEC at *HABsInfo@dec.ny.gov.* Know it, avoid it, report it!

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

Focus on Safety | Fall 2018

An Open-Heart Policy

Back in the Stone Age, when I was young and green and didn't know anything but the safety regulations, I worked for a utility company. I enjoyed working for them, and they encouraged me on my path to becoming a safety professional. They gave me plenty of training opportunities, including sending me on field visits to observe the various work crews and identify their safety "discrepancies." I had my shiny credentials and my observation pad, and I knew how to use them. We had a set quota of observations for each month. I was out there in the rain, snow and storms alongside the line crews, gas crews, tree crews and facility maintenance crews.

At the beginning of my career, I was the typical safety cop with the ticket pad. I relied on the rules and regulations. Compliance or non-compliance, behind the line or over the line: you can't argue with the rules. I relied on this clear-cut, black-and-white approach because I was afraid. I was young, new to the profession and, frankly, I was a girl in a boy's industry. I didn't have 20 years of experience like my colleagues; I had no "street cred". All I had was the rule book. And I was scared that I would miss something, scared that I would be found out, scared that I would be stared down into a withering pile of dust by someone who could see me hiding behind my book. Eventually someone did see me. Fortunately, it was a peach of a man who, having observed me over time, had the grace to help. His words to me were eye-opening: "Hon, if you don't care about others, it doesn't mean diddly."

I had it backwards! There I was, essentially focusing on myself, all Ivy-Leagued and certified, and it turns out I didn't know diddly. I knew that I had to give it up, let go of the book and become vulnerable. This didn't happen overnight, but I made the effort. The guys on the work crews noticed. For them, I started to become the Safety Lady.

Many years later, I still know the regulations and the reasons they are in place. However, the regulations do not mean anything unless my people know that I care about them. The organizational management gurus may call this "engagement." I see every single person hired onto my company, know all their names and their backgrounds. I look people in the eye and I am not skittish about laying it on the line. As a result, they are comfortable asking my advice and taking my suggestions. They also understand and respect that I have certain responsibilities to the needs of the business. I don't have an open-door policy where I wait for them to come to me. I have an open-heart policy; they know I have their backs.

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

The Shift to Smart Utility

by Michael Karl and Alan Ridgeway

The rise of the Internet of Things (IoT), and subsequently 'smart' systems, is revolutionizing the way we live and work. Nearly $6 trillion will be spent on IoT solutions over the next five years and much of that adoption will come from the government sector *(Meola 2016)*. These solutions are gaining momentum because of their ability to reduce operating costs, increase efficiency and justify business decisions. Increasingly, municipalities are adopting advancements in information technology like Smart Utility to address critical issues like limited water resources, growing populations and aging infrastructure.

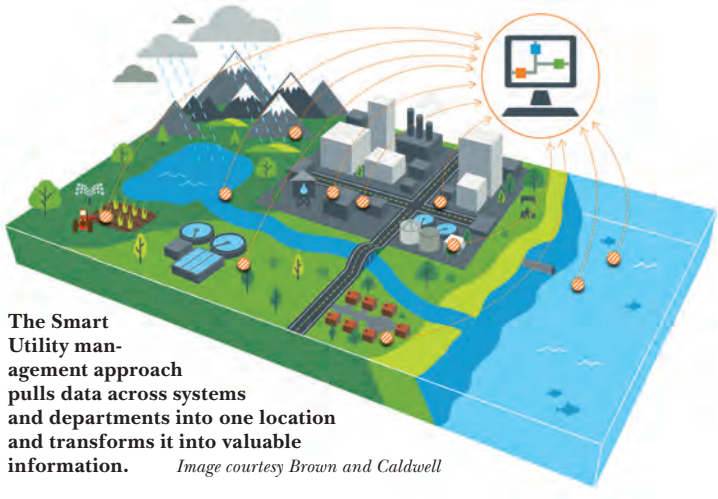
Smart Utility is a new approach to utility management that pulls data across systems and departments into one location and transforms it into valuable information, knowledge and wisdom. Low-cost sensors are enabling water and wastewater utilities to connect more equipment and devices throughout their water systems to have a broader understanding of their operations. This holistic approach is enabling utilities to realize benefits across their organizations. Those include:

- Improving water quality by detecting contaminants.
- Projecting infrastructure and equipment replacement through enhanced asset monitoring.
- Increasing situational awareness to respond to emergencies faster.
- Improving system efficiency through advanced asset management practices.
- Conserving resources through increased monitoring.

Market research suggests that municipalities that install smart water networks discover that leaking equipment is responsible for much of their unaccounted water. Utilities are losing anywhere from 10 percent to 30 percent of their water to leaks *(Smart Cities Council 2015)*. This type of data can be turned into valuable information by applying context, such as standards or goals, to the water loss data collected by connected sensors. Operators can then use this knowledge to detect leaks early and repair faulty equipment quickly to account for more water. By layering this knowledge with other tools, such as predictive analytics, utilities gain the wisdom they need to make the right future investments.

Jordan Valley Water Conservancy District (District), one of Utah's largest water districts, is an early adopter of this approach. "Utilizing smart utility concepts will help us bridge the gap between all aspects of our system, from water quality to source protection and energy use," said Todd Marti, former Project Manager. By providing greater transparency into its water system, the District expects to empower staff, justify decisions and validate future investments.

By using real-time business intelligence techniques, utilities like the District, can better organize and understand the data they collect, as well as capitalize on new and enhanced information through Smart Utility equipment and sensors like Automatic Meter Readers. It is fairly common for utilities to ignore the majority of the data they collect because they do not have the ability to analyze or apply it in an impactful way. Advancements in information technology are now making it possible to equip staff with the knowledge they need to proactively make decisions, reduce the risk of equipment failure and optimize performance. Initial pilot studies have also shown that utilities could save as much as 12 percent in operational costs by implementing Smart Utility concepts that combine Supervisory Control and Data Acquisition and Advanced Metering Infrastructure to detect inefficiencies.



The Smart Utility management approach pulls data across systems and departments into one location and transforms it into valuable information. *Image courtesy Brown and Caldwell*

While Smart Utility is helping utilities gain clarity and realize benefits across the organization, there are often financial constraints or other concerns, such as cybersecurity threats, that prevent early adoption. To help alleviate the financial investment, partnerships are forming to share infrastructure and data to avoid duplicating equipment and unnecessary costs. State agencies like the New Jersey Board of Public Utilities are also addressing cybersecurity concerns by adopting unprecedented requirements for water and wastewater utilities. These include developing a cybersecurity program, conducting risk assessments and providing training programs to bolster security *(New Jersey Board of Public Utilities 2016)*.

These creative solutions are some of the many approaches to reducing cost and risk to realize the benefits of Smart Utility and discover the best ways to allocate funding. Increasingly, utilities like the District are capitalizing on the abundance of data available and turning it into wisdom to achieve a sustainable, efficient and resilient water supply. This change in technology is driving a powerful cycle of better data, better systems and better decision-making.

Michael Karl is Brown and Caldwell's National Smart Utility Technology Leader, responsible for managing and overseeing the firm's portfolio of smart technology projects. He has more than 18 years experience in information and operational technology systems, including SCADA, Asset Management, and GIS applications; in addition, he is a commissioner and licensed water system operator. He may be reached at mkarl@brwncald.com. Alan Ridgeway is Brown and Caldwell's National Utility Performance Leader. He has more than 25 years of experience in utility consulting, operations, and program and project management within the water and wastewater engineering and environmental services industry. He may be reached at aridgeway@brwncald.com.

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Resources Abound for Understanding Intelligent Water Systems

by Corey Williams and Lisa McFadden

Intelligent water systems (IWS) are built to link together sensors, control systems, information management and communications systems. They emphasize the water sector's opportunity to take advantage of advanced technologies and dramatically shift management decision-making.

While there are varying ideas of what an IWS may be, there is not one singular definition. Some see the concept as a small piece to help analyze and process data, both historical and real-time; others see this integration as an opportunity to overhaul their entire decision-making or performance management approach.

How far each utility or facility chooses to take the IWS concept will vary, but many water sector organizations have produced resources to help guide these choices.

Key Mechanisms

The Water Science & Engineering Center within the Water Environment Federation (WEF) issued a technical report that identifies the key mechanisms needed for utilities to start and run a successful intelligent water systems program. Titled, ***Intelligent Water Systems: The Path to a Smart Utility,*** the report explores the following ten topics:

- Data prioritization.
- Data governance.
- Data capture.
- Data validation.
- Data processing, storage and access.
- Data integration.
- Data analytics.
- Business intelligence and decision support.
- Knowledge sharing.
- Performance reporting and visualization.

Data prioritization

First and foremost, utilities must decide what data is needed and how the data collected will fit into the ultimate strategy and goal of the utility. Data should not be collected for the sake of collection; collecting data takes time, staff and money. The right data, at the right time, needs to be captured. This critical data must be accurate, complete, and aligned with business and operational management requirements.

Data governance

Prior to data capture, system managers need to formulate a data governance approach. This includes identifying data stewardship, storage and access rights, and archiving and deletion protocols. For example, by deciding these responsibilities ahead of time, data processing issues can be ironed out. Developing a data management and governance plan also can help reveal gaps in the system.

Data capture

This aspect is probably the most notable component of the process. With all the new and emerging technologies, utilities have vast options for how to capture data and how much to capture. With many new technologies promoting real-time data capture, it is important to note the difference between *real-time data* and *data frequency*. While real-time data deals with how quickly the user receives measured data, data frequency refers to how often the data is gathered.

Data validation

With speed and an abundance of tool choices, data validation becomes an important component. While collecting data is easy, the goal is to be confident in the quality of the data being received.

Data processing, storage and access

Organize your data! Historically, data organization is sometimes forgotten. With newer platforms and easier accessibility, the storage, query and transfer of data is now more manageable than ever. Data organization includes the formulation and upkeep of database table structures that fit the needs for analytics (as distinct from the database table structures for transaction processing).

Data integration

By prioritizing and organizing data, users can more easily integrate this data into existing systems and processes throughout the utility and networks. Remembering the prioritization and overall purpose of the data can help ensure they are being applied in a useful way.

Data analytics

With Big Data come big opportunities. By incorporating data analytics, utilities can transform what has been collected into information. Utilities can choose many types of data analytics tools to use. The ultimate performance goal or outcome helps choose the right platform or tools to perform the analytics.

Business intelligence and decision support

With the information provided, utility personnel can make operational and business decisions. By incorporating the information provided from the data analytics into modeling, optimization and even predictive analysis tools, utilities can look at many different scenarios and find the best solution. By utilizing IWS, water sector agencies can get a big picture view, with the goal of making an informed decision. These decision support tools are not just for big capital improvement projects (CIP), but also can be applied to real-time situations and scenarios, through dashboards and cloud-based operations.

Knowledge sharing

Once useful information has been attained, it can be integrated throughout the utility's system and utilized in cloud-based systems, allowing the information to be centralized and used across all utility functional groups. By sharing information throughout a utility, data silos fall away. This enables all stakeholders to incorporate the same information into their decision-making processes. Further, data sharing can encourage its use for beneficial purposes that might not have been intended originally.

Performance reporting and visualization

IWS is not always just for predictive and decision-making tools, it also can show how efficiently a water sector agency is operating. Coupling tools for performance data and visualization – such as

interactive mapping or GIS, dashboards or chart pop-ups – can provide useful insight into areas of need and improvement. Once performance gaps are identified via these visualization methods, water sector agencies can use optimization tools to improve operations, reduce energy usage, lower costs, or develop adaptive master planning and CIP. IWS provides the data and information that utilities need to take a step back and look at where improvements may be needed.

IWS Drivers

Similar to the concepts identified by WEF, the National Association of Clean Water Agencies (NACWA; Washington, D.C.) identified several IWS drivers. NACWA published these findings in the white paper, *Envisioning the Digital Utility of the Future*. The paper lists eight drivers for utilities, which include:

- Reduce operational costs.
- Manage and mitigate risks.
- Enhance the customer experience.
- Improve financial execution.
- Optimize asset performance and uncover hidden value.
- Leverage existing communications and computing platforms.
- Maximize the engagement and efficiency of employees.
- Integrate water quality, policy and performance.

Wanted Results and Simple Framework

At the 2018 American Water Works Association (AWWA)/WEF Utility Management Conference (UMC), participants in the workshop *Demystifying the "SMART" Utility* shared their opinions on where IWS can help most. Fully two-thirds of the attendees ***(Figure 1)*** believed cost reduction and asset optimization to be the most important result of IWS implementation.

The Smart Water Networks Forum (SWAN) is a non-profit organization that seeks to be the leading global hub for the smart water sector. This group, a WEF partner, seeks to accelerate the awareness and adoption of data-driven technologies in water and wastewater networks worldwide. To help communicate the critical components of IWS, SWAN has developed a five-level framework to clearly define the components.

Figure 1. Most desired benefits of intelligent water systems, as voted by participants in the workshop, *Demystifying the "SMART" Utility*, at the 2018 AWWA/WEF Utility Management Conference.
Corey Williams and Lisa McFadden

- The *Physical* level comes first. This includes components such as its pipes, pumps, valves, reservoirs and tanks. As physical water infrastructure only, without data collection or analysis, this layer is often not considered "smart."
- The *Sensing and Control* level includes the initial components enabling IWS. These include sensors, meters, pressure-reducing valves (PRV) and automatic meter reading (AMR) and advanced metering infrastructure (AMI).
- The *Collection and Communication* level are technologies that enable storage and transmission of data. Examples include fixed cable network, radio, cellular and Wi-Fi.
- Supervisory control and data acquisition (SCADA) system, cybersecurity, and customer information systems (CIS) and geographic information system (GIS) are prime examples of the *Data Management and Display* level.
- *Data Fusion and Analysis* is the ultimate IWS level. These technologies perform data analytics and modeling to help operators by assessing effects of changes, responding to them in real-time, optimizing operations and planning for enhanced decision-making.

Based on these five levels, the same UMC workshop participants who identified cost savings and asset optimization as primary drivers claimed that the largest resource gap existed at the *Data Fusion and Analysis* and *Collection and Communications* levels ***(Figure 2)***. The implications are that, in general, water and wastewater utilities appear to have SCADA (level 4) for data management and display and instrumentation and sensors (level 2) in place. However, the need to communicate the data from the sensors to management platforms and the lack of ability to perform analysis for enhanced decision-making are the areas of greatest needs to take full advantage of IWS.

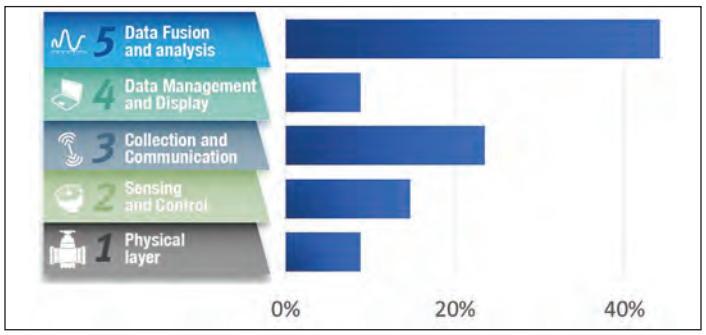

Figure 2. Largest resource needs for intelligent water system implementation, as identified by participants in the workshop, *Demystifying the "SMART" Utility*, at the 2018 AWWA/WEF Utility Management Conference.
Corey Williams and Lisa McFadden

Changing Workforce and Skills

With the implementation of IWS, utilities will start to see a rise in the need for some new skill sets, including data science and data engineering. While current utility personnel may hone some of these skills, these are things that the utility engineer of the future will need to possess. It is important to make students aware of resources that exist outside the "typical" water engineering realm, and that is evident in the large mix of water personnel we are starting to see today.

Corey Williams is CEO of Optimatics (Overland Park, Kan.) and chair of the Interoperability Task Force for WEF's Intelligent Water Technology Committee. Lisa McFadden is director of Integrated Technical Programs and associate director of the Water Science & Engineering Center at the Water Environment Federation (Alexandria, Va.).

Energy savings pay for the mixing project

Floating wastewater mixers can pay for themselves… fast!

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Buffalo's Smart Sewers

by Rosaleen B. Nogle

As with many rustbelt cities throughout the Great Lakes region, the City of Buffalo, New York, reached its peak in population by the middle of the twentieth century and has experienced a steady decline since. In recent years, the city's population has begun to stabilize at a level of less than half its peak. While this decline has created a multitude of problems for the city – including a shrinking tax base and a vast trove of abandoned buildings – it has also created opportunities.

The vast majority of the wastewater collection system in the City of Buffalo was constructed 40 to 50 years before the construction of the Bird Island Water Resource Recovery Facility (WRRF) in 1935. As such, the sewers were originally constructed to discharge to the Buffalo River, Scajaquada Creek, Black Rock Canal, Niagara River, or any one of many canals that once filled the Buffalo waterfront. When interceptor sewers were installed in the late 1930s to connect these existing sewers to the newly constructed WRRF, they were sized to accommodate only sanitary flows and limited wet weather flows based on population estimates that were expected to grow continuously into the 1980s.

The collection system was specifically designed to prevent basement backups or the washing out of the WRRF by allowing combined sewage to overflow through the old outfalls into the waterways. Improvements have been made in the intervening decades to reduce overflows, including: the separation of some of the storm sewers; a floatable control facility; a 40-foot deep 7.5-foot wide tunnel, which runs across the city; and numerous weir adjustments. Despite these improvements, the system has remained fundamentally the same.

On March 18, 2014, the Buffalo Sewer Authority received approval from the United States Environmental Protection Agency and New York State Department of Environmental Conservation for a 20-year, $380 million Combined Sewer Overflow (CSO) Long-Term Control Plan (LTCP). This plan is designed to significantly reduce the number of overflow events and improve water quality in the Niagara River and its tributaries. As part of the LTCP, 16 sites were designated for the installation of Real-Time Control (RTC) structures ***(Figure 1)***.

RTCs use mechanical gates or valves to detain flows within the existing collection system. These gates or valves are controlled by upstream and downstream flow monitoring devices and computer logic. By detaining the combined sewage in the system upstream until the system downstream has capacity to carry the flows to the WRRF, the RTC systems prevent CSOs from occurring. While the collection system in a city with a growing population runs near maximum capacity most of the time, in Buffalo the collection system runs at one-sixth or less of its capacity during dry weather. This means that there is significant capacity available during wet weather to use for storage, particularly in the larger trunk sewers.

Since 2014, three RTCs have been fully constructed and activated with another currently under construction. Several more RTCs are in various stages of design and bidding. The first two structures – one located on Bird Avenue on the city's West Side and the other on Lang Avenue on the city's East Side – are fundamentally very similar. Both have large gates which detain flows within the combined system and then release the flow once there is downstream capacity. The third structure, located on Smith Street, is significantly different. This structure is in an overflow line downstream of several existing weirs. Before the structure was installed, all flows in this line discharged directly to the Buffalo River. With the installation of a large weir within this line and a valved diversion pipe connected to an interceptor pipe, these overflows are detained and then

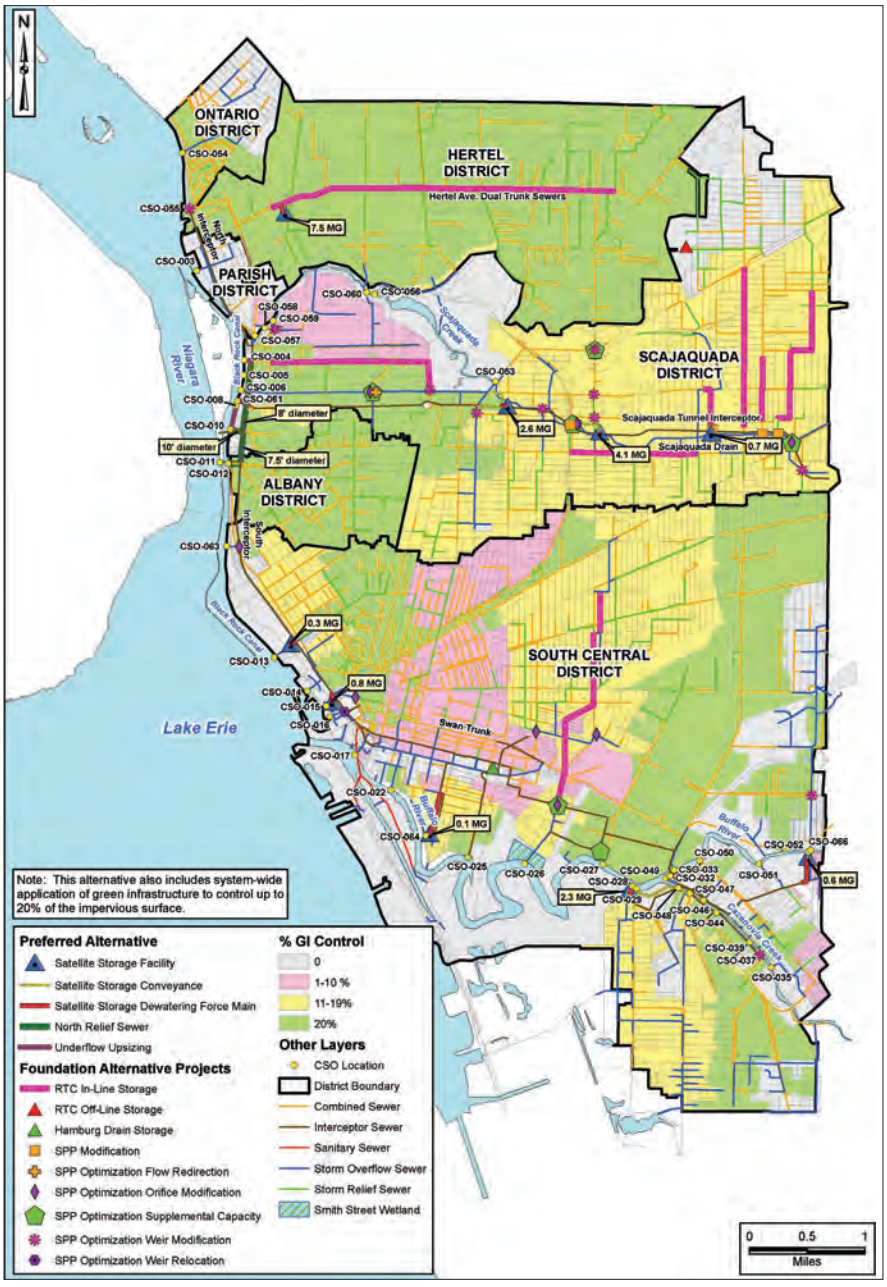

Figure 1. Long-term control plan (LTCP) overview map for Buffalo, New York. *Arcadis*

returned to the combined collection system and treated at the Bird Island WRRF.

Bird Avenue RTC

Construction of the Bird Avenue RTC began in the summer of 2014. The RTC was installed in a three-course brick, egg-shaped sewer that was constructed in 1880, with an interior height of 9 feet 9 inches and an interior width of 6 feet 6 inches ***(Figure 2)***.

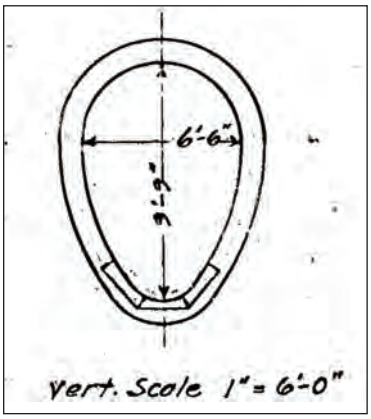

Figure 2. Cross-section diagram of Bird Avenue Sewer. *Buffalo Sewer Authority*

The 1880 sewer on Bird Avenue was designed to accept combined sewage flows from across the middle section of the City of Buffalo with multiple points of overflow to Scajaquada Creek. After 1925 these flows were rerouted to the Scajaquada Drain, which replaced Scajaquada Creek on the east side of Buffalo. Final discharges prior to the 1930s went directly to the Niagara River. After the 1930s, most of the flows from this sewer were diverted to the Northern Interceptor for treatment at the newly constructed Bird Island WRRF. In the 1960s a significant portion of the upstream flow received by this sewer was diverted by the construction of the NY-33 Kensington Expressway. As a result, during dry weather the sewer carries half of the flow it was originally designed to carry; it was therefore a prime candidate for an RTC ***(Figure 3)***.

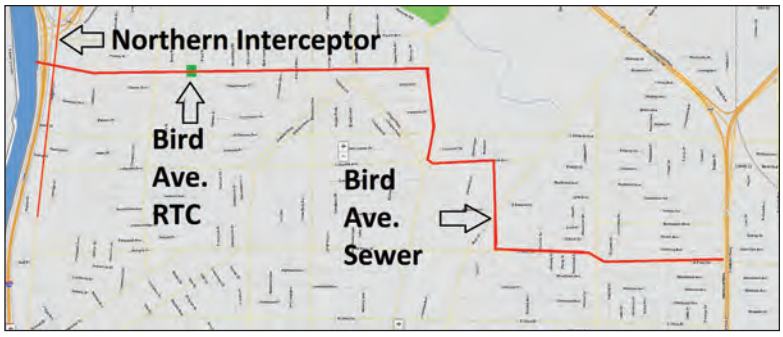

Figure 3. Bird Avenue sewer and RTC location. *Buffalo Sewer Authority*

The construction of the Bird Avenue RTC involved the removal of over 20 feet of the pipe. Flows were temporarily rerouted through two PVC pipes. Two large concrete boxes were then installed, with the inner box serving as a dry weather flow channel and weir walls, while the outer box serves as overflow capacity ***(Figure 4)***. At the discharge end of the interior box, two gates were installed to regulate flows. During construction there were some neighborhood complaints due to the noise, unsightliness and smells associated with constructing this structure in the middle of a street in a residential neighborhood. Since its construction, however, there have been no complaints from the neighborhood linked to the structure and it has routinely activated during even small storms to minimize overflows.

Figure 4. Construction of the Bird Avenue RTC underway. *GHD*

Lang Avenue RTC

The Lang Avenue RTC was constructed as part of the same contract as that of the Bird Avenue RTC. As such, construction of the two RTCs was conducted simultaneously by the same general contractor, Mark Cerrone, Inc., using two separate work crews. Similar to the Bird Avenue RTC, the Lang Avenue RTC involved the construction of two gates within an interior weir structure with an outer overflow containment structure built around the weir.

The pipe involved was originally constructed in the 1960s primarily for drainage of NY-33 Kensington Expressway. At the location of the RTC, the sewer is composed of reinforced concrete with a circular cross-section with an interior diameter of 8 feet 6 inches ***(Figure 5)***.

While this sewer primarily carries stormwater from NY-33 Kensington Expressway, it also has numerous combined and sanitary connections. During dry weather this sewer discharges to the Scajaquada Tunnel, a 90-inch diameter reinforced concrete sewer that was constructed in the late 1970s to convey flows, which had previously discharged to the Scajaquada Drain, to the Bird Island WRRF. During wet weather, overflows from the Lang Avenue sewer still discharge to the Scajaquada Drain ***(Figure 6)***.

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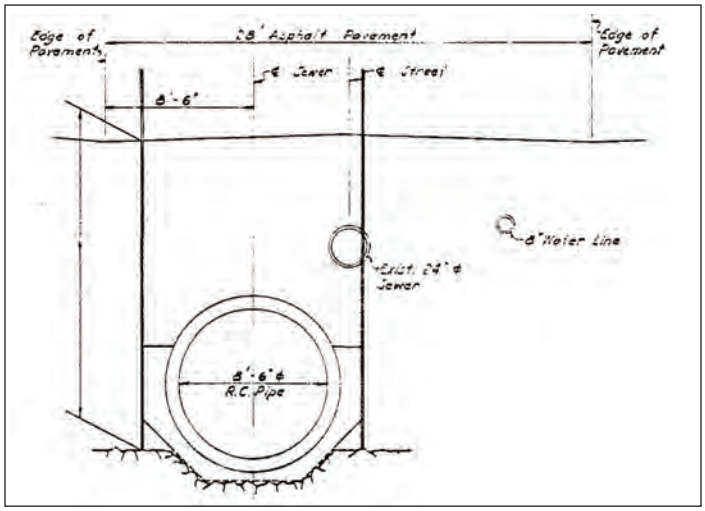

Figure 5. Lang Avenue sewer cross-section diagram. *Buffalo Sewer Authority*

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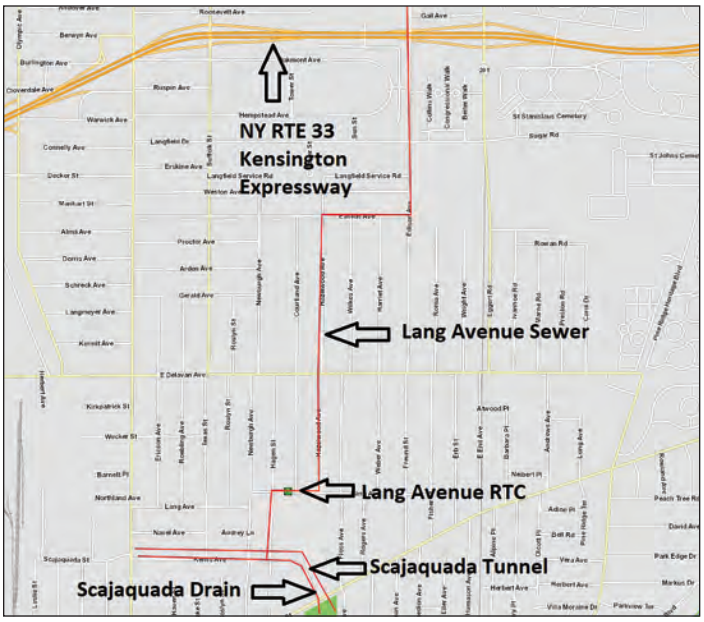

Figure 6. Location of the Lang Avenue sewer and RTC.
Buffalo Sewer Authority

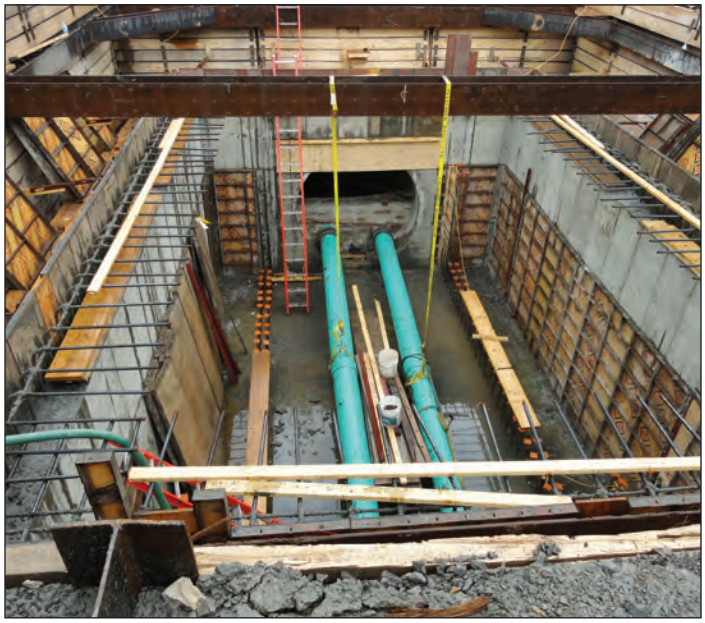

Figure 7. Lang Avenue RTC under construction, shown here after a recent inundation. *GHD*

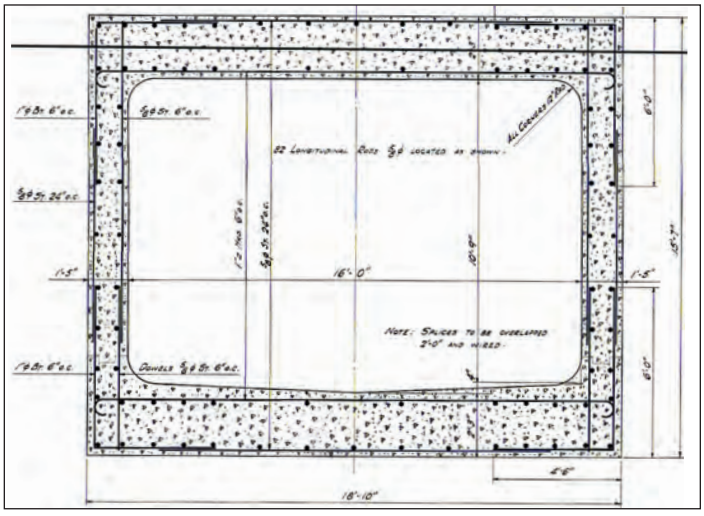

Figure 8. Cross-section of the Smith Street Drain. *Buffalo Sewer Authority*

Much of the area tributary to the Lang Avenue sewer never reached the population density forecasted in the 1960s and has since experienced a significant decline both in population and housing stock. Additionally, because this sewer is designed to convey primarily stormwater flows, it is designed to convey a large plug flow. But without the plug flow, the sewer has excess capacity.

As with the Bird Avenue sewer, two PVC bypass pipes were installed in the Lang Avenue sewer throughout construction during dry weather flows. During storms, the capacity of these two pipes was exceeded and the trench flooded out. The contractor then pumped down the trench and continued work ***(Figure 7)***.

Smith Street RTC

The construction of the Smith Street RTC started in the fall of 2016. Whereas the Bird Avenue RTC and Lang Avenue RTC were constructed in combined sewers upstream of overflow weirs, this RTC was constructed in a 16-foot by 10-foot 9-inch storm overflow box culvert, downstream from overflow weirs, known as the Smith Street Drain ***(Figure 8)***.

Whereas the two previous RTCs were located in the Scajaquada Creek/Drain drainage basin, the Smith Street Drain is located in the Buffalo River drainage basin in the south-central district of the city. The Smith Street Drain is hydraulically connected to the Buffalo River. As such the weirs upstream serve a dual purpose of both keeping combined sewers from overflowing into the Buffalo River and holding back the Buffalo River within the drain to create capacity for storage. This site also posed some construction challenges as it is located next to an off-ramp of the interstate highway I-190 ***(Figure 9)***.

While noise and other aesthetics were concerns during construction of the two RTCs in residential neighborhoods, the primary concerns surrounding construction of Smith Street RTC were traffic control and minimizing vibration of the I-190 overpass during pile driving. Additionally, because flows were diverted to a 30-inch sewer that is connected to the South Interceptor on the far side of the I-190, boring had to be conducted underneath this very active roadway.

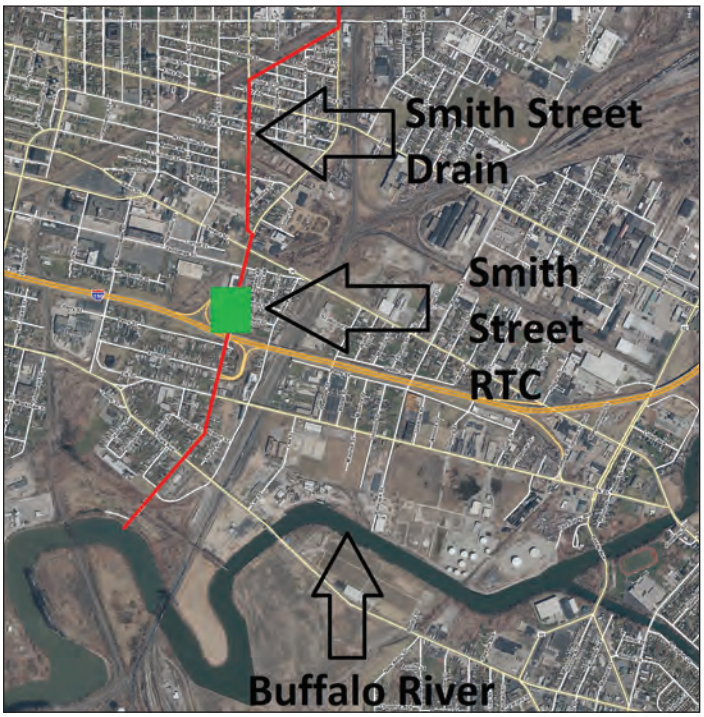

Figure 9. Location of the Smith Street sewer and RTC.
Buffalo Sewer Authority

Due to the interconnection between the Smith Street Drain and the Buffalo River, divers were required to construct the weir wall and to bore the hole through the drain for the connection to the 30-inch sewer. While pumps were able to keep the work relatively dry during much of the construction ***(Figure 10)***, water levels did exceed the capacity of the pumps at times, particularly when the Buffalo River was forced to flow backwards by seiche events on Lake Erie.

For the Smith Street RTC, a very large valve pit was required ***(Figure 11)*** in addition to the structure itself, to accommodate both a primary and redundant valve. Designing and constructing access to the valves and flushing points further complicated this construction beyond the scope of the first two RTCs.

Smart Flow Control

After the completion of construction and over the course of several months, computer logic was calibrated to assure the maximized usage of the RTCs. Rather than simply opening and closing gates and valves, the gates and valves are carefully calibrated to allow through the maximum flow possible to take advantage of downstream capacity while also detaining flows within the upstream capacity. So, the gates will close slowly as downstream levels rise and then modulate throughout a storm as the latent flows travel through the system. The gates will fully open only when the downstream system returns to full dry weather capacity.

By utilizing the capacity that already exists within the Buffalo Sewer system, the RTCs have saved millions of dollars in construction costs that would have been necessary for offline storage facilities. Through using only gates or valves to function, operational costs for pumps and maintenance of larger facilities have also been saved. Additionally, the Buffalo Sewer Authority has not had to purchase additional land or install new basins in neighborhoods, minimizing the disruption of the urban landscape and neighborhood life long-term. As the network expands, some of the future RTCs will be placed in series with these first three and other RTCs, which will in turn require dependent logic.

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Figure 10. Smith Street RTC under construction. *GHD and J.M. Davidson*

Figure 11: Smith Street RTC large valve pit under construction. *GHD and J.M. Davidson*

CSO Long Term Control Plans: Improving New York City's Waterways

by Keith Mahoney, Donald Walker, Aimee Boulet, Peter Young and Anni Luck

LTCP Program Overview

On March 8, 2012, the New York State Department of Environmental Conservation (NYSDEC) and New York City Department of Environmental Protection (NYCDEP) signed an agreement to reduce combined sewer overflows (CSOs) using a hybrid green and gray infrastructure approach. As part of the agreement, NYCDEP committed to develop 10 waterbody-specific Long-Term Control Plans (LTCPs) plus one citywide LTCP to reduce CSOs and improve water quality in New York City's waterbodies and waterways ***(Table 1)***. The goal of each LTCP is to identify appropriate CSO controls necessary to achieve waterbody-specific water-quality standards, consistent with the federal CSO Policy and the water-quality goals of the Clean Water Act.

Table 1. LTCP Planning Process

LTCPs Approved
• Alley Creek/Little Neck Bay
• Bronx River
• Flushing Bay
• Flushing Creek
• Gowanus Canal
• Hutchinson River
• Westchester Creek
• Coney Island Creek
• Newtown Creek
LTCPs under NYSDEC Review
• Jamaica Bay & Tributaries
Pending LTCPs
• Citywide/Open Waters

The agreement builds upon past investments and commitments including approximately $2.6 billion in previously committed gray infrastructure along with a commitment of an additional $1.5 billion in green infrastructure. This total of $4.1 billion in green and gray CSO commitments are included as the baseline condition in each of the waterbody-specific LTCPs. Additional CSO controls beyond the baseline are also evaluated within each LTCP and a recommended plan is developed based on public input, cost-effectiveness and water-quality benefits ***(Figure 1)***.

To date, NYCDEP has submitted 10 LTCPs of which nine have been approved and the final LTCP will be submitted in the near future. Each LTCP includes:

- Detailed waterbody/watershed characterization.
- Progress of committed CSO green and gray infrastructure.
- Gap analysis to assess the highest level of attainment with 100 percent CSO control and contribution of other pollutant sources to non-attainment of water-quality standards.
- Evaluation of alternatives.
- Recommended LTCP plan and implementation schedules.
- Robust public participation program.

Waterbody/Watershed Characterization

A thorough waterbody/watershed characterization is conducted for each waterbody-specific LTCP, in which available data sets including land use, zoning, sewer system, population projections, satellite flyover impervious imagery and NYCDEP harbor survey monitoring data are compiled. These data sets are then supplemented with robust programs for ambient water-quality sampling and landside flow monitoring and sampling.

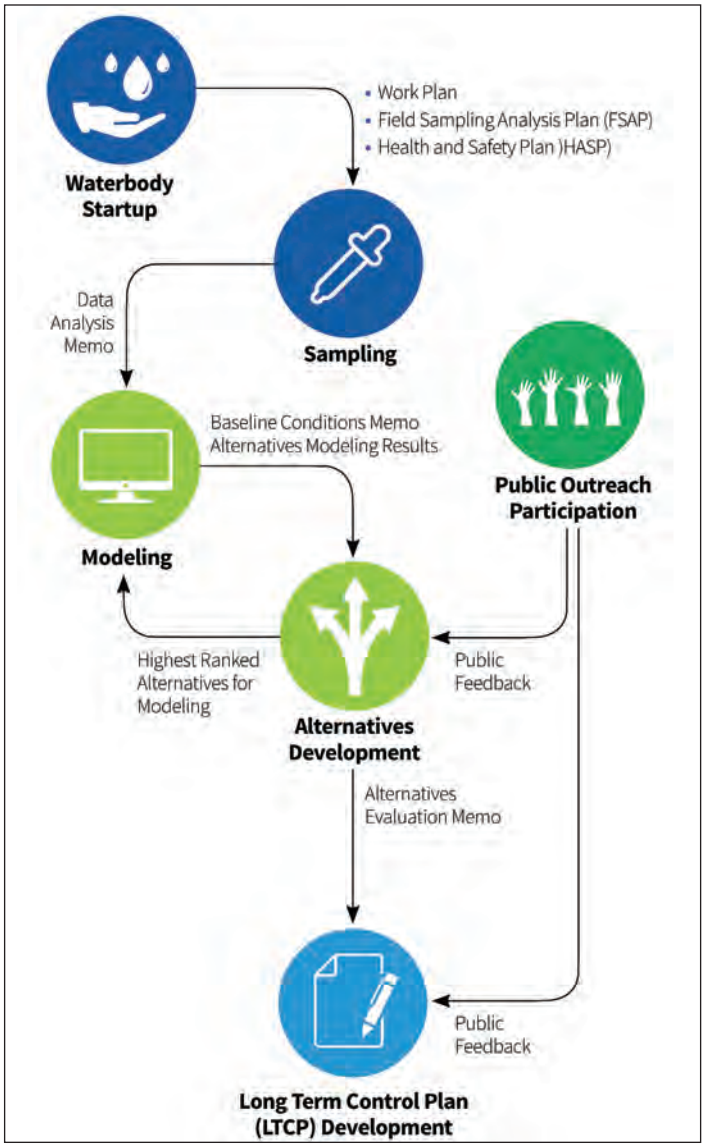

Figure 1. LTCP Planning Process *NYCDEP*

Ambient water-quality sampling (fecal coliform, *Enterococcus*, dissolved oxygen, temperature, conductivity and salinity) is conducted within 24 hours of a confirmed CSO event. Samples are collected twice a day for four consecutive days. This water quality data, in conjunction with the harbor survey data, is used to assess water-quality conditions and to calibrate/validate the water-quality models. Sampling of receiving waters has been completed across all 11 LTCPs ***(Table 2)***.

Landside flow monitoring is conducted for several months – but in some cases over a year – at major CSO and select municipal separate stormwater sewer system (MS4) outfalls. Water-quality sampling (fecal coliform, *Enterococcus* and, in some cases, biochemical oxygen demand, settleable solids and nitrogen) is also conducted during wet-weather events to help quantify the pollutant loadings associated with some of these outfall discharges. About three to five wet-weather events are targeted with a minimum of five samples col-

lected during each event. Flow monitoring and sampling of outfalls has been completed across all 11 LTCPs ***(Table 3)***.

Table 2. Ambient Sampling

LTCP	No. of Stations	No. of Days
Alley Creek	14	12
Bronx River	9	15
Coney Island Creek	7	2
Flushing Bay	12	20
Flushing Creek	6	20
Gowanus Canal	11	15
Hutchinson River	9	16
Jamaica Bay	12	10
Newtown Creek	14	25
Citywide/Open Waters	47	33
Westchester Creek	4	8

Table 3. Flow Metering

LTCP	No. of Flow Metered Outfalls	No. of Water Quality Sampled Outfalls
Alley Creek	4	5
Bronx River	4	4
Coney Island Creek	5	5
Flushing Bay	2	2
Flushing Creek	2	2
Gowanus Canal	2	3
Hutchinson River	6	6
Jamaica Bay	5	7
Newtown Creek	4	6
Citywide/Open Waters	14	18
Westchester Creek	1	2

The above data, in conjunction with field inspections and independent third-party reviews, are used to modify, calibrate and validate various models under the LTCP program:

- Landside Model incorporates available and field-verified sewer data, impervious data, past and current flow monitoring data, and gauge-adjusted radar rainfall (GARR) data to calibrate and validate the InfoWorks CS10 Model, which is currently the standardized platform for the LTCP program.
- Row-Column AESOP (RCA) Water Quality Model is calibrated and/or validated based on landside loading data in conjunction with water quality data (bacteria and dissolved oxygen) as well as collected CSO and stormwater concentrations and any other background loadings.
- Estuarine, Coastal, & Ocean Model (ECOM), which is used for hydrodynamic calculations, is calibrated and/or validated based on a portion of the ambient water quality data (conductivity, salinity, temperature, tide gauges and Acoustic Doppler Current Profiler).

The above calibrated/validated models are then used to perform a Gap Analysis to quantify highest attainable use and loadings contributing to non-attainment. These models are also used for developing knee-of-the-curve analyses to compare alternatives against CSO volume reductions and water-quality improvements.

Evaluation of Alternatives

The process for developing the recommended plans for the LTCPs includes:

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- Developing a "toolbox" of CSO control technologies ***(Figure 2)***.
- Conducting a series of screening steps to prioritize feasible alternatives.
- Conducting workshops with NYCDEP staff and public stakeholders.
- Assessing cost/performance and cost/attainment relationships.
- Evaluating construction impacts and siting issues.

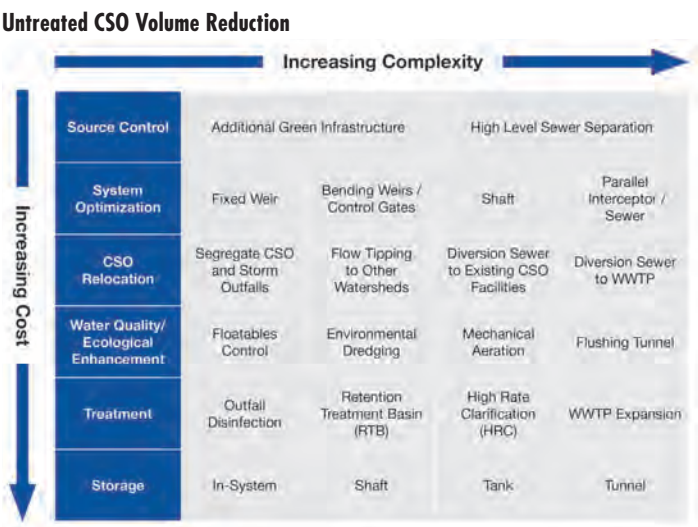

Figure 2. Sample CSO Control Toolbox *NYCDEP*

LTCP Recommended Plans

The recommended plans from the NYSDEC-approved LTCPs and Gowanus Canal Superfund program include a range of CSO control technologies with an estimated escalated cost of $4.9 billion with one LTCP still pending. The recommended LTCP projects are summarized below:

- **Alley Creek & Flushing Creek:** Adding disinfection and dechlorination to the effluent of existing CSO storage facilities and providing floatables control.
- **Hutchinson River:** Providing floatables control, constructing a new extended outfall and providing disinfection and dechlorination at the new outfall.
- **Bronx River:** Providing conveyance relief pipes and additional floatables control ***(Figure 3)***.
- **Flushing Bay:** Constructing a 25 million-gallon CSO storage tunnel.
- **Newtown Creek:** Constructing a 40 million-gallon CSO storage tunnel and increasing capacity of the Borden Avenue Pump Station.
- **Gowanus Canal Superfund:** Constructing two CSO storage tanks (4 million-gallon and 8 million-gallon).
- **Jamaica Bay & Tributaries:** Providing an additional 379 greened acres beyond current green infrastructure commitments; 7 acres of ribbed mussel colony creation; 50,000 cubic yards of environmental dredging; and 50 acres of wetland restoration.

The total cost of the CSO program is currently estimated to be $9.0 billion with one LTCP still pending. The committed and planned projects are projected to result in a significant reduction in CSO volumes and bacterial loadings into the receiving waters, particularly in the dead-ended tributaries. ***Figure 4*** shows the projected CSO reductions and ***Figure 5*** provides a summary breakdown of the CSO projects, costs, volume and load reductions.

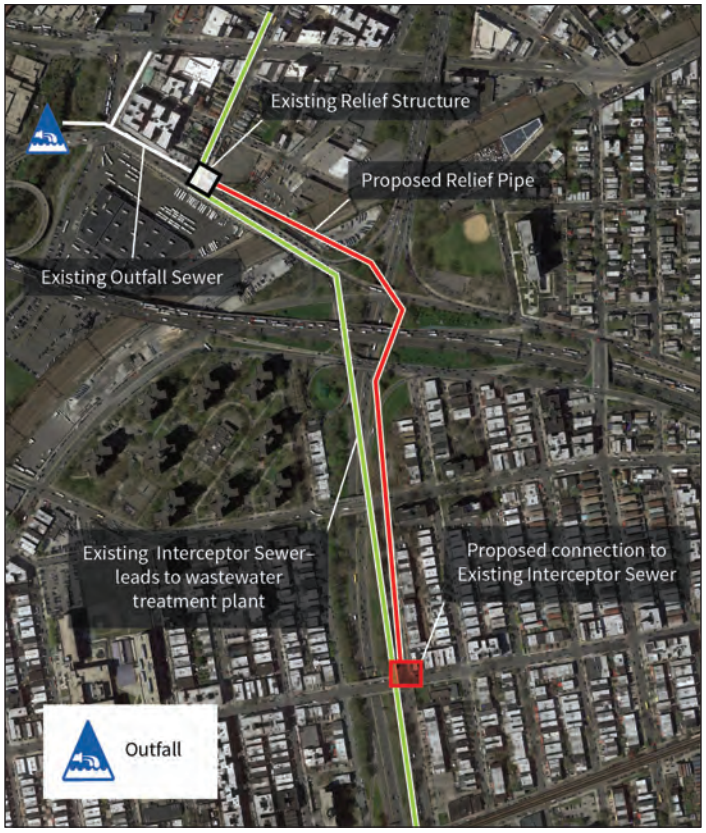

Figure 3. Bronx River Recommended Plan *NYCDEP*

Conclusion

Improving New York Harbor's water quality has been a NYCDEP priority for decades. Over $4.1 billion in investments ***(Figure 4)*** has led to an 80 percent reduction from historic CSO annual overflow volumes. NYCDEP's LTCPs identify and evaluate solutions to reduce the impacts of CSOs and improve water quality in New York City's waterbodies and watersheds. Each LTCP builds on

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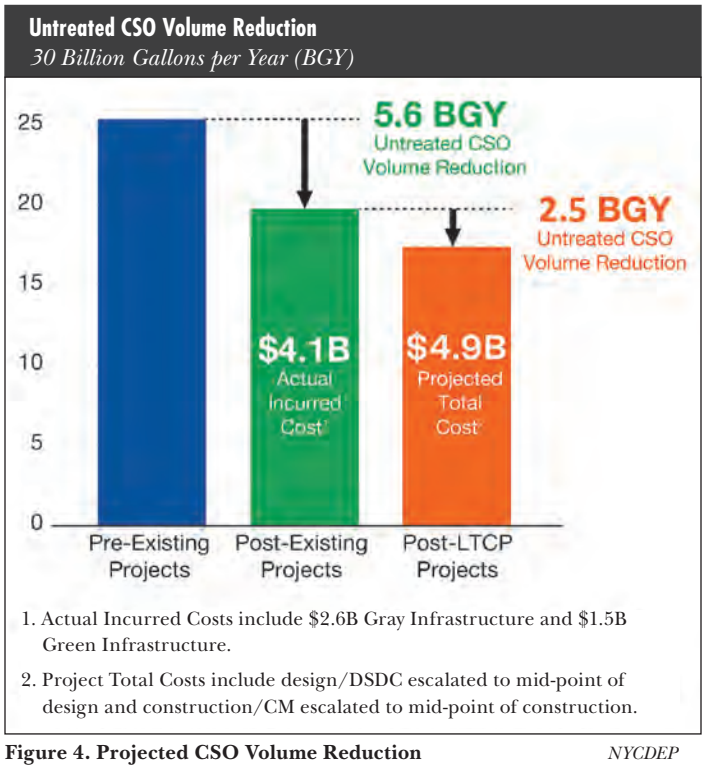

Figure 4. Projected CSO Volume Reduction *NYCDEP*

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Figure 5. LTCP Program Summary *(NYCDEP)*

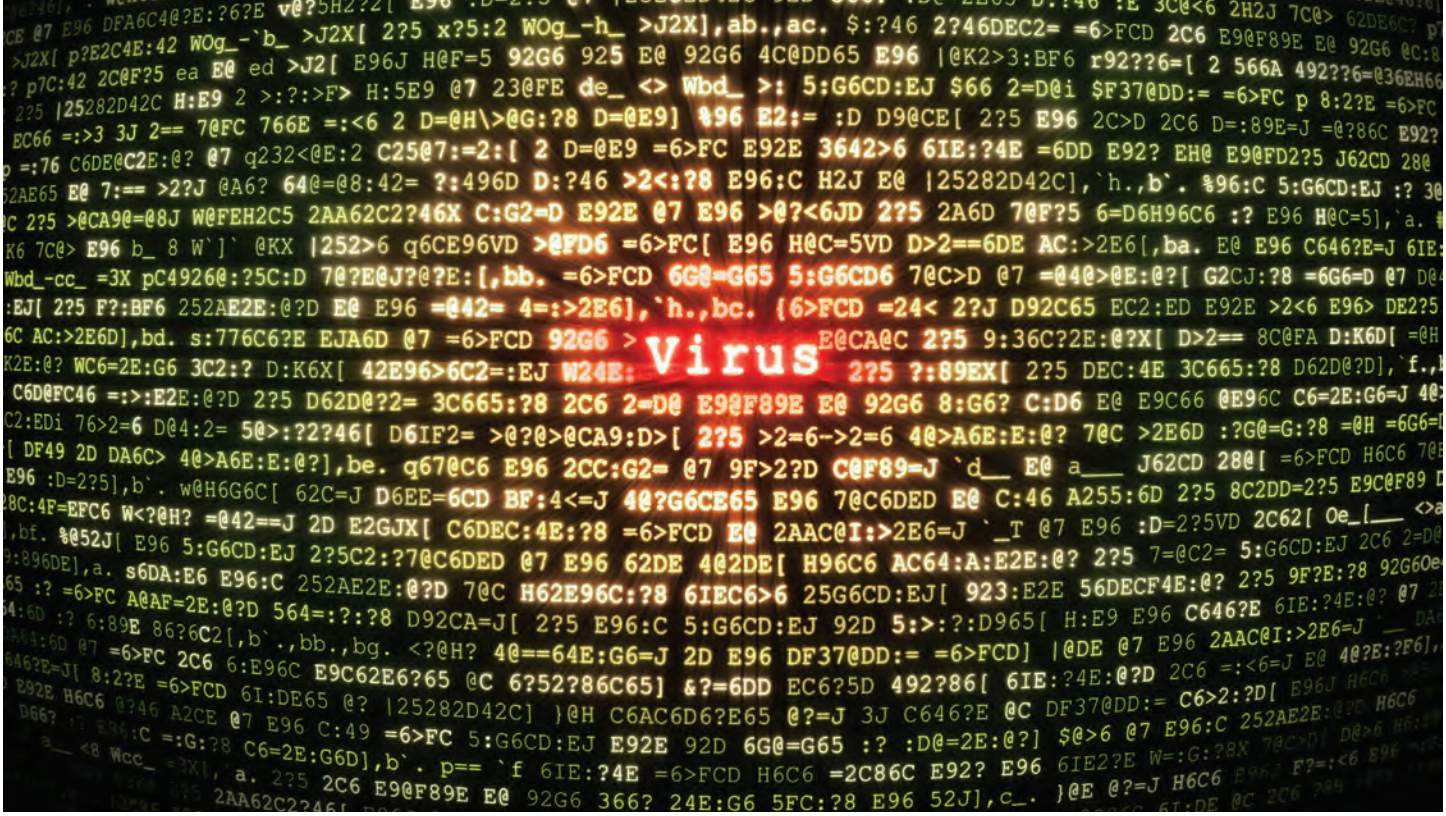
Waterbody	Existing Gray Infrastructure Projects	Actual Incurred Costs (Millions)	CSO Volume Reduction (%)	LTCP Project	Escalated Capital Costs (Millions)	CSO Volume Reduction (%)	CSO Bacteria Reduction (%)	Treated CSO Volume (MGY)
Alley Creek	CSO storage facility and other sewer improvements	$139	60%	Seasonal disinfection of existing CSO storage tank	$12	–	59%	78
Westchester Creek	Weir modifications and parallel sewer	$124	63%	None	$0	–	–	–
Hutchinson River	Hunts Point WWTP Headworks	$3	11%	Seasonal disinfection and floatables control for new outfall	$167	–	14%	65
Flushing Creek	CSO storage facility and Vortex facilities	$363	50%	Seasonal disinfection of existing CSO storage tank and outfall	$18	–	51%	584
Bronx River	Maximize flow to WWTP and floatables control	$46	39%	Hydraulic relief and floatables control	$185	33%	33%	–
Gowanus Canal	Flushing tunnel and pump station reconstruction	$194	43%	Superfund CSO storage tanks	$932	56%	56%	–
Coney Island Creek	Pump station expansion and wet weather force main	$197	68%	None	$0	–	–	–
Flushing Bay	Sewer diversion, dredging and regulator modifications	$69	19%	CSO storage tunnel	$1,616	51%	51%	–
Newtown Creek	Sewer and WWTP improvements and aeration	$259	21%	CSO storage tunnel and upgrade of Borden Ave. pump station	$1,422	61%	61%	–
Paerdegat Basin	CSO storage facility and dredging	$394	56%	Tidal wetland restoration	*	–	–	–
Jamaica Bay & Tributaries	Sewer improvements, CSO storage facility and dredging	$631	30%	Additional Green Infrastructure, ribbed mussel colony, creation, tidal wetland restoration, environmental dredging	$579	1%	10%	–
East River/ Open Water	Facility, conveyance, and regulator improvements	$196	–	TBD	TBD	TBD	TBD	TBD

**Cost included in Jamaica Bay & Tributaries cost.*

Existing Green Infrastructure Program Total		Existing Gray Infrastructure Projects		Pre-LTCP CSO Program Total	LTCP CSO Program Total
$1.5 billion	+	**$2.6 billion**	=	**$4.1 billion**	**$4.9 billion** (as of Fall 2017)

existing or planned projects from previous water quality and restoration efforts. With nine approved LTCPs, current and planned infrastructure investments will result in significant water-quality improvements with a projected cost of an additional $4.9 billion.

Keith Mahoney is the Director of Water Quality Planning at New York City DEP and can be reached at Kmahoney@dep.nyc.gov. Donald Walker is the CSO-LTCP Project Director and Aimee Boulet is CSO-LTCP Deputy Project Manager both working for AECOM. Peter Young is the CSO-LTCP Project Manager and Anni Luck is a Senior Associate, both working for Hazen and Sawyer.



Protecting Water Utilities from Cyber Threats

by Matt Guinn, Trevor Lewis and Alex Drake

Cyber Threats to Critical Infrastructure

Cyber-attacks against public and private organizations continue to increase in quantity and publicity every year. The most notable cyber-attacks on large enterprises recently have resulted in massive data breaches affecting not just the company but the consumers at large. These classes of cyber-attacks often focus on stealing proprietary information, credit card information, or other personal information that can be sold to the highest bidder. While many cyber-attackers focus on targeting enterprises that would provide the most profit, there are other groups of cyber-attackers that are not interested in attacking enterprises for monetary gain. Public and private power utilities, water utilities and other critical infrastructure operators face a unique threat as critical infrastructure has become the target of more advanced cyber-attackers in recent years.

The nature of what critical infrastructures provide to the general population make them a target for any type of attack whether it be physical or electronic. The focus of using "cyberspace" as the means to attack these infrastructures is growing due to the ease of causing a malicious effect and the difficulty in attributing the attack to a person. The most notable cyber-attacks against critical infrastructures in recent years have been carried out by groups of attackers known colloquially in the industry as "Advanced Persistent Threats" (APT). These cyber-attackers are either sponsored by a nation or some group with a large amount of financial resources. Since these groups are often not primarily interested in financial gain, their attacks can occur over large periods of time to reduce the likelihood that they will be detected.

Additionally, due to the complexities involved in the designs and operations of critical infrastructures, many of these APT groups are very skilled and devote a significant amount of time educating themselves on a target of interest prior to conducting an attack. This often increases the overall likelihood of causing a malicious effect. Depending on the intentions of the cyber-attackers, these malicious effects on critical infrastructures can range from simple degradation of services to wide-scale outages. This represents a significant threat to the safety and security of critical infrastructures all over the world. It is imperative that the protection of these systems from cyber-attacks be the primary focus for system designers, operators and maintainers before an attack that causes real-world effects occurs.

Ensuring Control System Security

The average laptop purchased at a big box retailer today represents a remarkable advancement in computer security over systems sold only a few years ago. Modern operating systems are hardened in ways only imaginable in the 2000s. Built-in malware detection quietly and efficiently swats away basic attacks, and most major web browsers prevent users from accidentally navigating to known-malicious websites out of the box. This is the direct result of years of negative customer feedback originating from spear-phishing victims, laptops taken over by adware and spyware and, worst of all, victims who find their computers encrypted and their valuable data held for ransom.

Industrial Control Systems (ICS) and Supervisory Control and Data Acquisition (SCADA) systems however, occupy a very different portion of the computing market. ICS/SCADA systems are the technologies used to monitor and control the physical aspects of a given critical infrastructure. These physical aspects can be anything from opening a breaker at a power substation to turning a pump on or off at a water pump station. Each of these physical processes are often connected to and controlled by specialized hardware and software devices that operate within the larger umbrella of ICS/SCADA systems. These devices include Programmable Logic Controllers (PLCs), Remote Terminal Units (RTUs), and Human Machine Interfaces (HMIs), among others.

Much of the time these specialized ICS/SCADA devices and systems are based on older technologies and communication protocols, and do not have the history of trial-and-error associated with security vulnerabilities that consumer personal computers have. While ICS/SCADA security is still a newer and developing topic, many critical infrastructure operators still maintain and implement these older technologies and systems since they provide expected functionality without introducing a large amount of complexity and maintenance that is required from traditional information technology (IT) systems. The tradeoff to this level of simplicity in device functionality is security. Many ICS/SCADA devices do not implement typical IT security mechanisms to prevent malicious use, such as access control, authentication, programming logic abuse, and others. Due to the nature of these ICS/SCADA devices and systems being able to control a physical process electronically, one primary cybersecurity concern comes into play. If a cyber-attacker were able to control these physical processes remotely without being stopped, the potential exists for large-scale catastrophic effects that can affect the general public.

Critical infrastructure operators are also often faced with the dilemma of establishing a connection between the ICS/SCADA control system network and typical enterprise IT systems and networks due to a larger business or operational need. The problem with establishing this connection is it increases the overall attack surface available to future or current attackers that could already be inside the enterprise network. Traditional ICS and SCADA network security principles dictate that control system networks should be "air-gapped", or disconnected, from other networks such as the public internet or enterprise networks. While this is a solid principle, it is rarely maintained in practice. Many of the ICS/SCADA assessments performed by Georgia Tech Research Institute Cyber Network Operations (GTRI CNO) have revealed that the enterprise IT network is allowed to connect to the control system network in more than one way.

If a cyber-attacker can compromise and remotely control an enterprise IT system (workstation, server, network device, or other means) and the enterprise IT system is allowed to communicate with the control system network, the attacker can simply use the enterprise IT system as a foothold or launch platform to conduct more attacks against the control system network. This could include altering, manipulating or damaging any of the physical processes that are accessible from this foothold. This, in addition to ICS/SCADA devices lacking typical security protections, is the primary reason why control system networks should be air-gapped as much as possible from enterprise networks and outside networks including the Internet. If a legitimate business need exists to connect enterprise networks and ICS/SCADA networks together, this connection needs to be monitored continuously for any malicious activity.

Risk Mitigation and Protecting Your Organization

When assessing the security of ICS/SCADA systems, two factors tend to come into play across industries. First and most straightforwardly, how secure are the systems and communication protocols themselves? Historically ICS/SCADA systems lag behind consumer systems for the reasons already described but also because they must support processes and systems that must remain up and in a reliable and predictable state to the greatest extent possible. When a laptop is attacked, and the Operating System intercedes, it may end up simply restarting and picking up from a clean slate. ICS/SCADA systems and their physical processes that have critical up-time requirements may not be able to handle these failure states. Therefore, when the system focuses on reliability and fail-safe operation, security considerations are more likely to fall by the wayside.

The second aspect that dictates how securely an ICS/SCADA system can be operated is its visibility to the Internet at large. A typical home wireless network may support any number of devices nowadays as multiple laptops, computers, phones, watches, televisions, toasters and toys are added to a single network. One of the biggest benefits such an arrangement conveys to the home user is the fact that all these devices are blocked from direct access over the Internet. The router that connects these devices translates each one of their individual network connections into a single address that is exposed to the Internet and, hopefully, protects that address with a built-in firewall or similar technology.

ICS/SCADA systems often lack similar "cloaking" and expose their interfaces to the Internet at large. This is largely a cost-consideration and a cost of doing business. It is certainly easier to connect directly to an ICS/SCADA system over the Internet rather than driving to it physically or even logging in through several security mechanisms to access the Human Machine Interface. No control more directly prevents successful attacks than simply making a system invisible to the Internet. This can be done in many ways, whether through Virtual Private Networks such as you might use to log in to your corporate networks, or through highly restrictive firewalls that allow only certain addresses on the Internet to access a given system, to name just a couple.

People are Often the Weakest Link

As the critical nature of ICS/SCADA systems and their inherent vulnerabilities gain more public exposure, the sophistication of attacks against both the systems and their operators and employees has also increased. The most common method cyber-attackers use to attack an organization is spear-phishing. The simple reason for this is that it is a very successful attack vector. Spear-phishing is the process of targeting very specific individuals within an organization and sending them an e-mail enticing them to do something on the attacker's behalf. Usually this involves enticing them to click a link or open an attachment along with a believable reason on why the victim needs to perform that action. The goal is usually to either steal the individual's corporate username and password or open a file that contains malicious code.

If an attacker can gain control of a spear-phishing victim's system, this establishes a foothold into the network allowing the attacker to conduct more attacks inside the network.

While many organizations invest large sums of money to combat this attack vector, the success of spear-phishing as an attack vector is still high. It is very difficult to discern legitimate e-mails from malicious e-mails if there are no obvious signs such as those associated with SPAM e-mails (poor grammar, unlikely story, etc.). To augment these technical solutions, organizations will also implement user awareness training on identifying phishing emails.

The core issue organizations face in combatting spear-phishing attacks is the potential variability in the specific deceit that is presented to users. Very poor spear-phishing attacks may include grammatical errors, slightly inaccurate phrasing, other signs of language translation that lead a user to feel that something may not be right. Very sophisticated spear-phishing attacks do not

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include any grammatical errors, are written very well, and may even originate from a legitimate e-mail address that is known to the victim. As enterprises continue to combat this threat, critical infrastructure operators must also be aware of this attack vector and the specific implications it has on the security of the critical infrastructure. ICS/SCADA system operators, engineers, dispatchers and even administrative assistants could all be targets in a spear-phishing campaign due to their direct or tangential relationship to the critical physical process.

Penetration Testing and Vulnerability Assessments

Organizations that wish to identify poorly secured or overly exposed systems can identify these issues in multiple ways. The two most common are known as Vulnerability Assessments and Penetration Testing. While it is easy to think of penetration testing as simply professional hacking, for ICS/SCADA systems other factors often come into play. First, even well-architected systems may expose weak points depending on their interconnectedness with corporate "enterprise" systems. These architectural issues are often not vulnerabilities on their own, but when they are chained together in a malicious way, together they become a vulnerability. Second, an attack on a piece of critical infrastructure is very likely to start, logically, "away" from the physical process in a more traditional IT system.

The attack may begin with a typical spear-phishing attempt to establish a foothold on a user's machine. This machine is then used as a foothold into the corporate network and the attacker engages in what is known as ***lateral movement***. This movement can be difficult to detect inside a network because most defenses are preventative in nature and face outwards towards the Internet, not inwards at an organization's own users. Once an attacker can move from machine to machine freely, they can begin to map out critical servers and assets and ultimately, on a poorly "segmented" or air-gapped network, identify a path to the true target which may be a PLC or other ICS/SCADA system or device. It is imperative that critical infrastructure operators identify and mitigate any vulnerabilities, whether they are in software or in the network architecture, before a real attacker takes advantage of them.

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Georgia Tech Research Institute (GTRI) is the applied research division of the Georgia Institute of Technology (Georgia Tech). Founded in 1934, GTRI has eight laboratories of various disciplines performing problem-solving research for government and industry. The GTRI Cyber Network Operations (CNO) Team is part of the cybersecurity laboratory (CIPHER) and performs various offensive and defensive cybersecurity assessments including penetration testing, red teaming, security operations assessments and threat hunting for customers of all sizes in government, DoD and industry.

The GTRI CNO team is composed of individuals with extensive experience in information security and team members are often regarded as subject-matter experts. Some examples of the organizations and systems the CNO team performs security assessments on include public utilities, critical infrastructure and ICS/SCADA systems.

From wef hq Leading-edge updates from the Water Environment Federation

Water Workforce Development

Newly Released Policy Report on Water Workforce Development Focuses on Obstacles, Innovations and Plans.

by Katherine Saltzman

Researchers at the Brookings Institute (Washington, D.C.), a bipartisan policy think tank, published a report focusing on establishing robust water workforce development programs to accommodate today's water infrastructure needs.

The report, *Renewing the Water Workforce: Improving Water Infrastructure and Creating a Pipeline to Opportunity,* addresses the unique employment opportunities available to the American worker in water sector jobs and the simultaneous high and urgent demand for these employees across the U.S.

The report highlights the diverse opportunities and employment options in the water sector. In 2016, the water sector included 212 different occupations ranging from operators and construction workers to administrative and managerial roles. Employees in water occupations, on average, earn higher wages compared to all workers nationally; water employees may earn up to 50 percent more compared to workers at lower ends of the income scale. In the 10th and 25th income percentiles, water workers earn hourly wages of $14.01 and $17.67, respectively "compared to the hourly wages of $9.27 and $11.60 earned by all workers at these percentiles across the country," according to the Brookings report.

As income inequality in the U.S. continues to rise – especially between populations with university degrees and those without, researchers note – the water sector can offer good-paying jobs. Water sector jobs require rigorous hands-on training and application of STEM skills and project management; this flexibility offers individuals with otherwise limited formal education sustainable incomes.

Finding the Right Fit

Despite the long-term economic and educational opportunities available in the water sector, there are obstacles with finding and retaining talent. In 2016, research showed that employees in "water occupations are significantly older than the national median (42.2 years), including water treatment operators (46.4 years old), the report says. Utilities and municipalities across the country are concerned about high retirement rates and limited pools of trained candidates to enter the water sector.

Water utility leaders, municipalities, and associations are finding innovative ways to engage and attract young people to opportunities available in the water sector.

Pipeline to the Water Sector

Researchers found the water sector lacks the public visibility needed to attract individuals to the water workforce. Despite lower education barriers and stable good-paying jobs, there are not enough people pursuing water jobs or gaining the necessary skills or training to obtain careers in the water sector.

According to researchers, though internships or apprenticeships are being used to recruit younger and more diverse employees, these programs may be limited by budget shortages and/or the need to retrain students in basic math, science and English skills, which are not necessarily taught in high school. It is also important to note that inadequate newcomers to the water sector also may be part of a "general shift away from the skilled trades and vocational education among students, which is compounded by the many existing water workers nearing or eligible for retirement," according to the Brookings report.

Based on communication with utility managers and other stakeholders, researchers recommended a more collaborative effort among utilities, municipalities, government agencies and policymakers to invest in and prioritize water workforce development programs to enhance the visibility and attractiveness of the sector. Plans to increase water workforce outreach programs include hiring and training diverse mentors. These mentors can connect with younger individuals, revitalize the recruiting process, and serve as long-term guidance counselors for students in water-related internship or fellowship programs.

Other ideas include acquiring funding from federal and state policymakers to establish "bridge programs" and educational initiatives to provide opportunities for younger workers or adult students to explore water careers and gain experience.

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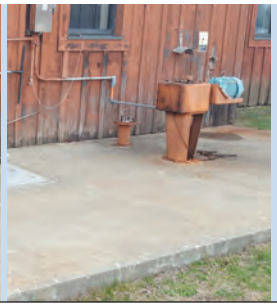

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Retention and Long-term Employees

There are financial and programmatic obstacles to developing workforce programs when water utilities also must finance infrastructure repair and investment. Utilities also face budget cutbacks and need to remain conscious of ratepayers' bills. In these cases, utilities may prioritize infrastructure improvements rather than workforce development programs. Though infrastructure investment is critical to maintaining water quality, limited funding for workforce development can lead to shortcomings in career advancement and earnings for water sector employees.

Some smaller utilities, for example, may have one or two employees with no supervisory role. In this situation, workers who have held the same role at a utility for several decades may seek other opportunities at a larger utility or consulting group. Meanwhile, trends indicate that younger workers prefer opportunities to diversify and have mobility in their careers. This leaves a significant gap in skilled workers available to run the critical daily operations at the utility.

"To have a team manage the water infrastructure, in water emergencies but also day-to-day operations, is really vital," said Keisha Powell, commissioner of the Department of Watershed Management for the City of Atlanta, at a panel discussion following the release of the Brookings report. "We have reached 130 water main breaks in the month of January and are facing a 55 percent eligibility retirement rate. Further, it is difficult to recruit young talent."

Researchers and stakeholders concluded that by increasing training for supervisory roles, developing income tiers for more experienced employees and creating more established career paths, utilities could better retain skilled employees and create workforce advancement opportunities in the water sector.

Programs Related to Workforce Development and Training

Several utilities, national agencies, municipalities, and nonprofit organizations are taking on the task to provide tools and programming to enhance recruitment and training.

National Green Infrastructure Certification Program (NGICP). This spring WEF, in collaboration with DC Water, launched the National Green Infrastructure Certification Program (NGICP). This program is a national certification standard for green infrastructure construction, inspection and maintenance employees. To earn the certification, students with a high school degree must complete 35 hours of course material and pass an exam. NGICP supports the development of proficient green workforces, and establishment of a career path for skilled green infrastructure workers.

PowerCorpsPHL. This 2013 initiative by the City of Philadelphia Americorp engages at-risk young adults and returning, formerly incarcerated citizens, to enroll full-time in the program and work to support Philadelphia's environmental stewardship, youth violence prevention and workforce development priorities. PowerCorpsPHL student crews work with the Philadelphia Parks and Recreation Department as well as the Philadelphia Water Department to improve stormwater management and revitalize public lands and parks. Students spend five months working and one month dedicated to career training. Students also can apply to a fellowship program that matches them with an external partner to gain additional environmental career experiences.

Bay Work. In 2008, amid concerns in the San Francisco Bay area regarding lack of water workforce development programs at local utilities, several water and wastewater utilities collaborated to develop Bay Work. This program's mission is to "develop and implement programs and strategies that support development of high-performance workforces." Bay Work's resources are open to all bay-area water and wastewater utilities. The program also provides opportunities for utilities to share research, ideas, programs and concerns related to workforce issues. Bay Work also provides extensive job and internship listings and training schedules for those interested in the water sector.

These initiatives are some examples of the workforce development training necessary to bring public visibility to the water sector and green infrastructure jobs while also offering critical preparation and training for diverse and skilled individuals to enter and find long-term careers in the water workforce. As highlighted in the Brookings report, continued collaborative workforce development programs can address the needs of water infrastructure and the water sector while also supporting greater and more stable economic opportunities for U.S. communities.

Katherine Saltzman is a publications assistant at the Water Environment Federation (Alexandria, Va.) where she works on WEF's Operator Initiative programs.


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Rebrand + Reconnect + Recruit + Retain + Sustain = The Future of Resource Recovery Operations in New York City

by Pamela Elardo and Kenya Lewis

Industries across the country continue to feel the effects of the shifting workforce resulting from the mass exodus of the Baby Boomer generation. The effects of this shift include losses in leadership, skills, institutional knowledge and overall years of experience that have been attributed to the success of industries and organizations for decades. What makes utility organizations different is that our losses don't simply impact goods or services; they directly impact our environment and the health and well-being of the communities we serve. With this great responsibility comes added pressure to find qualified applicants to fill the role of treatment plant operator.

The Strategic Planning team at the New York City Department of Environmental Protection (NYCDEP) is rebranding the agency by revamping its Mission, Vision, Values and Goals (MVVGs). The Bureau of Wastewater Treatment (BWT), in conjunction with this effort, is creating MVVGs for the bureau that will serve as a road map for strategic and workforce development. Our plan will focus on three primary areas: rebranding the image of the BWT and the operator title; succession planning; and training and development.

Rebranding the Image of BWT and the Operator Title

Within our city and our agency, BWT is the silent success story. We treat billions of gallons of wastewater each day, our work has revitalized the New York Harbor waters, and our efforts with energy and biosolids not only save our ratepayers money, but also make us key players in sustainability and combating climate change. In short, our work is vital to the success of our city's economy and quality of life. Yet when the public thinks of NYCDEP, it is primarily as the providers of drinking water.

In order to draw attention to the valuable services we provide, BWT has launched several efforts including: expanding educational tours at our Newtown Creek facility; increasing our presence at community events and at local board meetings; and looking at ways to become more transparent in our processes. This includes joining in with utilities across the country in shifting our name from "Wastewater Treatment Plants" to "Wastewater Resource Recovery Facilities". As a part of this initiative, we are working with the NYCDEP Public Affairs and Communications to change the names at our facilities, from the indoor and outdoor signage to printed materials. We also upgraded the title of our Assistant Commissioner position from "Assistant Commissioner of Operations" to "Assistant Commissioner of Wastewater Treatment and Resource Recovery Operations".

In addition to changing our name, we will be working with the treatment plant operators' union to rebrand the operator title. Currently, our treatment plant operators work under the civil service title of "Sewage Treatment Worker". While this title has been used for decades, it carries the stigma that we just treat sewage. While that may have been true in the 1800s, today's treatment plant operators do more than just "treat sewage", they are skilled in a wide range of resource recovery operations. They operate, maintain and repair basic and advanced equipment and structures at the treatment plants, pumping stations, combined sewer overflow (CSO) facilities, interceptors and regulators. Today's operators must understand the chemistry, biology and physics necessary for the successful delivery of clean water, biogas, biosolids and other recovered resources. They must also be mindful of odor control, safety, chemical storage, spill response and documentation. They need to understand gauges, charts and sampling procedures. In addition, our operators of the future must be technologically savvy as data collections, control systems and automation have reached new levels of sophistication.

As such, we believe that they deserve a title that creates a better image, encompasses everything they do and is consistent with their important role in environmental sustainability through resource recovery. We will be working with the unions and the staff to implement a suitable name in the coming months. A name we hope will be a source of pride for our current workforce and one that will attract new operators.

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Sewage Treatment Worker (STW) Graduation, June 15, 2018, at the Newtown Creek Water Resource Recovery Facility. *Nazim Hodzic*



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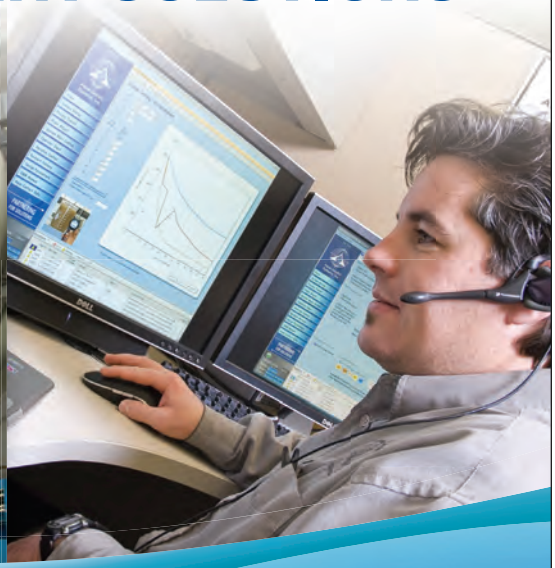

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Succession Planning

Recognizing the retirement trend, BWT launched its first succession initiative in October 2017. Across plant operations, we faced the prospect of losing 100 employees in 2018. This sector of the workforce includes our Senior Stationary Engineers (Plant and Deputy Plant Chiefs), Stationary Engineers, Senior Sewage Treatment Workers and Sewage Treatment Workers (entry level treatment plant operators). These titles combined account for over 900 employees, which means we faced almost a 10 percent reduction in our workforce in one year. This situation was critical for us, especially when we have numerous vacancies in these titles.

To combat this situation, leaders developed a plan to fill the vacancies at the higher-level positions with qualified staff and "front-load" those vacancies to the entry level treatment plant operator position. This created the opportunity for us to increase the total number of entry level vacancies, which is helping us hire

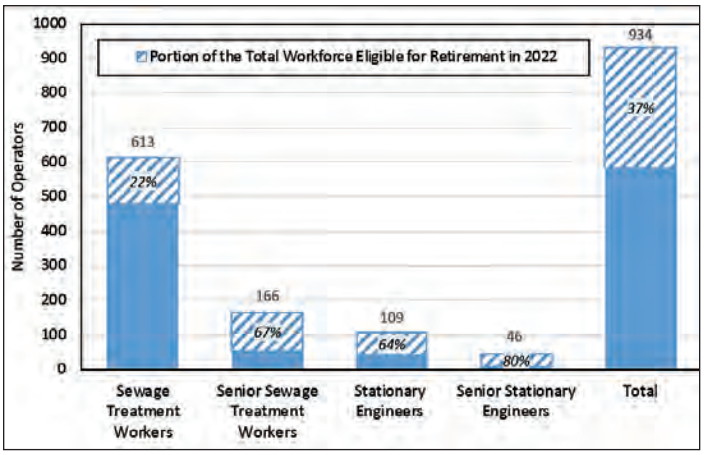

Figure 1. Retirement-eligible operators in 2022, as a proportion of the total workforce as of July 1, 2018. *NYCDEP*

and prepare for the future. The proposal also paved the way for reductions in overtime cost at facilities that were previously short-staffed. This plan was approved in October 2017. In November, we began recruiting entry level treatment plant operators, and to date we have filled 95 percent of the additional headcount.

While this was a great maneuver to close the gap, it was just a start. Over the next five years, we will continue to see increases in the number of retirements ***(Figure 1)***.

With 37 percent of our staff set to retire in the next four years, we look to fill the gaps through training and development. We will also use our rebranding efforts as a marketing tool to attract employees looking for green jobs. In addition we will be working with our leaders and the unions to revisit the qualifications and standards of our current civil service titles and explore the possibility of a trainee program for the treatment plant operator position. We hope to collaborate with local education partners to offer a program that will give workers hands-on treatment plant operator experience and help them obtain the Grade 1 License – skills and certifications we believe will help us expand the applicant pool for the civil service exam and bring us closer to bridging the diversity gap ***(Figure 2)***.

Training & Development

Lastly, the bureau's Training and Development team has been working on several fronts to help fill the knowledge and skills gap left by our retirees. We have developed a comprehensive training program to prepare operators for certification. The treatment plant operator union has assisted with this effort by providing opportunities for members to receive their Grade 1 and 2 licenses. Once operators have those licenses, we provide training in-house for Grade 3 and 4 licenses. In addition, we work with the NYCDEP Workforce Development and Training unit to customize the current supervisor and manager training to fit the needs of our Wastewater Resource Recovery Facilities. We will be having various workshops and forums to evaluate the value of several suggested programs, which include:

- Identifying the bench – This program would allow mid-level managers to identify operators with leadership potential. Selected candidates could be matched up with a mentor and receive quarterly training in operations one level above their current title.
- Leadership Development Program – The prospect of a year-long training program across all title levels for parties interested in learning all the facets of bureau operations to prepare future senior managers.
- Retiree Mentorship Program – This program would allow retirees to volunteer or work part-time with the bureau to teach aspiring managers, giving current employees a chance to learn from respected industry professionals.

With this three-pronged approach, we hope to strengthen our ability to recruit and retain a viable pool of treatment plant operators. We are also working with our Continuous Improvement Committee to develop other strategies to help us prepare for the departures and fill the gaps in titles across BWT.

Pamela Elardo, P.E., is the Deputy Commissioner with the New York City DEP Bureau of Wastewater Treatment and may be reached through Kristen Molfetta at KMolfetta@dep.nyc.gov. Kenya Lewis, SHRM-CP, is the Director of Organizational Development in Human Resources & Personnel Administration for the New York City DEP and may be contacted for questions regarding this article at krlewis@dep.nyc.gov.

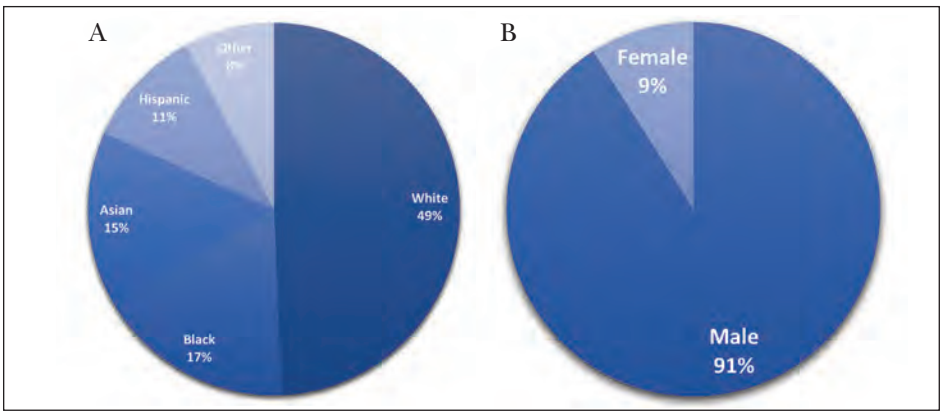

Figure 2. The Bureau of Wastewater Treatment's employee demographics as of 2017, (A) by race and (B) by gender, show that nearly half of the workforce is white, and over 90 percent of the workforce is male. *NYCDEP*

Co-Digestion with Food Waste Organics: The GLSD's Next Step Towards Net Zero Operation

by Cheri Cousens, Richard Weare, Benjamin Mosher and Michael Walsh

Abstract

The Massachusetts Department of Environmental Protection (MassDEP) imposed a ban on landfill disposal of source-separated organics (SSO), with the goal of diverting an additional 350,000 tons per year of SSO material from the solid waste stream statewide by the year 2020. Concurrently, the Greater Lawrence Sanitary District (GLSD) continues to investigate ways to reduce energy consumption at its treatment facilities and improve its biosolids processing systems and management strategies. These two interests have converged to provide the basis for an innovative project that may serve as a model for the recovery of energy from wastewater biosolids and food waste organics – materials that have traditionally been viewed as waste products – to provide a more sustainable environmental footprint and benefit the environment and rate payers.

Introduction

The GLSD owns and operates a 52 million gallon-per-day secondary wastewater treatment facility that serves a population of about 200,000 across six Massachusetts and New Hampshire communities. As was typical of 1970s-era facilities, the original GLSD facility design was based on the premise that sludge is a waste by-product from the liquid treatment process and that the goal of sludge management is to provide for reliable disposal of this material. Over the nearly 40 years since the GLSD facility began operation, major industry trends have steadily moved toward more sustainable approaches to biosolids management, with emphasis on beneficial use rather than disposal. Further, energy recovery, efficiency and creative applications of innovative technologies have been developed that are capable of achieving sustainable results. GLSD continues to be a leader in this move to more sustainable wastewater plant operations, as demonstrated by the ongoing Organics to Energy Project.

Focus on Organics

Like many states, the Commonwealth of Massachusetts implemented a ban on the disposal of food waste organics by incineration or landfill disposal. This new regulation resulted from a Solid Waste Master Plan that was completed by the MassDEP in 2010. The goals identified in the Solid Waste Master Plan include: reducing solid waste disposal by 2 million tons per year by 2020; reducing disposal of organics by 350,000 tons per year, accounting for 17 percent of the overall reduction goal; and developing the infrastructure to support an organics diversion process that will accommodate 250,000 to 300,000 tons per year of processing capacity, including the supporting collection infrastructure.

The GLSD, an innovator in biosolids treatment and energy recovery, operates one of the few anaerobic digestion facilities in New England. Digester gas is used in the facility as the primary fuel for a thermal biosolids drying operation and as a fuel source for building and process heat. The GLSD hopes to eventually achieve a Net Zero energy goal for their wastewater treatment facility. The ban on SSOs in landfills provides the GLSD an opportunity to further that goal. Specifically, the GLSD realized that these food waste organics can be used, along with biosolids, as a fuel to increase generation of biogas at their anaerobic digestion facility, thereby increasing the generation of clean energy.

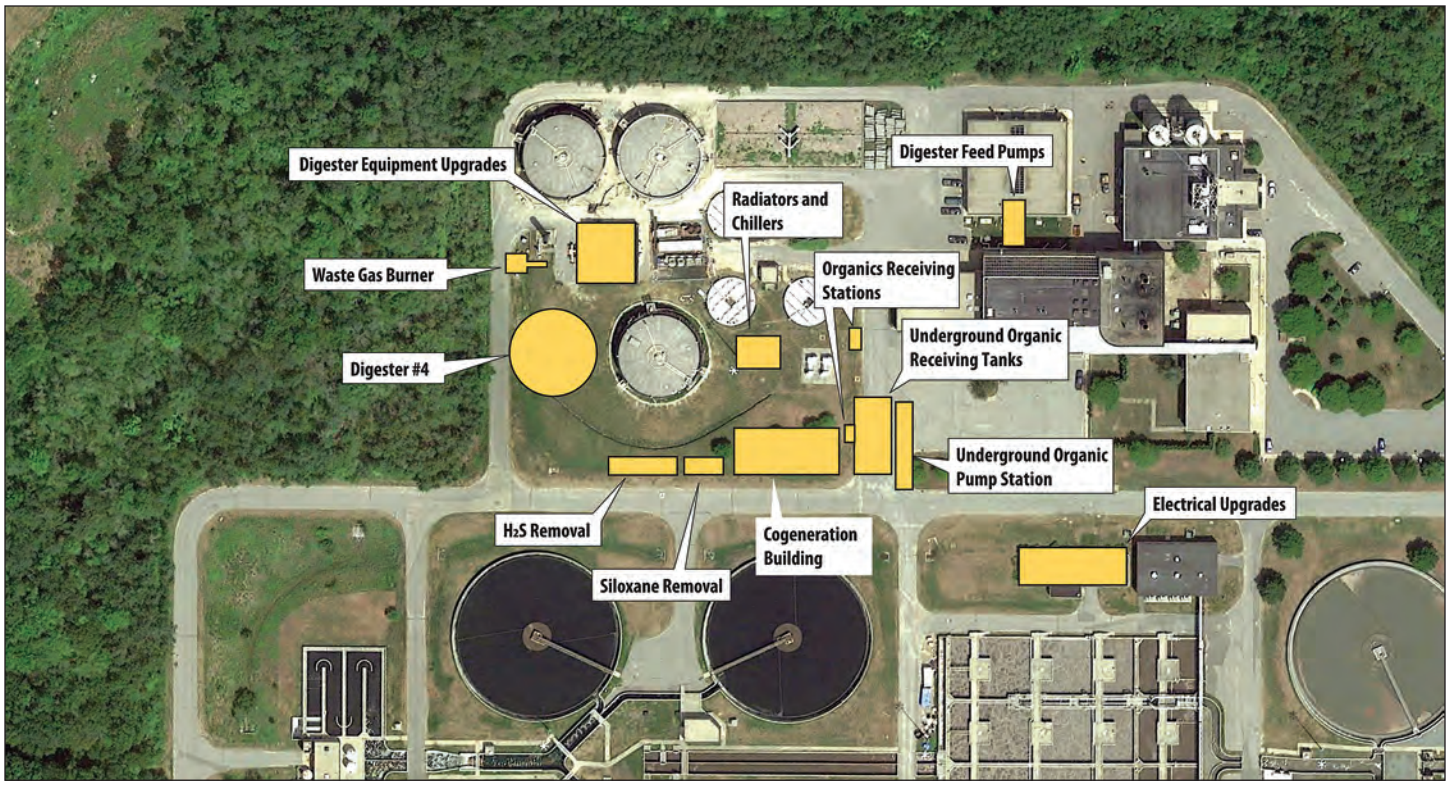

Figure 1. GLSD Organics to Energy Project Improvements. *GLSD and CDM Smith*

With these goals in mind the GLSD, with assistance from CDM Smith, completed an Organics to Energy Feasibility Study in June of 2013. The Feasibility Study evaluated the efficacy of expanding their existing digestion system to allow for co-digestion of biosolids and food organics, as well as adding a new biogas-fired co-generation system. This has the potential to provide a regional solution for organic waste disposal and produce renewable energy for both heating and powering the facility. Specifically, the study found that installing a fourth anaerobic digester at the facility and utilizing the excess capacity for co-digestion of food waste would improve the facility's resiliency and reduce operating costs, as well as greatly reducing or eliminating the GLSD's reliance on utility-supplied power. Based on the results of this study the GLSD, with CDM Smith, developed a final design for the required Organics to Energy infrastructure at the wastewater treatment facility. Final design documents were completed in January 2016, the project was advertised for construction bids in February, and a construction contract was awarded in April 2016. Construction is currently ongoing with completion expected in late 2018. ***Figure 1*** shows the organics to energy improvements recommended for GLSD's facility.

With the addition of the new infrastructure, GLSD will be able to accept SSO material for co-digestion and produce additional biogas. Under the new system, biogas will continue to be used as the primary fuel for the thermal drying process and to provide digester and building heat. But the increase in digester gas production will now also support a Combined Heat and Power (CHP) system. With the new CHP system, GLSD has the potential to produce enough electricity to remove its reliance on the electrical grid under many operating conditions, with the possibility of generating approximately 3 megawatts of power. This has the potential to save its member communities up to $2 million dollars per year in electrical costs and reduce the stress on the already overburdened electrical grid in the Northeast. When complete, this innovative project will produce quantifiable, long-term reductions in both electric and natural gas usage, representing a major step forward for the industry in terms of a more sustainable approach to wastewater treatment.

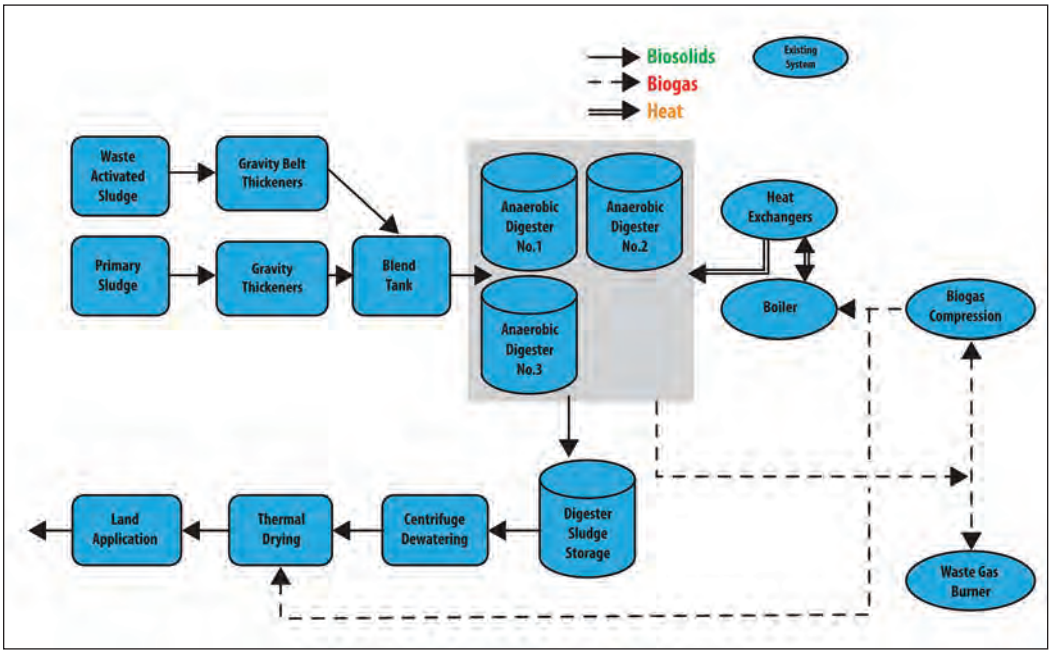

Figure 2. Existing GLSD Biosolids Process *GLSD and CDM Smith*

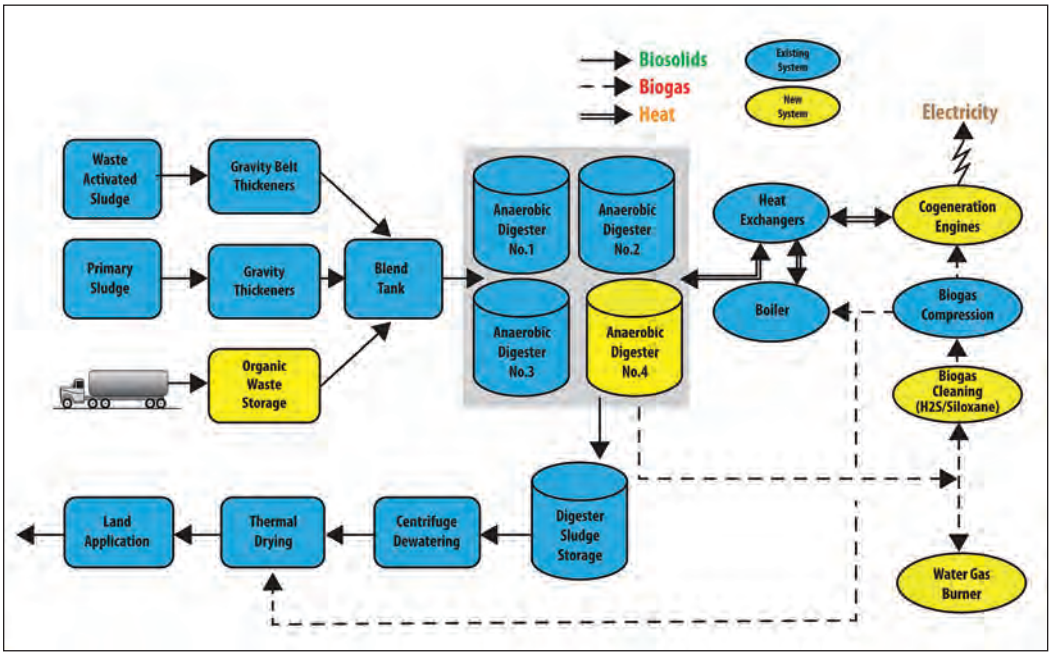

Figure 3. Proposed GLSD Biosolids and Organics Process *GLSD and CDM Smith*

The major components of the project include the following:

- *Organic waste receiving tanks.* Two new SSO receiving tanks, sized to provide approximately 238,000 gallons of storage. In addition, a pumped mixed system and SSO transfer pumps will mix and transfer the material to an existing sludge blend tank.
- *Anaerobic Digester No. 4.* A new 1.4-million-gallon digester tank has been constructed to provide additional digestion capacity. Similar to the existing digester tanks, Digester No. 4 will utilize draft tube mixers and a steel gasholder cover.
- *Anaerobic digestion ancillary equipment.* Additional equipment has been installed within the existing Digester Equipment Building to support the new digester, including two digester recirculating pumps, one concentric tube heat exchanger rated at 1.7 million British thermal units (Btu) per hour and one hot glycol recirculation pump. Space for this equipment had been incorporated in the existing Digester Building as part of the original digestion system design.

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- *Biogas conveyance and waste gas burner.* As a result of the anticipated significant increase in gas production from SSO co-digestion, additional biogas conveyance capacity has been added between the various biogas treatment systems and points of use, in addition to a second waste gas burner (flare).
- *Hydrogen sulfide and siloxane treatment system.* A high level of digester gas treatment is required to protect the CHP engines from damage. The biogas cleaning system includes a fixed-media hydrogen sulfide treatment system, in addition to a carbon media-based siloxane treatment system.
- *Biogas pressure boosting.* Treated biogas will be boosted to between 3.5 and 5.0 pounds per square inch (psi) to accommodate the needs of the cogeneration engines and boilers.
- *Combined Heat and Power (CHP) engines.* Additional biogas production will be utilized in reciprocating combined heat and power generators with a capacity of approximately 3 megawatts. The power produced will be fed to the site electrical system and excess electricity will be net metered back to the utility grid. Heat from the engines will be captured to supply process and potentially other on-site heating demands.

Figures 2 and ***3*** show the general process flow scheme for the current and proposed biosolids and organics processing systems to be installed under this project.

Economics

The cost to construct the Organics to Energy Project will be approximately $25.7 million. Due to the significant environmental and energy benefits of this project, there are several credits and grants available to assist in funding the construction cost of the proposed facilities. Approximately $8.2 million in grants and $25 million in State Revolving Fund (SRF) assistance are committed to the project, with grant funding provided by the MassDEP, the Massachusetts Department of Energy Resources, the Massachusetts Clean Energy Center, and National Grid. Additionally, the GLSD will be receiving approximately $1.6 million in SRF loan principal forgiveness due to its Environmental Justice designation.

The overall economics of the Organics to Energy Project are dependent on many variables, including:

- Current and future value of renewable and alternative energy credits, which could exceed $800,000 annually depending upon the quantity of energy produced.
- Tipping fees for the acceptance of SSO material, which are initially anticipated to be relatively low, but could increase over time as the SSO market becomes more developed.
- The ability to apply net metered power produced at the treatment facility to the Riverside Pump Station power demand, thereby providing a partial offset of the pump station's power costs.
- The savings realized by not purchasing power from the local utility, which is over $2 million at current rates and could increase in the future if, as many predict, energy prices continue to rise.

In large part, these variables are dependent on the volume of SSO material received at the facility. Processing more material will increase tipping fees, allow for increased generation of clean energy and associated energy credits, and subsequently lower the GLSD's power costs. Based on current costs, it appears that the Organics to Energy Project will provide a net positive cash flow, if the co-digestion system is operated at greater than 60 percent of the SSO design capacity. The higher the levels of SSO material accepted, the greater the economic benefit to the GLSD. Based on ongoing discussions with potential suppliers of SSO material, the GLSD believes that the 60 percent breakeven point will be met in the initial years of operation. The economic benefit of the project will continue to increase as the SSO market further develops and the demand for SSO processing outlets continues to increase.

Conclusion

In recent years, wastewater treatment facilities have moved from a mission of treatment and disposal to one of recycle and reuse. The industry has recognized the value of nutrients and organics in wastewater and biosolids and has moved to treat these materials as a resource rather than a waste product.

The GLSD's Organics to Energy Project represents a major step in this progression towards more sustainable water resource recovery operations. This innovative project will take two materials traditionally viewed as waste products – food waste organics and wastewater sludge – and convert them to an important clean energy source that will, to a large degree, meet the energy needs of the GLSD facility. Additional benefits to the GLSD include:

- Greater protection against future increases in energy costs.
- Greater facility resiliency and operational flexibility, including the ability to utilize the CHP engines during a loss of utility-supplied power.
- The ability to provide an important service to the Commonwealth and to local businesses in terms of processing and beneficial use of SSO material.
- Greater system reliability, as the additional digester tank added as part of this project will make it easier to clean digester tanks on a regular basis.
- A major reduction in net greenhouse emissions associated with organics processing.

The project will also provide a net economic benefit to the GLSD and its member communities that could increase over time as the cost of traditional energy sources continues to rise. In these and other ways, the Organics to Energy Project can serve as a model for the wastewater industry as treatment plants develop a more sustainable environmental footprint, move to renewable energy sources and find new ways to recover the nutrient and energy value of wastewater. Ultimately, the beneficiaries of this project will be the environment and the rate payers in the community.

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Striving Toward Energy and Carbon Neutrality

by Mikael Amar and Pamela Elardo

In 2014, Mayor Bill de Blasio committed in his *One City: Built to Last* plan *(One City)* that New York City would continue its role as a global leader on sustainability by reducing greenhouse gas (GHG) emissions by 80 percent by 2050 (80x50) from 2005 levels. This undertaking makes New York the largest city in the world to commit to this United Nations *Framework Convention on Climate Change* goal. In each year following *One City*, additional supporting sustainability plans and roadmaps were released by the mayor's office, including *One New York: The Plan for a Strong and Just City (OneNYC)* and *New York City's Roadmap to 80x50*.

Most recently, in response to the U.S. federal government pullout from global climate initiatives, the *1.5°C: Aligning New York City with the Paris Climate Agreement* climate action plan *(1.5 Plan)* was released as an addendum to *OneNYC*. The *1.5 Plan* committed New York City not only to 80x50 but also to an additional 20 percent decrease in GHG emissions by 2050, thus achieving carbon neutrality, via carbon sequestration and credits or via further reductions.

Other goals relevant to New York City Department of Environmental Protection (NYCDEP) set since 2014 include:

- The city's first-ever municipal operations energy reduction target of 20 percent by 2025 from 2017 levels.
- Energy-neutral water resource recovery facilities (WRRFs) by 2050.
- Sending zero waste, including food waste and biosolids, to landfills by 2030.
- Various renewable energy, energy storage and reliability, and GHG reduction targets in the interim to 2050.

1.5°C: Aligning New York City with the Paris Climate Agreement **climate action plan.** *NYC Mayor's Office*

The mayor's office has called on all city agencies and the public to engage in these efforts, and NYCDEP is proud to lead the way. NYCDEP is evolving from the mission of meeting permit conditions for water and wastewater management to also being progressive leaders in sustainable operations, resource recovery, and seeking the best investments for environmental and social solutions. In fact, the wastewater treatment industry is transforming into one of water resource recovery, producing valuable products for local, regional, national and international sustainability. NYCDEP has assets distributed across New York City and in the watershed that are poised to provide local solutions in each borough.

Nevertheless, NYCDEP will face many obstacles to meet the mayoral goals. The utility requires a tremendous amount of energy to fulfill its mission of providing safe drinking water and treating wastewater to protect the public and the environment. NYCDEP consumes annually about 10 trillion source British thermal units (Btus) at an expenditure of about $100 million in utility energy and liquid fuel costs. As such, NYCDEP is the third-largest energy consumer and second-largest GHG emitter among the city agencies. Wastewater treatment alone accounts for 80 to 90 percent of NYCDEP's energy usage and GHG emissions, making the pathway toward energy-neutral WRRFs all the more elusive.

Meeting the significant *OneNYC* energy and GHG reduction targets simultaneously while integrating and not sacrificing NYCDEP's state-of-good-repair (SOGR) needs is an ongoing challenge. New and increasingly strict water- and wastewater-quality regulatory mandates often require energy-intensive solutions to be met, but NYCDEP's unique infrastructure presents opportunities to achieve carbon offsets and to educate policymakers and the public about the invaluable work that the utility does every day.

Since its initial GHG reduction efforts began in the mid-2000s, NYCDEP has made significant progress toward closing in on the carbon neutrality goal. GHG emissions have decreased by 22 percent from base fiscal year 2006 (New York City's community and municipal GHG inventories are based on calendar years and fiscal years respectively), or by 32 percent effectively, if normalizing for federal and state mandates requiring NYCDEP to implement energy-intensive processes and facilities to meet stringent environmental compliance requirements. These GHG reductions speak in part to efforts to reduce the carbon intensity of the electric grid in New York City over the last decade, as well as GHG reduction efforts by NYCDEP, including:

- Improving biogenic anaerobic digester gas (ADG) infrastructure and developing projects to maximize its direct beneficial use in boilers and engines.
- Identifying and implementing energy conservation measures (ECMs) and other operational improvements.
- Performing routine preventive and predictive maintenance.
- Replacing equipment with more energy-efficient alternatives.
- Switching fuel sources to less carbon-intensive options.
- Deploying renewable energy systems.
- Reducing citywide water demand and thereby the energy needed to treat and supply that water.
- Pursuing the energy and GHG co-benefits of green infrastructure and other sustainability projects.

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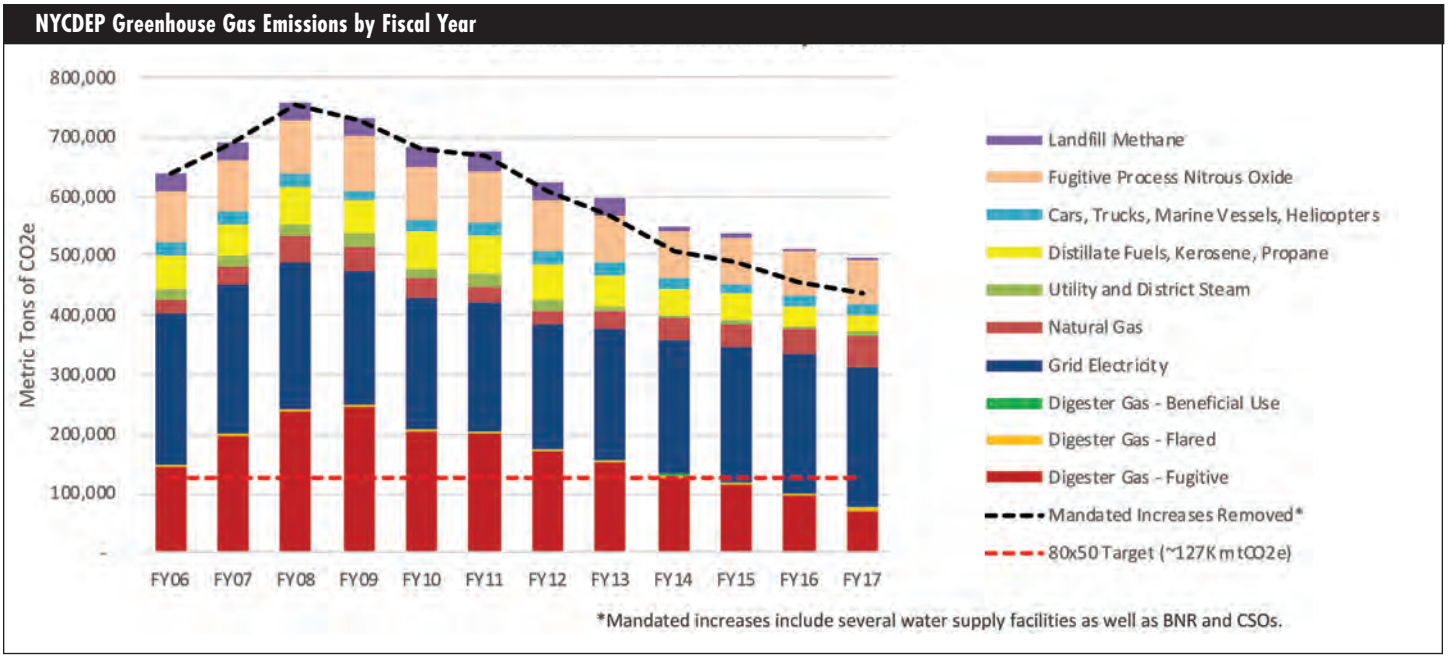
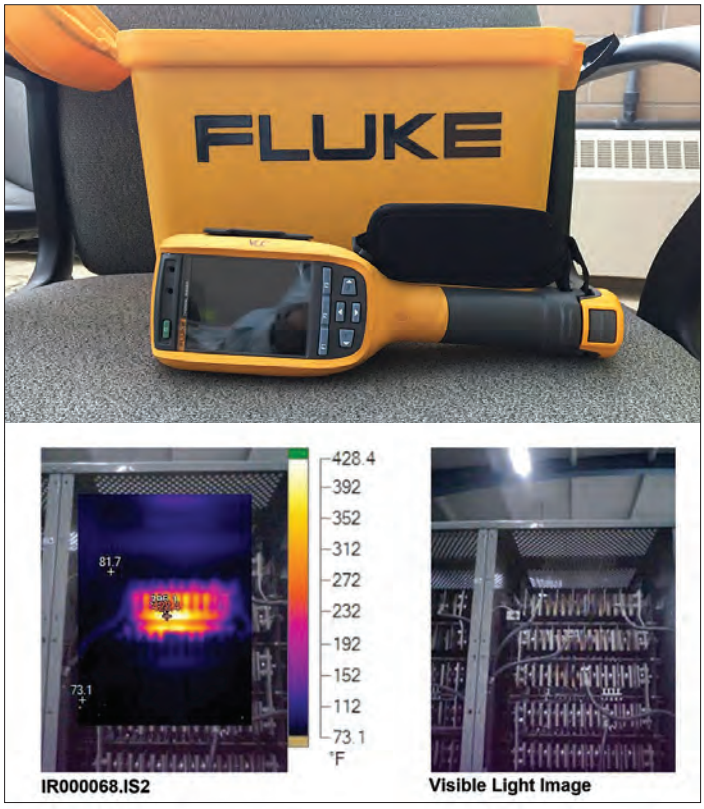


NYCDEP experienced a 22 percent actual reduction and a 32 percent effective reduction in GHG emissions since the base year. The effective reduction excludes mandated increases in energy such as at new CSO facilities, aeration facilities, the UV Disinfection Plant, the Croton Filtration Plant and BNR processes. *NYCDEP*

To oversee NYCDEP's progress toward achieving the *OneNYC* energy and GHG targets – and, before those, Mayor Michael Bloomberg's *PlaNYC* targets set in 2007 through 2013 – the agency created the NYCDEP Office of Energy. This office manages NYCDEP's energy, biosolids, and GHG policy, planning, projects, budgeting and accounting while leveraging external funding opportunities, such as those made available under *PlaNYC* and *OneNYC* by a sister agency, the Division of Energy Management (DEM) at the Department of Citywide Administrative Services.



A thermal imaging camera and a hotspot identified on the main sewage pump resistor bank at 26th Ward Water Resource Recovery Facility. *NYCDEP*

To date, NYCDEP has been awarded over $90 million in funding via the various capital, expense, innovative technology demonstration and demand response grid reliability programs offered by DEM. Securing outside funds plays a key role internally in helping to keep water and sewer rates low for NYCDEP customers, to enable energy and GHG management projects to begin sooner, and to alleviate concerns over competition for funds.

As the GHG accountant for NYCDEP, the Energy Office also formulated a four-pronged strategy for GHG reductions. These initiatives include demand-side solutions, supply-side solutions, traditional renewable energy solutions and carbon-offset solutions, all achieved through engineering and systems changes, as well as organizational culture shift.

Demand-side Solutions

Demand-side solutions include on-site energy conservation and efficiency, on-site equipment and operational improvements, and citywide water demand management.

Total energy usage at NYCDEP over the last decade has remained

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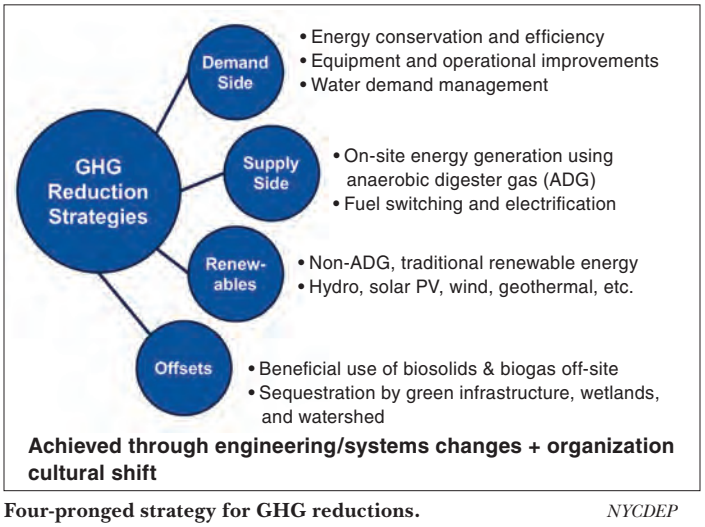

Four-pronged strategy for GHG reductions. *NYCDEP*

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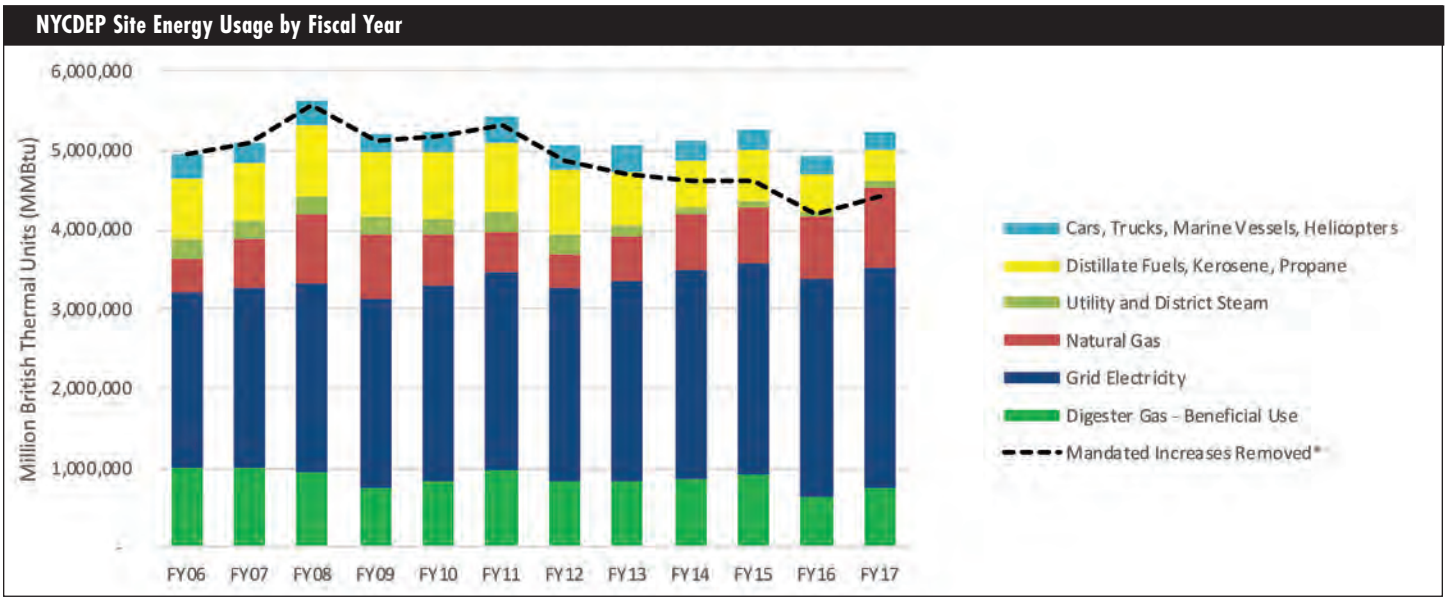


NYCDEP experienced a 5 percent actual increase and an 11 percent effective reduction in energy usage since the base year; energy usage has been fairly constant despite mandates. *NYCDEP*

relatively constant despite the addition of energy-consuming facilities and upgrades, including: the 2-megawatt Catskill-Delaware Ultraviolet Disinfection Facility; the 12-megawatt Croton Water Filtration Plant; several new combined sewer overflow retention facilities; biological nutrient removal at six WRRFs; and other major infrastructure and process upgrades occurring since base fiscal year 2006. This success is due in part to NYCDEP's demand-side solutions.

In 2011 and 2012, NYCDEP completed detailed American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Level 2 energy audits which resulted in the identification of hundreds of ECMs at the fourteen in-city WRRFs and many facilities outside of the metropolitan area. These ECMs included:

- Aeration initiatives such as balancing and optimizing air distribution, maintaining dissolved oxygen at lower thresholds, and inspecting and maintaining diffusers.
- Digester initiatives such as more frequent maintenance of heat exchangers and sludge-to-sludge preheating of thickened sludge.
- Main sewage pump and other large pump initiatives such as eliminating daily dry-weather pumping from combined sewer overflow facilities and operating at higher wet-well levels to reduce head.
- Thickening operation initiatives, such as separate thickening of the primary and secondary sludges through gravity and low-energy mechanical thickening, respectively.
- Odor control initiatives such as operating fans at lower speeds and performing source control.
- HVAC initiatives such as changing thermostat set points and reducing ventilation rates.
- Lighting initiatives such as performing LED upgrades and installing occupancy sensors.

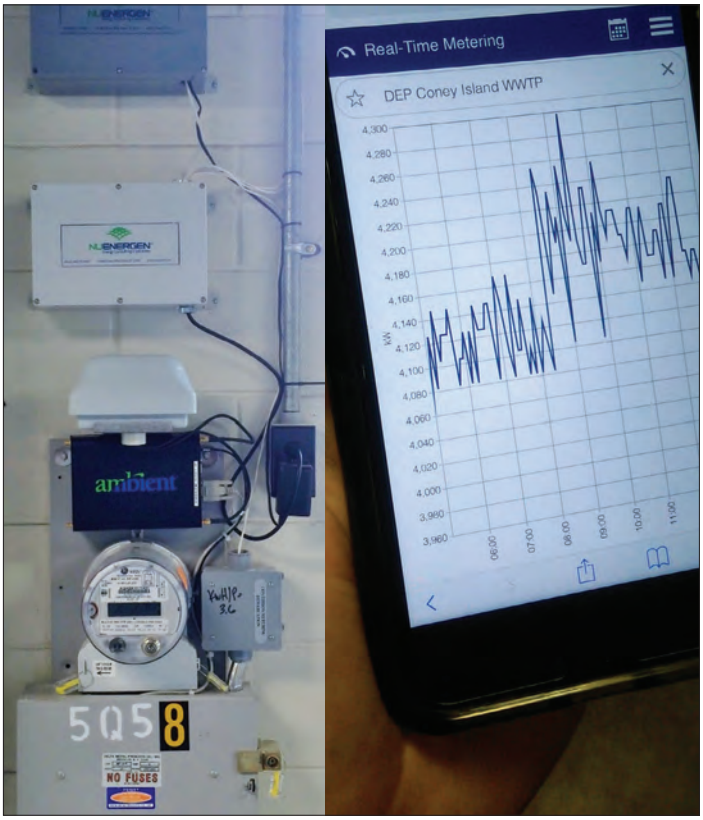
In 2018, NYCDEP completed the SOGR-ECM Integration Study which evaluated existing and identified new ECMs, then recommended any ECMs that are synergistic with NYCDEP's SOGR needs to be incorporated into the capital plan. The integration aims to prioritize energy projects while qualifying these SOGR capital projects for external energy grants, thus mitigating competition for funds, reducing operating costs and helping NYCDEP to realize the *OneNYC* goals.

New turbo process air blowers at 26th Ward Water Resource Recovery Facility. *NYCDEP*

New dewatering centrifuges at Wards Island Water Resource Recovery Facility. *NYCDEP*

In partnership with DEM, NYCDEP has incentivized Energy Reduction Challenges to leverage the competitive spirit between facility staff while instilling long-term behavior changes for active daily energy management. NYCDEP has also installed real-time electric meters (RTMs) at the utility meter level at facilities that participate in the citywide and statewide demand response programs. Through its Operational Excellence continuous improvement program, NYCDEP identified operational set points and standard operating procedures that allow facilities to react quickly if power usage veers from optimized levels. NYCDEP and DEM also offer courses on energy-efficient building and equipment operations and maintenance practices to municipal staff. Finally, although minimal sub-metering exists currently, NYCDEP is exploring measurement and verification solutions for projects that receive DEM funding. In general, the value of training opportunities and of energy data availability and reporting must not be underestimated when empowering facility staff to manage energy and demand on a daily and real-time basis.

NYCDEP is also seeking embedded energy usage avoidance through its sustainability efforts, described further under the Energy and Carbon Offsets section of this article.



A real-time electric meter at a water resource recovery facility; photo of mobile functionality of real-time data. *NYCDEP*

Supply-side Solutions

Supply-side solutions include fuel-switching and on-site electric and thermal energy generation from beneficial use of biogenic anaerobic digester gas.

NYCDEP has experienced measurable GHG reductions by switching both stationary and transportation energy sources from residual fuel oils to distillate fuel oils, natural gas and ADG; from diesels to biodiesels and gasoline; and from strictly fossil-based fuel combustion to electrification. NYCDEP has two WRRFs with on-site cogeneration engines that beneficially use biogenic ADG to produce electricity and heat, and a third system is expected to

Cogeneration system at Coney Island Water Resource Recovery Facility. *NYCDEP*

come online at North River facility by 2021. Furthermore, most in-city WRRFs have boilers that beneficially use ADG to produce heat, and several more WRRFs will be installing these systems in the decade to come.

Even so, only about 15 percent of NYCDEP's total energy usage is derived from ADG. Currently, NYCDEP is beneficially using only about 35 percent of the 3.6 billion cubic feet of ADG that it produces annually. Therefore, because current levels of ADG production are insufficient for NYCDEP to accomplish energy neutrality, the agency will need to improve its wastewater treatment process train and handling systems in order to maximize ADG production. The agency must also eliminate fugitive emissions of ADG, explore opportunities to co-digest high-strength wastes to boost ADG production rates, and pursue on-site traditional renewable energy solutions.

Traditional Renewable Energy Solutions

Traditional renewable energy solutions include non-ADG renewable energies such as solar photovoltaic, hydropower, wind power, and geothermal systems.

NYCDEP's portfolio of real estate includes some of the best locations in the city to produce renewable energy. The WRRFs and landfills are generally large, unshaded parcels of land that are at a premium in New York City, which can offer a rare potential for large-scale solar and wind power installations. NYCDEP already has several solar photovoltaic (PV) systems installed, the largest of which is a 1.2-megawatt rooftop system at the Port Richmond facility on Staten Island. NYCDEP has installed portable solar carport electric vehicle charging stations at three facilities. The agency is also exploring other non-rooftop innovative applications of solar PV, including solar canopies over wastewater treatment process tanks and parking lots, ground-mounted systems on vacant land, and floating or mounted installations over reservoirs.

Hydroelectric power is a key component of NYCDEP's efforts to create a clean power portfolio, while simultaneously supporting economic development in the host communities, generating revenue for New York City, and reducing NYCDEP's overall carbon footprint. NYCDEP owns several hydroelectric facilities and is studying

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Solar PV system at Port Richmond Water Resource Recovery Facility. *NYCDEP*

Solar carport portable electric vehicle charging station at Newtown Creek Water Resource Recovery Facility. *NYCDEP*

Cannonsville Spillway. *NYCDEP*

the feasibility of building more full-scale hydroelectric plants. Micro-hydroelectric and tidal power applications are also being explored to harness the potential energy in the water distribution and wastewater treatment systems.

Further downstream, NYCDEP will be piloting an organic Rankine cycle system on-site at a WRRF to generate a small amount of electricity from boiler heat that would otherwise have been wasted. There may be other opportunities to leverage the fairly-constant temperature of the water in NYCDEP's sewerage collection and conveyance systems to make this energy available for district heating and cooling. NYCDEP aims to evaluate these and other innovative solutions in its upcoming *Energy and Carbon Neutrality Plan*.

Energy and Carbon Offset Solutions

NYCDEP is pursuing energy and carbon offset solutions such as the off-site beneficial use of biosolids and ADG, as well as carbon sequestration and avoided energy usage occurring in green infrastructure, restored wetlands and forested lands.

WRRFs can provide considerable value in addressing both citywide and global energy and GHG concerns. In support of the *OneNYC* "Zero Waste to Landfills" goal to eliminate new landfill methane emissions, a food waste co-digestion demonstration and study at the Newtown Creek facility became operational in 2016. The demonstration reached a milestone of 100 daily tons of source-separated organics diversion from landfills in 2018. By the end of this three-year project in 2019, the WRRF targets ramping up to 250 tons of food waste diverted per day. The addition of these high-strength wastes to NYCDEP's digesters is expected to increase the production and quality of NYCDEP's ADG significantly, and the study is already showing promising results in its first two years. NYCDEP is exploring other opportunities to co-digest food waste at WRRFs across the city, especially at the Hunts Point facility where a new digester complex is currently in design.

In a related project, NYCDEP is partnering with the local natural gas utility to construct a biogas conditioning system on-site at the Newtown Creek facility which will clean the plant's unused ADG to pipeline quality then inject it into the local natural gas grid for beneficial use by residences and businesses in the area. This system is expected to be operational by summer 2019. NYCDEP is seeking other opportunities to inject renewable natural gas into the pipeline at WRRFs across the city, including to supplement neighborhood system shortages during the coldest winter days and for district energy microgrids.

Although NYCDEP is currently landfilling the majority of its biosolids due to expense, these wastewater treatment process by-products are incredibly valuable resources that can provide carbon sequestration or avoidance advantages if beneficially used. Sustainability-enhancing products, like phosphorous and bioplastics, can be extracted during the wastewater treatment process, thereby avoiding GHG emissions from otherwise intensive manufacturing processes. NYCDEP is investigating various technologies and process improvement opportunities that can increase the quality of its biosolids and make available other products for beneficial use.

NYCDEP's water demand management efforts have incentivized municipal, residential and non-residential water efficiency programs by performing toilet replacements, overseeing water reduction challenges and providing funding for water reuse projects. The utility has optimized the water distribution system by performing repairs and installing metering for leak detections. These measures

Food waste storage tank and digester eggs at the Newtown Creek Water Resource Recovery Facility. *NYCDEP*

Alley Pond Park Salt Marsh in Queens. *NYCDEP*

A rain garden in Queens. *NYCDEP*

have resulted in a reduction in citywide consumption of 9.4 million gallons per day, equating to over 100 metric tons of carbon dioxide equivalent emissions avoided annually.

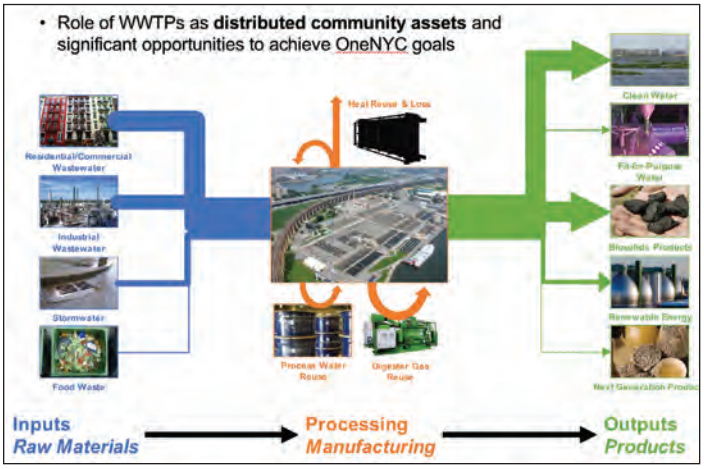
An ongoing study will identify water conservation opportunities at WRRFs, such as utilizing plant effluent instead of city water, retrofitting mechanical seals and replacing float valves. This study is an extension of the Water-Energy Nexus study completed in 2016, which developed an award-winning Excel-based tool to better understand the carbon footprint and embedded energy benefits of NYCDEP's sustainability programs.

The green infrastructure (GI) program captures about 500 million gallons of stormwater flow per year, thus avoiding energy usage at WRRFs to treat that runoff. Over 3,900 GI assets constructed or under construction across the city are saving over 200 metric tons of carbon dioxide-equivalent emissions annually. Another element of GI, restored wetlands, can both improve water quality and sequester carbon emissions. As of fiscal year 2015, NYCDEP had created and restored 42 wetlands, which are sequestering 200 metric tons of carbon dioxide-equivalent emissions annually. Finally, NYCDEP acquired over 138 thousand acres of land to attain its Filtration Avoidance Determination, and these acres sequester about 160,000 metric tons of carbon dioxide-equivalent emissions annually via their vegetation and soil.

Summary

NYCDEP's core mission to protect public health and the environment defines the agency and provides the basis for enhancing sustainability for the utility. Among New York City agencies, NYCDEP has the widest geographic distribution of the most varied types of assets, which presents the utility with numerous opportunities to increase energy efficiency, improve electricity reliability and invest in renewable energy projects, thus enabling NYCDEP to be an essential leader and make major strides toward accomplishing the ambitious energy and sustainability goals set for the city.

NYCDEP thanks its employees and project partners for their diligence and enthusiasm in supporting these initiatives together as the city strives to mitigate the worst effects of climate change and to move the wastewater treatment industry toward its destiny of resource recovery and global sustainability.



Wastewater treatment plants are becoming Resource Recovery Factories. *NYCDEP*

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UNLEASH Innovation Lab and Singapore NEWater

by Taylor Brown

If you had asked me at the beginning of this year to find Singapore on a map, I wouldn't have been able to. That changed when I was selected by the United Nations to attend the UNLEASH Innovation Lab in Singapore in June 2018. UNLEASH is a global initiative that annually brings together 1,000 young academics, entrepreneurs and technical experts (talents) from around the world; the talents this year represented 110 countries. Over one week, talents are tasked with developing an innovative, practical and scalable solution to one of the United Nations Sustainable Development Goals (SDGs).

The SDGs were agreed upon in 2015 by all United Nations member states and consist of 17 goals ***(Figure 1)*** and 169 targets to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030. To realize the SDGs, it is estimated that the world will need to invest a staggering $5 trillion to $7 trillion per year, or roughly 7 percent to 10 percent of global annual gross domestic product. This will require new and innovative solutions that will challenge traditional business models and approaches.

Figure 1. The 17 United Nations Sustainable Development Goals (SDGs). *United Nations (United Nations n.d.)*

UNLEASH Working Group

For the conference, I was put into the working group for SDG #6: Ensure access to water and sanitation for all. I worked with a diverse team to address the issue of arsenic-contaminated groundwater in Bangladesh.

In Bangladesh, 39 million people are consuming water with arsenic concentrations above 10 µg/L. This problem was discovered in the 1990s and 46 percent of shallow tube wells exceeded the limit. There was a massive tube well screening campaign from 2000 to 2006, where wells were tested for arsenic and painted red if the water tested above the Bangladesh standard (50 µg/L) or green if the water tested below the Bangladesh standard. By 2006, an estimated 100,000 alternative sources were installed in arsenic-affected areas and 70 percent of new installations were deep tube wells *(Inauen, et al. 2013)*. Technologies that avoid arsenic contamination, rather than remove arsenic, are more cost-effective in the long term and maintenance of arsenic removal technologies can be cumbersome.

A study conducted in 2013 *(Inauen, et al. 2013)* used the RANAS model (Risks, Attitudes, Norms, Abilities, and Self-regulation) to report that one-third of households in Bangladesh who are both at risk of drinking arsenic-contaminated water, and who have access to an arsenic-safe water option, do not use these safer options. Users and non-users both understood the negative impacts of drinking arsenic-contaminated water, but many non-users reported that their safe water option involved more time, effort, and/or cost.

My working group team used the UNLEASH five-step Innovation Process to build a complex problem tree and look at how to influence household decision-makers to create long-term behavior change. The five phases of the UNLEASH Innovation Process are: Problem Framing; Ideation; Prototyping; Testing; and Implementing *(Drain 2018)*. The process ensures that we are not solving for a problem that doesn't exist and ultimately leads to the implementation of solutions that can help address the Sustainable Development Goals.

Through the UNLEASH Innovation Process, we determined that the top-down blanket-testing approach of the past left no infrastructure in place for monitoring existing wells or for testing new wells. Based on this framing of the problem, my team developed a solution that would build testing capacity locally, leading to sustained awareness in areas with high arsenic exposure and giving people more control over their water supply. At the end of the conference, we pitched our solution to judges, peers and potential funders. I am still working with my team to publish a paper and I am also exploring this emerging issue in Pakistan.

Arsenic in Drinking Water

Inorganic arsenic is naturally present at high levels in the groundwater of several countries; at least 140 million people in 50 countries drink water containing arsenic at levels above the World Health Organization provisional guideline of 10 micrograms per liter (µg/L). Long term exposure to arsenic from drinking water can cause many health issues including cancer, skin lesions, cardiovascular disease, diabetes and impaired intellectual function. In utero and early childhood exposure has been linked to negative impacts on cognitive development and increased deaths in young adults.

(World Health Organization 2018)

NEWater: Recycled Water in Singapore

Built into the conference were field trips to explore Singapore. The SDG #6 working group was able to visit the NEWater Visitor Centre, a water museum showcasing Singapore's journey towards water sustainability and how NEWater is produced.

The NEWater process recycles used water into ultra-clean, high-grade reclaimed water, cushioning Singapore's water supply against dry weather and moving the country towards water sustainability ***(Figure 2)***. Today, there are five NEWater plants supplying up to 40 percent of Singapore's current water needs. By 2060, NEWater is expected to meet 55 percent of Singapore's future water demand.

In the 1970s, the Singapore government commissioned a study to determine the feasibility of producing reclaimed water. At that time, the necessary technology had a much higher cost and unproven reliability. By the 1990s, the cost and performance of membrane technology had improved greatly. The energy cost of reverse osmosis has come down by 75 percent since the 1970s.

As it is ultra-clean, NEWater is used mainly for industrial and air-conditioning cooling purposes at wafer fabrication plants, industrial estates and commercial buildings. NEWater is delivered to industrial customers via a dedicated pipe network. The biggest users of NEWater are wafer fabrication plants, which create the sil-

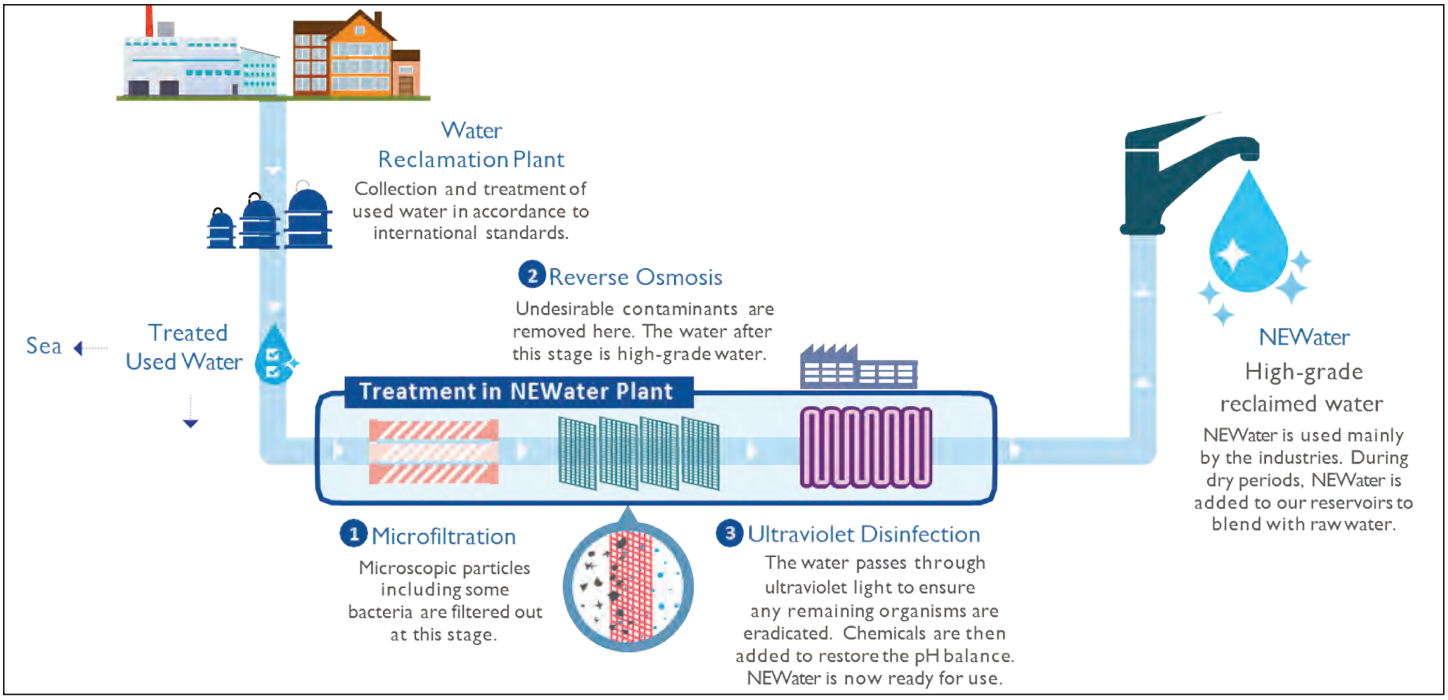

Figure 2. Diagram of the NEWater collection and treatment process. *Public Utilities Board, Singapore's National Water Agency (Public Utilities Board 2017)*

icon base for circuitry used in electronics and for microprocessors used in computers. Wafer fabrication occurs under clean-room conditions and requires water quality that meets even more stringent metrics than drinking water.

During dry periods, NEWater is added to Singapore's reservoirs to blend with raw water. The raw water from the reservoir is treated before it is supplied to consumers as tap water. This is done to be mindful of public attitudes and acceptance of reused water, as well as to provide an additional environmental buffer and allow for trace minerals to be reintroduced by blending with reservoir water.

When then United Nations Secretary General Ban Ki Moon visited a NEWater plant in 2012, he said he would recommend the strategy of recycling wastewater to other countries suffering from water scarcity. Instead of toasting Prime Minister Lee Hsien Loong with the traditional glass of wine, Mr. Ban toasted him with a bottle of NEWater calling it something far more valuable than a glass of wine.

Recycled Water in the U.S.

The introduction of reuse systems can be difficult due to a high degree of public skepticism. There have been attempts to recycle sewage in the most water-scarce areas of the United States. California's Orange County Water District (OCWD) began recycling sewage water for non-potable use in the 1970s. It was not until 2008 that the recycled water was brought into the drinking supply, which required extensive public relations and education campaigns *(Monks 2015)*.

Texas aims to generate 10 percent of all new water supplies through reclaimed water by 2060. Big Spring, Texas, has the first Direct Potable Reuse system in the United States, which sends reclaimed water to the final treatment without passing it through groundwater reserves first *(Monks 2015)*. Mixing reclaimed water with groundwater is unnecessary, as it has the potential to re-contaminate the reclaimed water, but it is done to ease the minds

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My team from left to right: Lucky Musonda from Zambia, myself, Vismit Bansal from India, Anna Thyssen from Australia, Bulbul Ahmed from Bangladesh and Anita Etale from Kenya. *Taylor Brown*

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Me at the NEWater visitor center with my NYWEA t-shirt that says "WATER'S WORTH IT". *Taylor Brown*

of the public.

With improved awareness, reclaimed water can be brought to drinking water supplies directly, which would decrease energy use and costs. In the coming decades, drinking water that comes from recycled sewage will be normalized and be a great defense against water scarcity.

Taylor Brown is a Civil Engineer with Wendel and may be reached at tbrown@wendelcompanies.com.

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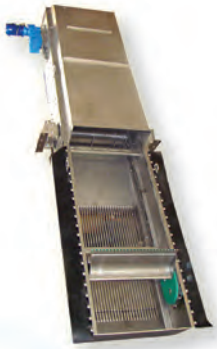

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Habitat Restoration Using Local Compost

by Christopher Calkins, John McAuliffe, Tony Eallonardo and Brad Kubiak

The Resurgence of Onondaga Lake

Onondaga Lake is a vital resource for the Central New York community. Contaminated for decades, the lake is now making a historical resurgence that is the result of one of the largest, most complex lake cleanup and ecological restoration projects in North America. Water quality in Onondaga Lake is the best it has been in more than 100 years.

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.

OBG, an integrated engineering solutions company, has served as a strategic partner to Honeywell in this restoration project, focused on creating healthy, sustainable habitats that will benefit the lake's ecosystems and neighboring communities.

The lake cleanup combined dredging and capping designs with long-term habitat restoration leading to an environmentally protective solution. Habitat enhancements focused on diversification, the reintroduction of native species, and connectivity. These were achieved through new and enhanced wetlands, shoreline improvements and the robust habitat layer for the lake bottom.

Restoring the Western Shoreline of Onondaga Lake

The cleanup also included remediation of several upland sites adjacent to Onondaga Lake that contributed to the lake's pollution. To achieve a clean lake and restored habitats, these upland areas needed to be addressed to prevent contamination of local tributaries and groundwater that discharge to the lake.

One such upland site is located along Onondaga Lake's western shoreline, south of Nine Mile Creek. The site is an extensive complex of inactive waste-settling basins (comprised of by-products from the local soda ash industry) located at the western nexus for the City of Syracuse and adjacent suburbs. Nearby is the New York State Fairgrounds, as well as industries, businesses, municipal facilities and natural resources such as Onondaga Lake and its tributaries.

Restoration of this site has integrated the goals of the overall Onondaga Lake restoration program with various recreational desires and habitat enhancements. Over the last five years, the site has grown into a hub of activity with more than $100 million of private and public investments. This has consisted of the design and implementation of a wide range of remedial measures, including the installation of 10,000 linear feet of groundwater collection systems; rehabilitation of 45 culverts totaling 6,000 linear feet of stormwater pipes; stabilization of 1,600 linear feet of waste bluffs that were impacting Onondaga Lake; leachate seep collection and remediation along a 7,000-foot stormwater ditch; and the ongoing installation of waste cover systems totaling 171 acres.

Recreational investments have included construction of the Lakeview Amphitheater, extension of the West Shore Bike Trail and boat dock, a large, redeveloped parking area, and upgrades to the Onondaga County sanitary sewer pump station.

Developing a Green Remedy

As part of the program's ecological restoration and enhancement efforts, the New York State Department of Environmental Conservation (NYSDEC) required a green remedy that would cover more than 170 acres of this western shoreline site to limit exposure to the underlying waste materials. The composition and thickness of the needed covers varied across the site according to the intended end use of the site and the level of contamination.

While thick, traditional covers were designed and constructed in areas intended for recreational use, a large, 76-acre portion of the site that would not be used recreationally required a different approach. This area had low contaminant concentrations and could support beneficial ecological features. Placing a traditional cover over this area also would have increased ecological costs through transport of materials and disrupted habitats. As a result, the best approach was determined to be a vegetation enhancement cover comprised of native species, and more extensive cover of the waste to reduce erosion.

A pilot study was performed with the input of the State University of New York College of Environmental Science and Forestry (SUNY-ESF) before full-scale implementation of the vegetation

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OCRRA compost was applied at a rate of 300 cubic yards per acre. *Klineberg Photography (OCRRA)*

Use of compost resulted in the successful establishment of vegetation and improved habitat diversity for birds and other wildlife. *OBG*

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Onondaga Lake's restoration program is creating healthy, sustainable habitats that benefit the lake's ecosystems and neighboring communities.

Honeywell

enhancement cover. The study evaluated two basic approaches to applying a specified native seed mix to determine which approach had the greatest improvement in vegetation development and cover of the site: hydroseeding and compost application.

The hydroseeding application consisted of hydraulic application of hydromulch and seed, while the compost application consisted of pneumatically applying compost, with the seed mixed into the compost from a hopper. While the hydroseeding treatment provided the best short-term results for vegetation growth, the initial benefits waned after a year as the cover crop vegetation declined, and the hydromulch material delaminated from the soil surface, limiting its protective value.

Over the course of two growing seasons, the compost application supported robust vegetation growth. The material was resilient, especially on steep, exposed banks, where it provided lasting protection from erosion. Based on this study, compost was selected for the vegetation enhancement cover.

Local Compost: Businesses and School Children Help Onondaga Lake Flourish

The Onondaga County Resource Recovery Agency (OCRRA) collects food scraps from 15 schools across Central New York, as well as from dozens of businesses, including restaurants, hospitals, cafeterias, colleges and grocery stores. The scraps are turned into compost for use in gardens, landscapes, and green roofs. Together, these schools and businesses are keeping millions of pounds of food scraps out of the trash and turning them into a valuable resource.

The organic material is transported to OCRRA's award-winning Amboy Compost Facility in Camillus, New York, where it is processed into nutrient-rich compost. The composting is done through OCRRA's aerated static pile system, which is permitted to process more than 9,000 tons of food scraps and 27,000 tons of yard waste into 30,000 yards of compost.

The compost is rigorously tested as part of the U.S. Composting Council's Seal of Testing Assurance (STA) program and is utilized in a wide variety of applications ranging from wetland restoration to residential landscapes and gardens. The material has been used at the Rosamond Gifford Zoo's rain garden, the green roof at the Jacob Javits Convention Center in New York City, and on the parade grounds of U.S. Military Academy at West Point.

For the Onondaga Lake cleanup, OCRRA's compost has been used with a specified native seed mix and other amendments for the phased implementation of the vegetative enhancement cover system on Onondaga Lake's western shoreline. Using OCRRA compost resulted in a 25 percent reduction in material costs, and a five percent reduction of application costs due to the quality of the compost. The effective screening processes used at OCRRA in making the compost require less equipment on site, resulting in less time needed to apply the material.

Establishing Vegetation and Improving Habitat Diversity

The use of this local compost for the western shoreline of Onondaga Lake has resulted in the successful establishment of vegetation and improved habitat diversity for birds and other wildlife. More than 60 species of fish, birds, and other wildlife have returned to this site. While dozens of native plant species can be found throughout the vegetative enhancement areas, the aesthetic improvement of the site is significant, with parklike views now available year-round for patrons of the Lakeview Amphitheater and West Shore Bike Trail.

It is expected that as the vegetation continues to develop over time, the annual growth of the vegetation will continue improving soil conditions on site and attracting a wide range of birds and other wildlife.

Christopher Calkins is a Senior Vice President with OBG and may be reached at Christopher.Calkins@obg.com. John McAuliffe is the Honeywell Syracuse Program Director and may be reached at John.McAuliffe@Honeywell.com. Tony Eallonardo, PhD, is a Subject Matter Expert/Technical Manager with OBG and may be reached at Tony.Eallonardo@obg.com. Brad Kubiak, PE, is a Senior Project Manager with OBG and may be reached at Brad.Kubiak@obg.com.

Welcome Madison Quinn!

Madison Quinn

NYWEA welcomes Madison Quinn to its staff. Prior to joining NYWEA, Madison was the project coordinator for Onondaga County's nationally-renowned comprehensive stormwater management program, *Save the Rain*. From 2011 through 2013, she worked for the Onondaga County Executive's Office and was a project manager for the combined sewer overflow public notification website for the Sewage Pollution Right to Know regulations. More recently, she administered the county's Green Improvement Fund. This public-private partnership program provides millions of dollars of grant funding to implement green infrastructure. The Onondaga County Department of Water Environment Protection (WEP) awards the grants to program partners in the business and nonprofit sectors within the City of Syracuse. Madison also managed the *Save the Rain* community outreach team, including planning and marketing for the award-winning *Save the Rain* Clean Water Fair, the department's largest public outreach event held each year, which draws hundreds of visitors to the Metro Wastewater Treatment Plant.

Madison holds her Master's Degree in Public Administration, with a concentration in Environmental Policy and Administration, from the Maxwell School of Citizenship and Public Affairs at Syracuse University. She earned a Bachelor of Science Degree in Environmental Science & Policy, with a minor in Biology, from Clarkson University.

Madison is very familiar with NYWEA's programs, having served in various volunteer capacities on several committees and task forces including the Public Outreach and Publications Committees, as well as NYWEA's website task force. In her new role as NYWEA's Communications Manager, she will coordinate the Member Education training program as well as administer our $1 million scholarship program, which awards $50,000 in scholarships annually to students pursuing environmental degrees.

In Madison's spare time she enjoys attending the local Syracuse film festivals, pickling vegetables, welding and experiencing all things water!

Tap Water Taste Test Competition Results Are In!

Here is an excerpt from the September 4, 2018 edition of the weekly NYCDEP "Pipeline"

New York City tap water was awarded the top prize in the 2018 New York State Tap Water Taste Test competition. The statewide event began with 30 municipalities competing in regional competitions. The winners met on Thursday, August 30, at the Great New York State Fair in Syracuse. In the finals, New York City's tap water was pitted against drinking water from other regional winners, including Saratoga County and the Village of Holley (Orleans County). State Fair visitors sampled tap water from the three suppliers and ranked them by taste, with New York City's tap water judged the best.

(http://www.nyc.gov/html/dep/pdf/pipeline/09452_pipeline.pdf)

A Week in the Life of a Great Lakes Scientist on the Research Vessel *Lake Guardian*

by Emily Sheridan

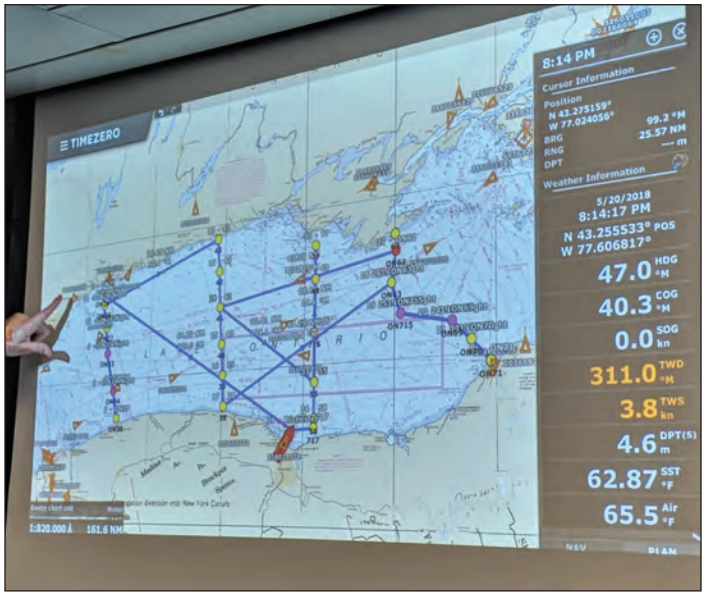
A science cruise is an awfully big adventure! That's what I learned from my May 2018 experience working on board the United States Environmental Protection Agency's (USEPA's) Research Vessel (R/V) *Lake Guardian* ***(Photograph 1)***. The experience was a once-in-a-lifetime opportunity, as the *Lake Guardian* only conducts intensive research on Lake Ontario once every five years as part of the Great Lakes Cooperative Science and Monitoring Initiative (CSMI). CSMI is a binational collaboration designed to carry out critical Great Lakes research needed to aid our understanding and management of Lake Ontario's nearshore and offshore water quality and fisheries.

Photograph 1. The *Lake Guardian* at dock. *Emily Sheridan*

This rare opportunity to learn more about Lake Ontario's nearshore and offshore conditions will help me, as a Great Lakes Watershed Coordinator, to better understand and communicate with stakeholders. Lake Ontario nearshore and offshore research can help us better understand the connections between the Lake Ontario watershed and conditions in the open lake. The Lake Ontario CSMI aligns with the goals of New York's Great Lakes Action Agenda for coordinated science, monitoring and information management. The CSMI results will inform management actions needed throughout New York's Great Lakes basin to achieve water quality and natural resource management goals.

For the research cruise completed in May, we traversed five transects within the 7,320 square-mile area of Lake Ontario ***(Photograph 2)***, and sampled water quality, zooplankton and larval fish at 22 different stations during daylight conditions. Sampling was repeated at night at some stations to collect mysids, a type of small freshwater shrimp that is most active at night, which is an important source of food for fish.

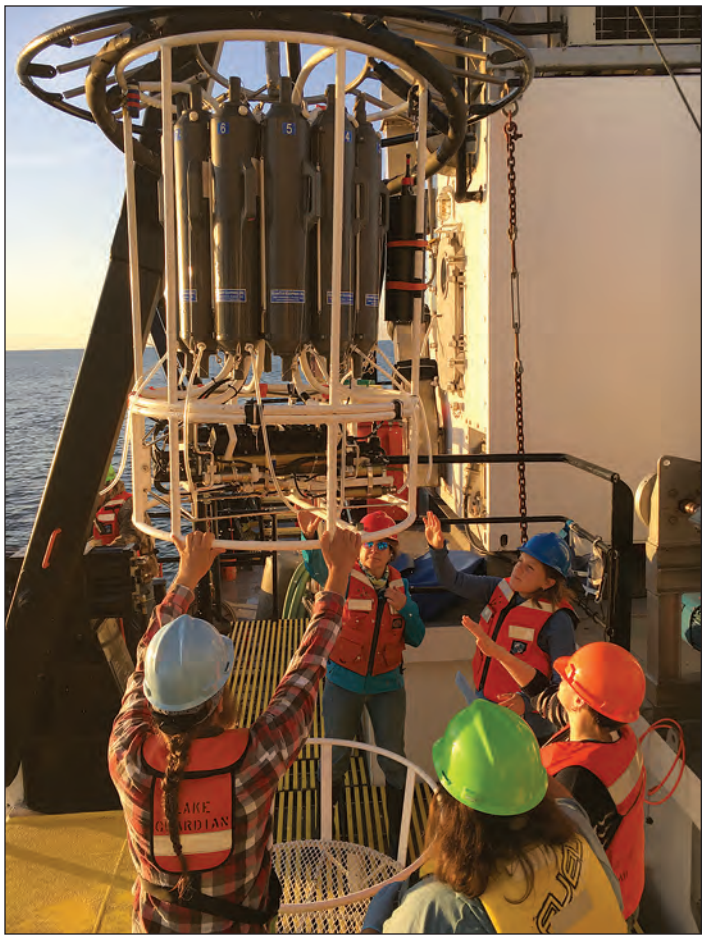
On my first night on the ship, I met the dedicated crew and marine technicians that serve on the *Lake Guardian*. The hospitable and talented chefs prepared excellent meals in the ship's



Photograph 2. Survey route for spring sampling in 2018. *Emily Sheridan*

Photograph 3. The ship's galley. *Emily Sheridan*

Photograph 4. The ship's sleeping quarters. *Emily Sheridan*



Photograph 5. The rosette sampler with Niskin bottles. *Conrad DeBarros*

Photograph 6. Emily Sheridan (foreground) and Cornell researcher James Watkins placing the Tucker Trawl. *Conrad DeBarros.*

kitchen ***(Photograph 3)***. I shared a small cabin – four bunkbeds and a bathroom/shower ***(Photograph 4)*** – with two very knowledgeable researchers from Cornell University and the USEPA. Aside from the motion of the boat and the sounds of machinery and foghorns, it felt like we were staying in a dorm room.

The ship and its crew sample all five of the Great Lakes – Superior, Michigan, Huron, Erie and Ontario – each year. The R/V *Lake Guardian* conducts routine spring and summer monitoring every year on all the lakes, while the more intensive CSMI monitoring occurs on only one lake each year, rotating around the lakes on a five-year cycle. The crew and technicians have mastered how to operate the ship and the high-tech equipment used to sample the waters and aquatic food web, often under challenging weather conditions.

One of the specialized tools they use is the rosette sampler ***(Photograph 5)***, which allows researchers to capture water samples from precise depths between the lake bottom and the surface in special bottles known as Niskin bottles. An electric winch system and remotely operated switches control the depth of the rosette sampler, as well as the depth that the Niskin bottles are triggered to open and collect a water sample. Detailed analysis of these water samples, which are taken at different depths across the lake, can help us understand the seasonal flow of nutrients through the system. Researchers from USEPA and Environment and Climate Change Canada processed these samples in a shared lab on board the ship.

I also worked with Cornell researchers who were responsible for collecting the zooplankton and mysid samples on the cruise. They used nets with two different mesh sizes to collect plankton from various water depths between the lake bottom and the surface. Understanding the condition of phytoplankton and zooplankton populations at the base of Lake Ontario's aquatic food web is essential to understanding the lake's ability to support fish populations that rely on these species for food. Researchers also used a Tucker Trawl ***(Photograph 6)***, a large net towed at different water depths behind the *Lake Guardian*, to capture native larval fish. This information will inform fish stocking programs and native fish restoration efforts on how best to sustain the delicate balance of the predator-prey dynamics of Lake Ontario.

While on board the ship, I was able to see things that were not part of the surveys, including a bundle of balloons floating in the middle of the lake that likely will persist there for years to come. When completing the fish larvae surveys using the Tucker Trawl, there were floating debris, fibers and plastic particles visible in the samples. Additional research may help us understand what impacts these small plastics have on the open lake and near shore ecosystems.

After an amazing work experience on board the *Lake Guardian*, I came away with a better understanding of Lake Ontario research, and an appreciation for the Lake Ontario open waters. I may never see Lake Ontario the same way again, but I will always have the cherished memories of this adventure, working on the open lake with the great minds that tirelessly work to collect this data to help us ensure that our decisions about this complex and dynamic system are informed by science.

Thank you to the Captain and crew of the *Lake Guardian*, the USEPA, the researchers that shared their knowledge with me, and to the New York State Department of Environmental Conservation (NYSDEC) Great Lakes Program for supporting my participation

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in the research cruise. I look forward to learning the results of the Lake Ontario CSMI that should be released in January of 2020. Keep an eye out for them on the NYSDEC's CSMI webpage at: *https://www.dec.ny.gov/lands/95533.html*. For more information on the USEPA's R/V *Lake Guardian*, visit: *https://www.epa.gov/great-lakes-monitoring/lake-guardian*.

Emily Sheridan is the Eastern Great Lakes Watershed Coordinator with the New York State Department of Environmental Conservation Great Lakes Program. She may be reached at emily.sheridan@dec.ny.gov.

Photograph 7. Sunset view in the middle of Lake Ontario on the Lake Guardian. *Emily Sheridan*

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Upcoming Events

October 24, 2018 November 8, 2018	Advanced Primary Treatment and Nutrient Removal Slater Chemical Fire Co., 76 Old Glenham Rd., Glenham, NY Chenango Town Hall, 11529 State Rte. 12, Binghamton, NY
November 7, 2018 November 29, 2018	Mathematics for Water and Wastewater Operators New Rochelle WWTP, 1Le Fevres Lane, New Rochelle, NY Vischer Ferry Firehouse, 360 Riverview Road, Rexford, NY
November 13, 2018 November 15, 2018	Wastewater Professional's Guide to Online Process Instrumentation for Biological Nutrient Removal (BNR) Activated Sludge Monitoring Van Lare Plant Training Room, 1574 Lake Shore Blvd., Rochester, NY Niagara County Fire Training Center, 5574 Niagara St. Ext., Lockport, NY
November 15, 2018	NYWEA/NYSAWWA Asset Management Conference Hilton, Downtown Albany, NY
February 3-6, 2019	NYWEA's 91st Annual Meeting & Exhibition New York Marriott Marquis, New York, NY

Operator Quiz Test No. 121 – Math Math Math

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. Which of the following is the correct equation for the area of a circle?
   a. (Base)*(Height) / 2
   b. (π)*(Radius^2)
   c. (Length)*(Width)
   d. (π)*(Diameter)

2. What is the approximate detention time in hours of a clarifier with a total volume of 0.5 million gallons and an influent flow rate of 12.5 MGD?
   a. 1.0 hour
   b. 25 hours
   c. 2.5 hours
   d. 0.5 hour

3. Calculate the surface overflow rate of a tank that is 15 ft deep x 30 ft long x 10 ft wide with an influent flow rate of 0.15 MGD.
   a. 200 gpd/ft^2
   b. 300 gpd/ft^2
   c. 400 gpd/ft^2
   d. 500 gpd/ft^2

4. If a rectangular tank is 150 ft x 25 ft x 15 ft, what is the volume in cubic feet?
   a. 375 ft^3
   b. 3750 ft^3
   c. 56,250 ft^3
   d. 420,750 ft^3

5. If a rectangular tank is 90 ft x 30 ft x 12 ft, what is its approximate volume in gallons?
   a. 270,000 gal
   b. 242,000 gal
   c. 32,000 gal
   d. 320,000 gal

6. 1 MGD = _____ gpm?
   a. 1,000,000
   b. 41,666
   c. 1440
   d. 694

7. Plant influent BOD averages 130 mg/L. The daily average influent flow is 100 MGD. What is the average daily BOD loading for this plant?
   a. 108,420 lbs
   b. 13,000 lbs
   c. 97,240 lbs
   d. 130,000 lbs

8. Calculate the mean cell residence time using the following data:
   Aeration system flow: 5 MGD
   WAS: 400 lbs/day
   Aeration tank size: 90 ft x 30 ft x 12 ft
   FE TSS: 3.0 mg/l
   Aeration tank MLSS: 2,000 mg/l
   Clarifier volume: 150,000 gal
   Clarifier total solids: 400 lbs
   a. 15.5 days
   b. 12.2 days
   c. 8.4 days
   d. 6.3 days

9. Calculate the Food to Microorganism ratio with a BOD_5 of 20,000 lbs/day and MLVSS of 100,000 lbs.
   a. 0.1
   b. 0.2
   c. 0.3
   d. 0.4

10. Calculate the Sludge Volume Index from the following data. Assume a 1,000 mL sample is used.
    30 min settling test result: 150 mL
    MLSS: 2500 mg/L
    a. 60
    b. 120
    c. 180
    d. 240

Answers and math explained 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

New York Water Environment Association, Inc.

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

Operator Quiz Test No. 121 "Math Math Math" Answers Explained

1. (a) Is the area of a right triangle; (b) is the correct equation; (c) is the area of a rectangle; (d) is the circumference of a circle.

2. Detention time = Volume / Flow = 500,000 gal / 12,500,000 gal/day = 0.04 days; 0.04 days * 24 hr/day = 0.96 hr, or approximately 1.0 hour

3. SOR = Total flow, gpd / Area ft^2 = 150,000 gpd / 300 ft^2 = 500 gpd/ft^2

4. Volume = L * W * H = 150 ft * 25 ft * 15 ft= 56,250 ft^3

5. V = L * W * H = 32,400 ft^3; 1 ft^3 = 7.48 gal; (32,400 ft^3)*(7.48 gal/ft^3)= 242,352 gal

6. 1,000,000 gal/day * 1 day/24 hr * 1hr/60 min = 1,000,000 gal/1440 min = 694.4 gal/min

7. Mass = (Volume, MG) * (Concentration, mg/L) * (8.34 lbs/gal) = (100 MG) * (130 mg/L) * (8.34 lbs/gal)=108,420 lbs

8. MCRT = (Aeration tank TSS, lbs + Clarifier TSS, lbs) / (TSS wasted, lbs/day + FE TSS, lbs/day)
   - Aeration TSS = (90ft * 30ft * 12ft) * (7.48 gal/ft^3) = 242,352 gal; (0.242352 MG) * (2,000 mg/l) * (8.34) = 4042 lbs
   - FE TSS, lbs/day = (5.0 MGD) * (3.0 mg/l) * (8.34 lb/gal) = 125.1 lbs/day
   - MCRT = (4042 lbs + 400 lbs) / (400 lbs/day + 125 lbs/day) = 4442 lbs / 525 lbs/day = 8.46 days

9. F:M = (BOD_5, lbs) / (MLVSS,lbs) = (20,000 lbs) * (100,000 lbs) = 0.2

10. SVI = (settled sludge volume, mL/L * 1000) / suspended solids, mg/L = (150 mL/L * 1000) / 2,500 mg/L = 150,000/2,500 = 60

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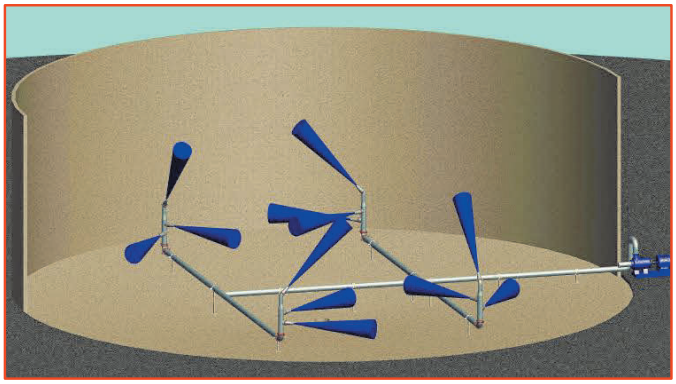

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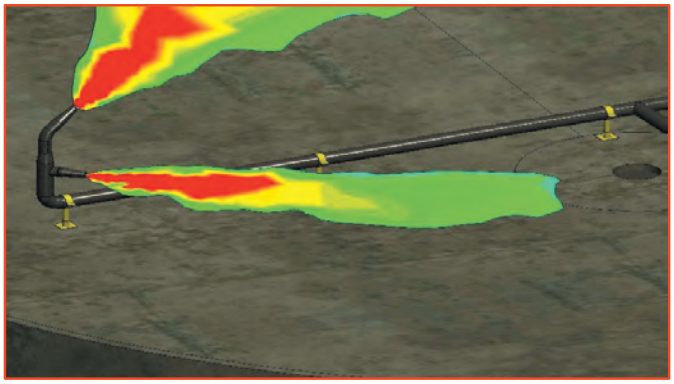

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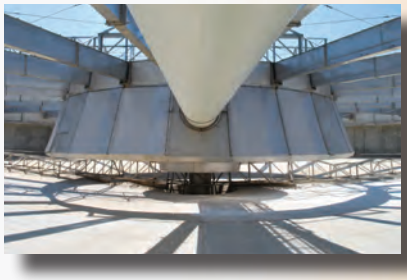

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