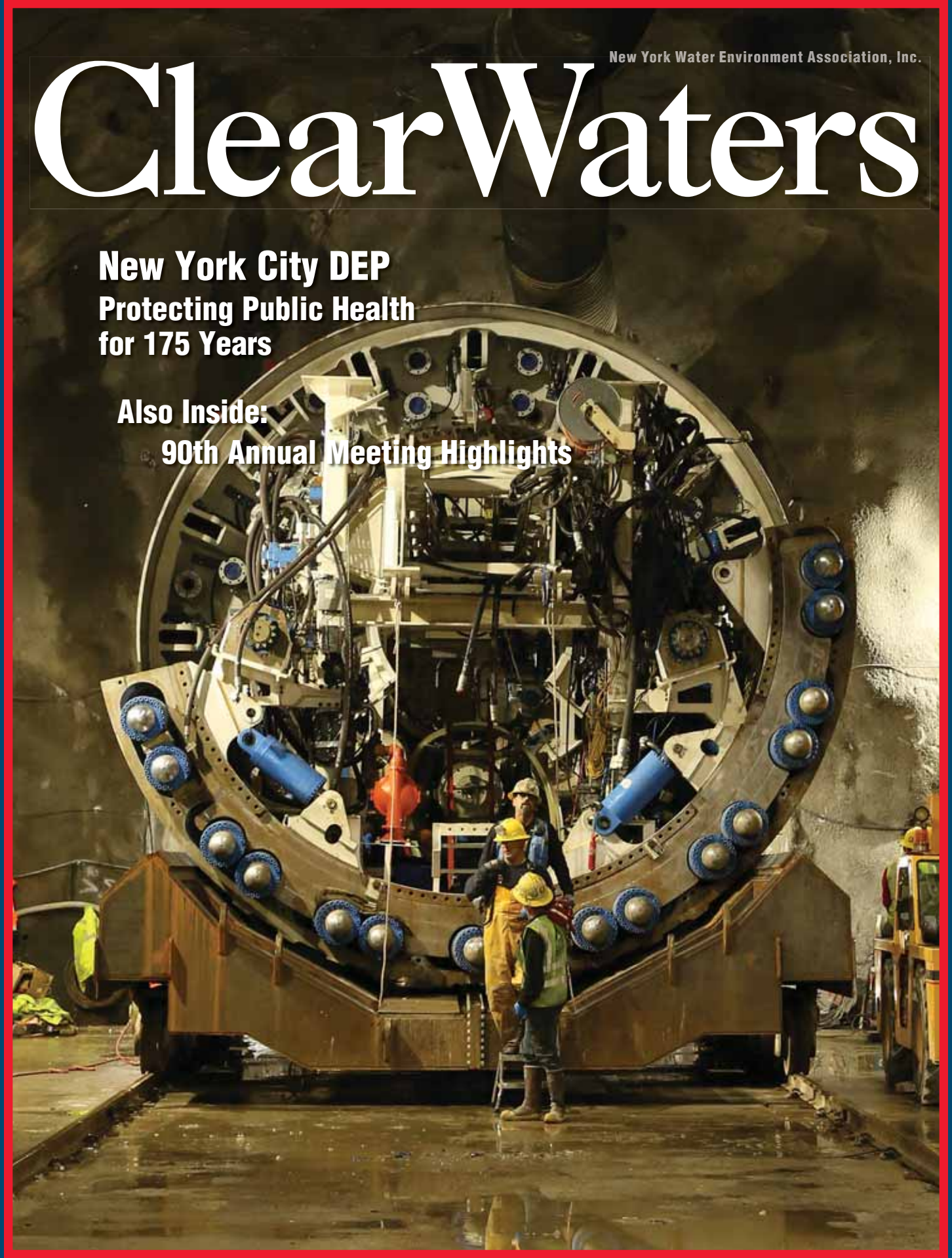
Spring 2018, Vol. 48, No. 1

New York Water Environment Association, Inc.

ClearWaters



New York City DEP
Protecting Public Health for 175 Years

Also Inside:
90th Annual Meeting Highlights

Spring 2018, Vol. 48, No. 1

Clear Waters

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Cover: The tunnel boring machine (TBM) is a massive and unique piece of equipment. The entire machine – including its cutter head, body and trailing gear – is more than 470 feet long and weighs 2.7 million pounds. Its cutter head is 21.6 feet in diameter. The TBM was named "Nora", after engineer Nora Stanton Blatch Deforest Barney, noted suffragist and the first woman in the United States to earn a civil engineering degree. *New York City DEP*

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♻ **Clear Waters** ***is printed on recycled paper, using soy-based ink.***

President's Message | Spring 2018

Happy Spring everybody! What more fitting theme for this "Year of the Water Superhero" than the New York City Department of Environmental Protection. With nearly 6,000 people working in all facets of our industry – running the gamut from watershed maintenance, process operations, capital budgeting, customer service, permitting, environmental compliance, sciences, information technology, and construction, just to name a few – DEP truly represents the essence of a Water Legacy and shows us what a team of superheroes can do.

"If I can make it there, I can make it anywhere …" But consider this: what if the planners and builders of the New York City water supply hadn't had the foresight to put in the seeming superhuman effort to build the reservoirs, aqueducts and tunnels over the last 175 years? And what if the sanitary engineers, operators and constructors of the 20th century hadn't put in the effort to fully understand and create a workable environmental solution to a dense population largely living and working on a small island? Then New York would not be the greatest city in the world as it is today!

Speaking of superhuman effort, I applaud everyone who worked so hard to prepare this Spring issue – with a full 14 articles covering all sorts of aspects of the work and dedication of DEP, the coordination was a daunting task. The Publications Committee and all of the authors are due a huge round of thanks. But I want to offer our sincerest debt of gratitude to Toby Siegman who wrangled the authors, identified these fabulous topics and gathered approval from DEP management, all in ample time to produce this issue of *Clear Waters* without a hitch.

So, as we kick off this year, I hope you take the time to savor the work that our colleagues at DEP have done, are doing and will do in the future. There is something in this issue for everyone. I hope you are inspired, and take away a renewed pride in our shared work of serving an economically vibrant society, protecting the earth, and saving lives.

Geoffrey G. Baldwin, PE BCEE
NYWEA President

NYWEA's 90th Annual Meeting a Huge Success!

Over 1,800 people attended NYWEA's 90th Annual Meeting held at the New York Marriott Marquis, February 5-7, 2018. With 26 technical sessions to select from, it was a challenging decision which ones to attend. Nearly all of the presentations were eligible for contact hours – a testament to the high quality of the presentations.

There were many unique events during the three-day conference: New York City DEP Commissioner's historic presentation during the opening session; the Operations Challenge pipe cutting event in the Exhibit Hall; the Student Design Challenge; the recognition of so many members during the Awards Luncheon; and the memorable, well-attended YP reception to name a few!

Many thanks to the Exhibitors, Sponsors and Advertisers for their generous support, which is the backbone of this meeting's success. Our sincere appreciation goes out to the many volunteers who are so generous with their time, including members of the Program Commiittee with Lisa Derrigan at the helm. Our appreciation also goes out to the Conference Management Committee and all of the speakers and moderators for their help in pulling together one of the best environmental technical programs in the nation! Highlights from the meeting are featured on pages 6, 7 and 51.

Left: NYWEA's Sustainability Award was presented to the Omega Center for Sustainable Living (Category 1).

Right: President-Elect Geoff Baldwin presents Clarkson University with their Student Chapter Recognition Grant.

Executive Director's Message | Spring 2018

What Matters Most is the People

As NYWEA celebrates its 90th year, it seems fitting to reflect on our history. Of course, there's programmatic achievements, growth in membership and conference attendance, and incredible technological advances. What matters most – in my opinion – is the people that made NYWEA a success.

Join me as we go back in time, to October 14, 1926 in Buffalo, New York. The Conference of State Sanitary Engineers met to form a national organization for our industry, the Federation of Sewage Works Associations (FSWA). In time, the FSWA became the Water Environment Federation (WEF). We are proud to note that a New Yorker, George W. Fuller, was a driving force behind the creation of FSWA!

The first meeting of NYWEA – known then as the New York State Sewage Works Association (NYSSWA) – was held in Albany on May 4, 1929 with an attendance of 23. The 152 members who enrolled in the first three months were considered "charter members." In our files are the original mylar paper and a leather-bound folder with the names of the charter members!

I found more than a few fascinating individuals in the archives of our formative years. George W. Fuller, who started a consulting engineering firm in New York City in 1899, is credited with developing a chlorination system, setting the stage for similar treatment across the nation. Kenneth Allen, the first president and founder of NYSSWA, worked as a Sanitary Engineer for New York City until his death. Arthur Sidney Bedell, the first secretary/treasurer of NYSSWA, later became the president of WEF. The WEF Member Association Service Award is named in his honor.

NYWEA was an adjunct of the New York State Department of Health for nearly 40 years. By 1967, the Health Department withdrew its involvement. To keep the New York Water Pollution Control Association (as NYWEA was known then) going, committed individuals administered its work out of their homes. In 1970, a secretariat was established at SUNY ESF. The office moved to Manhattan College for six years under the leadership of our own Dr. Walter Saukin. In 1985, the office moved back to its present home in Syracuse.

I could go on. Over its 90-year history, NYWEA's members have made notable achievements in our industry and cared deeply for the work that NYWEA does.

More Historical Tidbits

Combing through our historical files, I noticed reoccurring themes. These issues are as relevant today as they were 90 years ago: safety; operator pay; technological advances; lack of employer support; and public education. Threats were also a concern. At a 1942 meeting, Major Brewster of the state's Office of Civilian Defense discussed protecting wastewater treatment facilities against sabotage, as well as training emergency personnel to repair war-damaged utilities. Today our concerns are terrorism and cybersecurity. The more things change, the more they stay the same!

Initially established as an "engineers" association, today everyone involved in water quality management is welcome to join. When it became obvious that local geographic chapters could better serve our members, we welcomed local chapters Long Island (1936), Genesee (1938), Western (1939), Capital (1940), Central (1941), Lower Hudson (1947) and Metropolitan (1947).

Students were admitted as members in 1937. We are so proud that today student membership is our fastest growing sector with nearly 400 members!

During my tenure with NYWEA it has been wonderful to see women serving in leadership roles: Presidents Gale Wolfe (1994) and Janice Jijina (2006), and our 2018 Vice President-Elect Lauren Livermore. Yet we still have some catching up to do!

New Initiatives

In response to changing conditions in our more recent history, NYWEA has adopted new initiatives that would make our founders proud!

- NYWEA became the administrator of the state's Wastewater Operator Certification Program in 2011.
- NYWEA has certified over 350 individuals through the Voluntary Collection Systems Certification program.
- In 1998 we created a Utility Membership Program, through which employees of member utilities can attend events at the member rate.
- NYWEA became an approved sponsor with the New York State Department of Education in 2004, assigning professional development hours to our technical programs.
- A Young Professionals membership category was created, bridging the gap between being a student and starting on a career path.
- The NYWEA's scholarship program has reached its goal of $1 million, and awards $50,000 annually to students pursuing environmental careers.
- NYWEA is working with the Civil Service to ensure the exams accurately reflect job requirements.
- We continue to collaborate with our sister organization, New York Section American Water Works Association (NYSAWWA), on joint programs.

Since 1999, NYWEA has expanded its outreach to environmental advocacy organizations, resulting in a stronger voice heard by elected officials. I'd like to say that we played a role in the $2.5 billion allotment in the state's Clean Water Infrastructure Act of 2017!

Partnering with the NYSAWWA and the Rural Water Association, we are sharing the services of a hired Legislative Liaison, who helps us track pending legislation that may affect our members.

The Value of Water

At a meeting last fall, I heard someone state that water is "valued." I think the point is that "water is in the news more often." Think Hoosick Falls; Flint, Michigan; Newburgh. The bottom line: water is still tremendously ***undervalued***. This issue was a challenge for our founding members, as it is for us today!

How proud would our founders be to see the technological advances and committed volunteers who are advancing the clean water mission started 90 years ago! Many thanks to each of you for your role in shaping the history of our water industry and of NYWEA!

Patricia Cerro-Reehil, pcr@nywea.org

New York Marriott Marquis, February 5-7, 2018

NYWEA's 90th Annual Meeting: Celebrating the Past While Moving Forward

NYWEA President Paul McGarvey addresses the members during the Opening Session.

NYWEA Executive Director Patricia Cerro-Reehil talks about NYWEA's 90-year history.

WEF Executive Director Eileen O'Neill shares the organization's rich history.

DEP Commissioner Vincent Sapienza

Adrienne Esposito, Executive Director of Citizen's Campaign for the Environment, speaks during the Opening Session.

Assemblyman Steve Otis addresses the members after receiving the Nelson A. Rockefeller Award.

Tim Taber talks about Asset Management.

NYWEA President-Elect Geoff Baldwin shares his passion about NYWEA's members being "superheros!"

Standing room only at the Opening Session

Joe DiMura, NYSDEC

Dr. Jeanette Brown coordinated the first-ever Student Process Control Design Challenge.

Operator scholarship winners in attendance at the meeting: (l-r) Anthony Cervone, Michael Smith, Joshua Solon, Miquel Loachamin, Erik Vickerd, Tim Ryan and Vincent Matthew.

Zach Patterson, left, and Briana Fitzgerald of SUNY-ESF

Right: Leo Aparri receives NYWEA's Life Membership Award.

Treasurer Tom Lauro, left, and Assistant Treasurer Anthony Della Valle

The sessions were well attended.

Aimee Boulet speaks during the Public Education and Outreach session.

Water Ambassador, Steve Fangmann

Paul McGarvey and Bill Grandner having too much fun!

Erika Jozwiak, left, and Tara Saber-Khiabani speak to students about NYWEA's opportunities and benefits for Young Professional members.

Conference Management Chair, Joyette Tyler, and President McGarvey present the Single Booth Exhibit Award to Steve Poling (center) of EIM Valve Actuator.

Khrisopher Dodson receives NYWEA's Public Education Award.

Pipe cutting event in the Exhibit Hall

Will Stradling receives NYWEA's Board Service Award

Above and right: A busy Exhibit Hall on Tuesday!

continued on page 51

Water Views | Spring 2018

Source Water Protection and FAD

It is not an overstatement to say that the source water protection program for the New York City Watershed is a world-class success. More than 9.5 million New Yorkers rely on the clean drinking water that comes from the Catskill, Delaware and Croton water supply systems. The Catskill and Delaware systems are particularly unique because the water is not filtered. Keeping such waters safe requires strong leadership, careful oversight, expert partnerships and innovative initiatives. NYSDEC is proud to be part of this ongoing collaboration.

All surface drinking water sources are required by federal law and regulation to be filtered or to meet the highly stringent water quality, disinfection and site-specific protection criteria outlined in a "Filtration Avoidance Determination" (FAD). New York City's water supply system – one of only five large unfiltered systems in the nation – qualified for a renewed 10-year FAD in December 2017. The city will commit about $1 billion over the next decade to comply with the FAD requirements. Continued filtration avoidance saves more than $10 billion in cost to build a filtration plant and more than $300 million in annual plant operating expenses.

The new FAD will continue many core initiatives: land acquisition; flood mitigation; stream restoration and stabilization; advanced wastewater treatment; upgraded septic systems; nutrient management on farms; and robust water quality monitoring. The FAD adds funding and new watershed protection elements, including: expanding the small-business septic program; expediting Shokan's community wastewater facility; implementing or updating best management practices on farms; and protecting sensitive streamside lands through focused purchases and easements.

Key to source water protection success has been the watershed communities and locally-based organizations. While fully funded by water ratepayers, many of the source water protection programs are administrated by watershed-based entities, such as the Catskill Watershed Coalition, the Watershed Agricultural Council, county soil and water conservation districts, and Cornell Cooperative Extension.

NYSDEC has been an active partner in the management and protection of the city's watershed since 1997, when the New York City Watershed Agreement was signed. Our role is expansive given our direct regulatory involvement in watershed protection programs and technical expertise in source water protection. Moreover, NYSDEC works with DEP to oversee water quality permits for water resource recovery facilities; assure adequate controls on erosion in runoff; collect pharmaceuticals from healthcare facilities; and develop pollutant budgets ("total maximum daily loads") for individual waterbodies.

The state of New York is committed to working with the many watershed partners for years to come. There are many lessons to be learned from the ongoing success of this unprecedented program.

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

Focus on Safety | Spring 2018

A Little Eye in the Sky

Contrary to the Rolling Stones' lyrics, time is not on your side. Increasingly, demands on everyone's personal and professional life leave a person spinning. At least on the professional side, one tool that could both free up time and add to project understanding is a drone, also known as an Unmanned Aerial System (UAS) or an Unmanned Aerial Vehicle (UAV). This is not a remotely-controlled helicopter for the kiddies, but a sophisticated aerial device able to go where people can't, won't or shouldn't go. Drones have become very popular over the past few years, progressing in design from fragile exoskeletons to sturdy mini-aeronautical devices.

For storm restoration, a drone in the sky (up to 400 feet) allows a real-time, detailed visual account of the extent and severity of damage. Outfitted with an infrared camera, even water infiltration can be surveyed. General property inspections may be enhanced by drones, allowing inspections on high locations like roofs and towers. During catastrophic failures, sending in a drone is more acceptable than risking personnel. When considering new property acquisitions, a drone gives the aerial view of the topography, making it easier to identify potential issues. During construction activities, drones provide photographic documentation that CAD drawings cannot. This can give the property owner peace of mind that all is on schedule – or show the reasons for delays.

Drones are regulated by the Federal Aviation Administration (FAA), as well as by state and local governments. Do the due diligence. As part of your decision-making process, please refer to your local municipality's specific laws regarding the use of drones. It may very well be that in your location, your organization cannot use drones due to restricted airspace; proximity to airports, heliports, or correctional facilities; or even privacy issues.

All that said, drone flight isn't just a "rev it up and let it rip" activity. Professional use is not the same as personal use. Before any venture, documented critical safety steps must be taken to ensure the safety of the public, the workers, and the operators. These include a pre-flight inspection, safety plan review, risk assessment, and post-op review. Just like many complex work activities, safety is important with this remotely-operated activity.

For municipalities or organizations that operate facilities, drones can find a home in your arsenal of tools. Then, once you've decided to use drones, should you purchase and operate the drone in-house or contract with a commercial drone service? One requirement that may tip your decision to contract commercial drone services is that any commercial or industrial use of drones requires a trained and licensed pilot. Whether owned or contracted, there is little doubt that drones in the workplace, in industry, and in construction will alter the traditional way of doing business, by having that little eye in the sky.

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

A Brief History of Our Industry in New York City

The earliest days of New York City were fraught with public health challenges that centered on its lack of clean water. The nascent city was much smaller than the five-borough metropolis that exists now. For the first 200 years of its history, starting with the settlement of Manhattan Island in the 1600s, New York was a small city whose borders housed as many farm animals as it did people.

1600s

Settlement of Manhattan Island by Europeans. The city got its water from primitive sources, including shallow wells, pits, and a few large ponds situated throughout the city. As was practiced in those days, beer and wine were the chief forms of liquid consumption since those potables were innately safer to drink.

1677

The first public water well was dug in front of the old fort at Bowling Green.

Early to mid-1700s

In addition to small local wells, there were two other sources of water, the Tea Water Pump and the Collect Pond, both of which suffered from overuse and contamination. The Collect Pond was used to dump tannery waste, dead animals and other refuse, even while serving as a reservoir.

1776

The first attempt to create a water distribution network was initiated by Christopher Colles, an Irish engineer. The system consisted of hollowed logs laid under the street surface and a horse-powered pump to raise the water from a well.

1800

Aaron Burr, in collaboration with his brother-in-law, Dr. Joseph Brown, seized upon a plan to establish a water department in response to the latest yellow fever outbreak. The system consisted of hollowed logs joined by hub and spigot joints throughout lower Manhattan, supplied by water from the Collect Pond.

1804 to 1830

Disastrous fires in 1804, 1811, 1816, 1825 and 1830 highlighted the inability of the water system to provide an adequate supply of water for firefighting.

1

1835

The Great Fire destroyed 17 city blocks, and was so bad that city leaders attempted to deprive it of fuel by destroying buildings in its path. The U.S. Marines were recruited to fetch gunpowder from the Brooklyn Navy Yard, which they used to blow up buildings in Manhattan, creating a fire line by destruction.

2

1837 to 1842

Construction started on the Croton Aqueduct in 1837. The first components of the Croton System were activated in October 1842. The occasion was met with parades and concerts and a new fountain at City Hall that shot the city's new water 50 feet into the air.

1840 to 1900

The population of New York City grew from about 300,000 to 3.5 million. The growth rate soon outstripped the ability of the Croton System, and a second Croton Aqueduct was constructed, along with added sources and storage.

Late 1890s to early 1900s


3

Wastewater treatment consisted of chemical coagulation for settling, as well as seasonal disinfection with chlorine. The primary impetus for treatment was to keep the beaches clean and to protect the health of beach-goers. The 26th Ward, Coney Island and Jamaica Wastewater Treatment Plants were the highest priority sites.

1904

Creation of the Metropolitan Sewerage Commission, which studied the harbor and developed a City Master Plan.

1906

Work began on the Ashokan Reservoir and the 92-mile Catskill Aqueduct. This system supplied surface water to Queens, Brooklyn and Staten Island for the first time, by conveying water from the Catskill Mountains, under the Hudson River to Kensico Reservoir, and ultimately distributing water through City Water Tunnel No. 1.

1907 to 1915


4

New York City built 127 miles of aqueducts and tunnels, constructed huge dams to impound the waters of four reservoirs – Ashokan, Hillview, Kensico and Silver Lake – and grew 3 million trees in nurseries and planted them around the reservoirs to protect them from erosion. The city employed 17,243 workers simultaneously at the peak of the job, providing them with shelter, education and recreation in labor camps along the path of the aqueduct.

1917

Water from the Catskills reached all five boroughs of New York City. The occasion was met with three days of celebrations and a New York Times headline: "Water Famine Now Impossible".

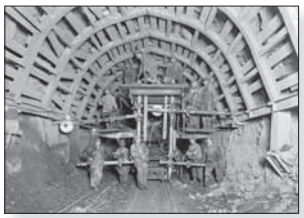
1917 to 1960s

Additional reservoirs, aqueducts and water treatment facilities were constructed, including Schoharie Reservoir in the Catskill Water Supply System. Rondout, Neversink, Pepacton and Cannonsville reservoirs were built to create the Delaware Water Supply System.

1935 to 1945

Construction of three new WWTPs: Wards Island in Manhattan; Bowery Bay; and Tallman Island in Queens. The Wards Island Plant was one of the first in the country to use the conventional activated sludge process to treat sewage.

1936 to 1964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Work began on the Delaware System in 1936, taking water from the Delaware River, sending it through the Delaware Aqueduct to Kensico Reservoir, and ultimately supplying City Water Tunnel No. 2. The Delaware System construction continued through World War II and was completed in 1964.

1945 to 1965

Construction of five new WWTPs (Hunts Point, Oakwood Beach, Port Richmond, Rockaway and Owls Head). The older Bowery Bay, Coney Island and Tallman Island WWTPs also were upgraded to include the newly invented step-aeration process. New York City's population was approaching eight million.

1970 to 1998

Construction of City Water Tunnel No. 3 began in 1970 to provide needed redundancy and improve water pressure stability throughout the five boroughs. After halting work during the fiscal crisis of the 1970s, work resumed in 1980. Stage One of City Water Tunnel No. 3 was activated in 1998. A celebration in Central Park was held, highlighted by the reactivation of a fountain last used in 1917.

2012

Hurricane Sandy impacted 10 of 14 DEP WWTPs and 42 of 96 wastewater pumping stations.

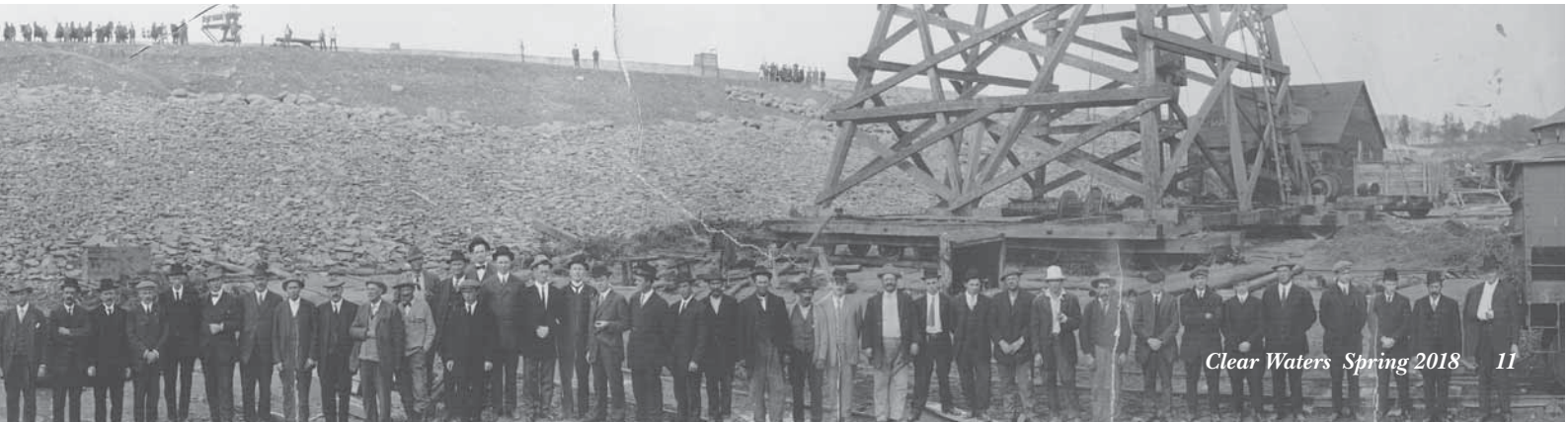
2013

Stage Two of the Manhattan Leg of the City Water Tunnel No. 3 was completed and placed into service.

The Editor recognizes the contributions of authors Adam Bosch, Pamela Elardo and Doug Greeley in the compilation of this time line.

Photos courtesy of New York City DEP: **1.** Great Fire of 1835; **2.** Croton Water Celebration, 1842; **3.** 26th Ward WWTP early 1900s; **4.** Catskill Aqueduct Construction, 1908; **5.** Drill operators with a drill carriage, Rondout-West Branch Tunnel of the Delaware Aqueduct. October 24, 1939; **6.** Ashokan Reservoir Under Construction, 1911. A group of suit-clad men stand on the downstream side of Olivebridge Dam as it was constructed. This photo is believed to be one of the earliest panoramic photos of its kind.

6



Protecting Public Health and the Environment in New York City

by Vincent Sapienza

The New York City Department of Environmental Protection (DEP) is the largest public water and wastewater utility in the United States. It requires nearly 6,000 employees to provide the world-class drinking water and wastewater services that 9 million New Yorkers rely on. Each day DEP delivers approximately 1 billion gallons of water, treats approximately 1.3 billion gallons of wastewater, and then returns it safely to our waterways. To carry out the activities of this large and complex system, DEP is comprised of multiple bureaus, whose activities are organized by functional areas.

DEP Operations and Agency Organization

Stretching 125 miles north of the city, 2,000 square miles of protected lands provide a natural barrier to shield pollution from entering our 19 reservoirs and three controlled lakes. Maintenance of these protected lands, reservoirs, dams and associated waterworks fall under the jurisdiction of DEP's Bureau of Water Supply (BWS). Overall, BWS has responsibility for planning, engineering, management and acquisition of watershed lands; enforcement of watershed regulations; watershed security; water monitoring; and disinfection. BWS ensures the delivery of enough high-quality drinking water to residents, tourists and commuters of New York City and the counties of Westchester, Putnam, Orange and Ulster.

In New York City's metropolitan area, the water and sewer systems consist of 7,000 miles of water mains; 7,500 miles of sewers; 114,000 fire hydrants; 140,000 catch basins; and over 90,000 valves. Responsibility for these drinking water distribution and wastewater collection systems rests in the Bureau of Water and Sewer Operations (BWSO). BWSO maintains daily routine water and sewer operations, responding to emergencies and complaints including those related to: water main breaks; leaks from water and sewer mains; broken or open fire hydrants; sewer backups; clogged catch basins; street flooding; and poor water pressure, taste, or odors. BWSO also works closely with other city agencies on construction and capital infrastructure planning.

DEP's Bureau of Wastewater Treatment (BWT) is the largest bureau with more than 1,800 employees who are responsible for operating 14 wastewater treatment plants and 96 pumping stations. BWT strives to implement new treatment technologies that protect harbor water quality for future generations in the recovery of valuable resources from wastewater. BWT is also addressing the challenges that climate change and extreme weather events, such as Hurricane Sandy, pose to our facilities in low-lying coastal areas by investing in resiliency and energy efficiency projects.

The three operating bureaus (BWS, BWSO, and BWT) work in partnership to deliver high-quality water and sewer services every day, while the Bureau of Engineering, Design and Construction (BEDC) supports the capital project management and delivery of those systems. In addition, DEP has a Bureau of Environmental Planning and Analysis (BEPA) to address policy issues that focus on stormwater management, water demand management and water conservation, water quality, air quality and water resource protections.

Environmental Health and Safety

DEP administers a consistent, efficient and comprehensive Environmental Health and Safety (EHS) program. Across our entire organization, DEP prioritizes compliance with the environmental, health and safety rules that govern operations. DEP holds trainings, workshops and outreach meetings to keep our nearly 6,000 employees current and proficient on safety practices. This emphasis on safety improves the welfare and working environment for all DEP employees and contractors and extends to members of the public.

Balancing Competing Needs – Water Rates and Affordability

DEP operates one of the most complex water and wastewater systems in the world, serving a diverse population of New Yorkers and visitors to the city. To financially support DEP's operations and ongoing capital improvement program, the New York City Water Board collects nearly $4 billion in revenue annually from 836,000 ratepayers through the efforts of DEP's Bureau of Customer Services.

Between 2002 and 2012, New York City ratepayers saw their annu-

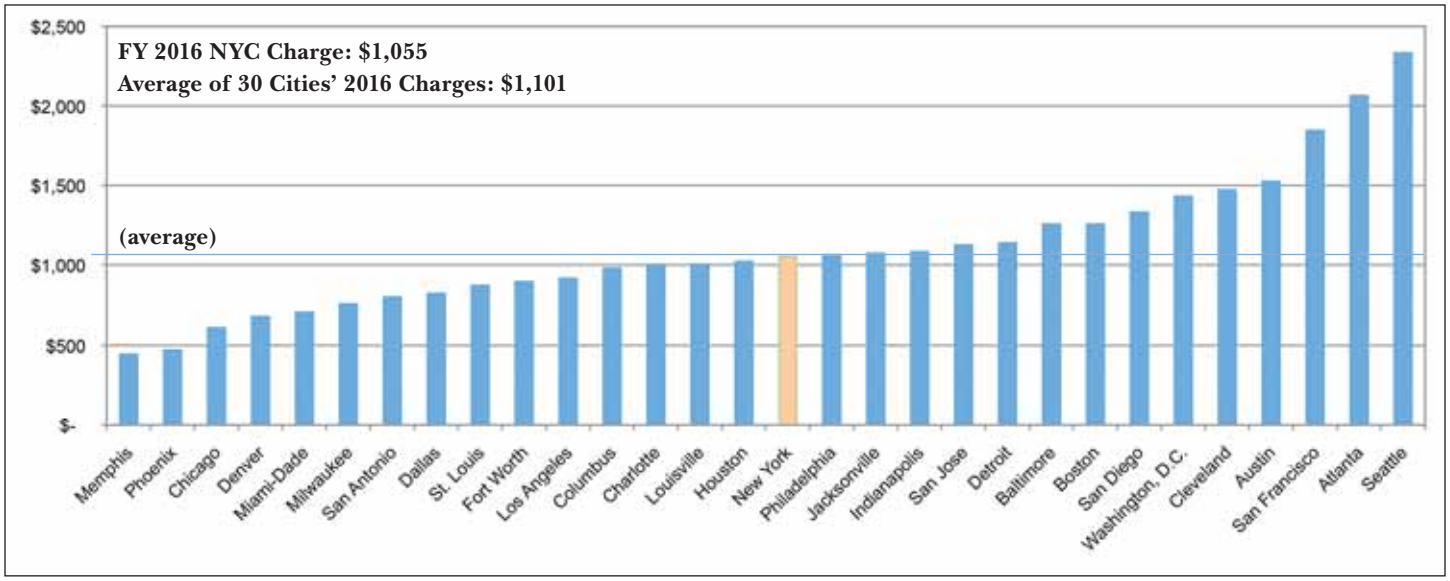


Figure 1. Average annual residential charges based on 80,000 gallons per year consumption and rates as of February 2016. *New York City DEP*

al water rates increase by 235 percent, from an average of $374 to $877 for a single-family home based on 80,000 gallons of water per year. Much of this growth is attributed to a sharp increase in unfunded state and federally mandated projects. In fact, between 2002 and 2012, 66.5 percent, or $15.69 billion, of DEP's capital program funded mandated projects such as the construction of the Catskill Delaware Ultraviolet Light Disinfection Facility ($1.7 billion), the Newtown Creek Wastewater Treatment Plant ($4.8 billion), and the Croton Water Filtration Plant ($3.3 billion).

Despite significant increases in the mid-2000s, annual water rate increases have leveled off in recent years. While costs for almost every commodity in New York City soar above national averages, the cost for water and sewer services remains slightly below the national average ***(Figure 1)***. These lower rates are attributed to internal cost saving measures, lower interest rates from excellent bond ratings, and Mayor de Blasio's elimination of the rental payment made by the utility to the city.

DEP has an important obligation to make smart investments to our system that improve the dependability and resiliency of our services while keeping water rates affordable for all New Yorkers, especially as 21.2 percent of the city's population lives below the federal poverty level. Over the past several years, DEP has introduced several affordability programs aimed at lessening the burden of water rates on particular populations, including low-income families, seniors, the disabled and the affordable housing community. Although New York City's vast water infrastructure requires significant capital investment, DEP understands the implications of these costs to the water rate, and thus to the ratepayers. The agency strives to uphold the commitment to continue the expansion of our efficiency programs, while also keeping water rates affordable and sustainable in the short and long-term.

Major Capital Projects

To ensure the reliability of drinking water and wastewater infrastructure, DEP operates a robust capital program. Over the next ten years, DEP intends to spend $18.8 billion on system-wide infrastructure improvements ***(Figure 2)***. Some examples of major capital investments over the next decade include:

- Kensico-Eastview Connection Tunnel – $1.2 billion
- City Water Tunnel No. 3, Brooklyn/Queens – $658 million
- Hunts Point Digesters – $221 million
- Resiliency Upgrades at Wastewater Facilities – $206 million

Broadening Our Scope with Green Infrastructure

Capacity and space limitations at the city's 14 wastewater plants, as well as social, economic and environmental factors, led DEP to develop new ways to retain and filter stormwater through the use of green infrastructure. Under a 2012 agreement with the New York State Department of Environmental Conservation (NYSDEC), DEP has expanded the use of green infrastructure throughout New York City in an effort to manage runoff from 10 percent of impervious surfaces citywide by 2030.

Green infrastructure is fast-becoming a preferred solution to managing stormwater, as it is significantly less expensive than gray infrastructure, quicker to build, and ultimately creates savings for ratepayers. The implementation of green infrastructure is also less energy-intensive and has numerous additional quality-of-life benefits such as air-quality improvements, temperature reduction from the urban heat island effect in hot summer months, and neighborhood beautification. DEP is currently targeting green

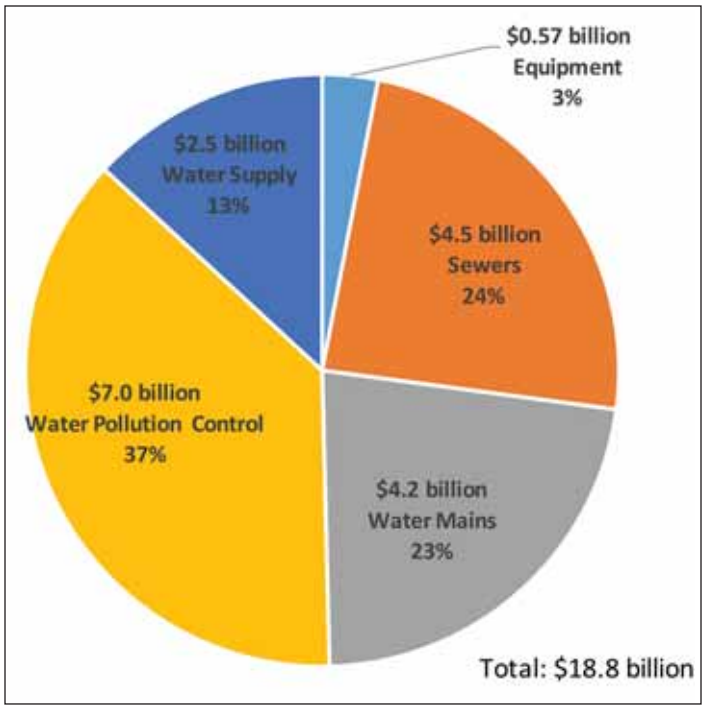


Figure 2. DEP's ten-year capital plan, for the fiscal years 2018 through 2027. *New York City DEP*

infrastructure investments to improve water quality in the city's priority watersheds, which include the Gowanus Canal, Flushing Bay, Newtown Creek, Jamaica Bay and the Bronx River. To date, DEP has constructed more than 4,000 green infrastructure assets citywide.

Maintaining a State-of-Good-Repair

As DEP continues to pursue capital priorities and mandates, we are also deeply committed to caring for the vast water and wastewater infrastructure that was painstakingly built by seven generations of our predecessors. Maintaining a state-of-good-repair of these assets is critical for the long-term sustainability of our system. DEP has developed an Asset Management program to continually assess the condition of our operating equipment so that rehabilitation cycles can be forecast, and funding set aside.

A few of our largest state-of-good-repair projects in the ten-year horizon include:

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Bioswales are one of the green infrastructure assets that have been implemented throughout the city for control of stormwater runoff. *New York City DEP*

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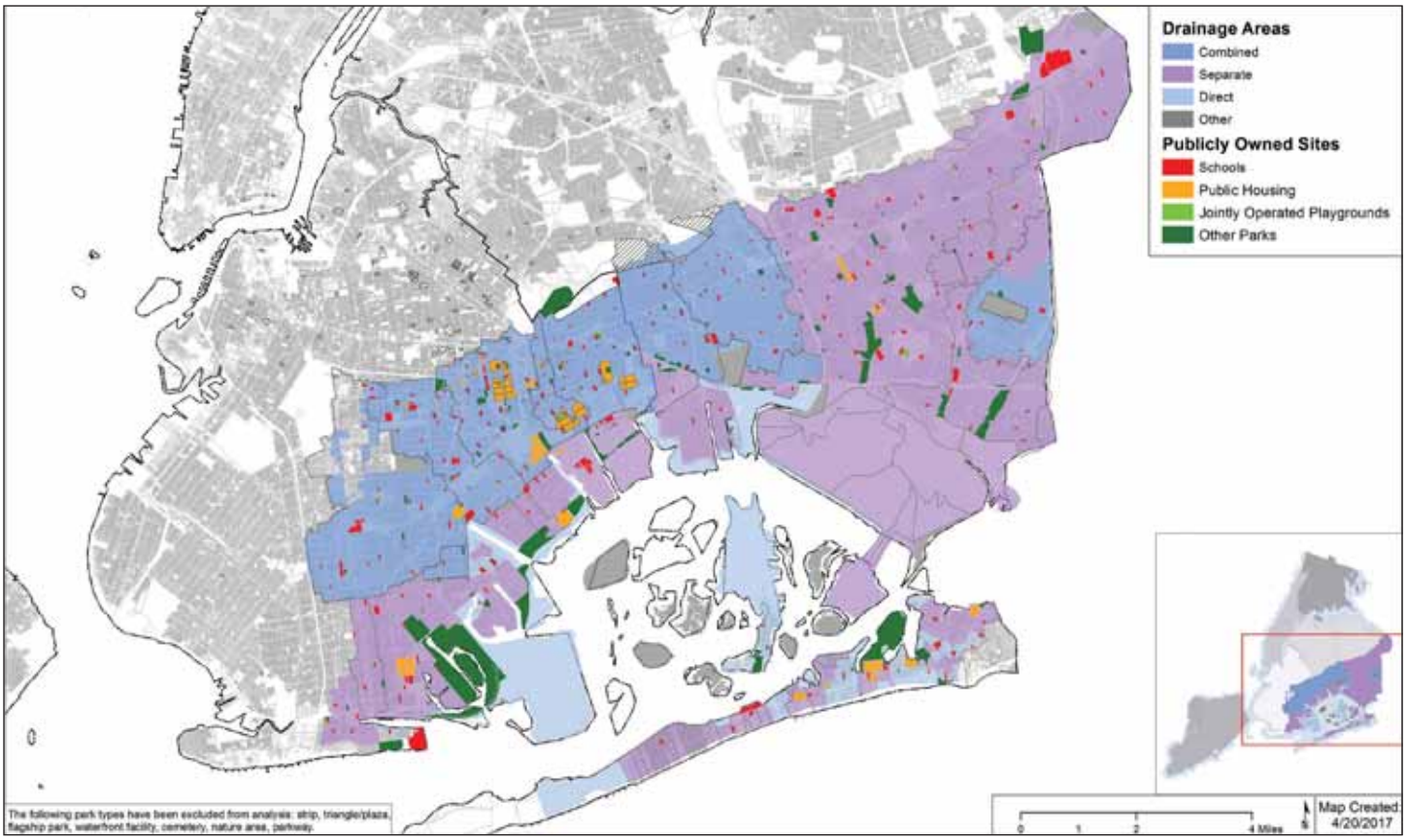


Figure 3. Integrated stormwater planning for public sites in the Jamaica Bay watershed involves managing different types of drainage areas.
New York City DEP

- Citywide water and sewer main replacements – $6.74 billion.
- Ashokan Reservoir and dividing weir improvements – $743 million.
- Structural improvements at North River Wastewater Treatment Plant – $360 million.
- Modification of chambers at Hillview Reservoir – $340 million.

Improving Energy Efficiency at Our Facilities

Released in 2015, *OneNYC* is Mayor de Blasio's comprehensive plan for a sustainable and resilient city for all New Yorkers. The plan seeks to address the city's long-term challenges, such as a growing population, changing climate conditions, an evolving economy as well as aging infrastructure.

One of the commitments embedded in the plan is to dramatically reduce greenhouse gas emissions by 80 percent by the year 2050. As the third largest municipal user of energy and emissions – mainly at the 14 wastewater treatment plants – DEP is moving to become carbon-neutral at its facilities.

Adhering to the overarching goals outlined in *OneNYC*, DEP is developing a plan to achieve carbon neutrality at all in-city wastewater treatment plants by 2050, reducing our energy demand and carbon footprint. One approach that DEP is already exploring to limit the use of purchased electricity and fuel oil is to invest in cogeneration engines, which use digester gas to generate electricity. At the North River Wastewater Treatment Plant, a $220 million project is underway to replace the existing direct-drive engines with five new natural gas/digester gas cogeneration engines. DEP is also evaluating cogenerating engines at Wards Island and Hunts Point wastewater treatment plants.

DEP is also partnering with the New York City Department of Sanitation to dramatically reduce our reliance on landfills. In an effort to eliminate landfill waste by 2030, DEP is developing a diversified plan for the disposal of biosolids, where at least 10 percent of our solids are beneficially reused instead of being trucked to a landfill.

To further improve energy efficiency and minimize landfill waste, DEP is also accepting organic food waste at our wastewater treatment plant. Incorporating organic food waste into the treatment process will produce more digester gas that can then be used to power the wastewater plants, and at the same time reduce the amount of trash that is sent to landfills. During this process, these organics are liquefied and fed directly into the digesters at the Newtown Creek Wastewater Treatment Plant, where they will be further broken down during the anaerobic digestion process, creating additional digester gas. The program began in June 2016, and over the next few years, DEP will gradually increase the amount of food waste accepted at the plant up to 250 tons per day.

Balancing Competing Goals and Integrated Planning

Continued improvements to stormwater and wastewater handling and treatment have resulted in the cleanest water quality New York Harbor has seen in at least the last 100 years. To balance the competing goals and interests of various stakeholders, DEP continues to incorporate an integrated planning approach to municipal stormwater and wastewater management. Integrated planning is a flexible framework that allows the agency to prioritize projects with the greatest water-quality benefits through the use of innovative approaches and solutions (such as green infrastructure projects and other structural retrofits).

An integrated planning approach offers DEP the opportunity to meet multiple Clean Water Act requirements by identifying

Back of the cutter head support, Delaware Aqueduct repair.
New York City DEP

In 2012, DEP launched a major effort to repair the Delaware Aqueduct, one of two primary drinking water tunnels that feed water from the watershed towards New York City. This $1 billion repair project to alleviate leaks in the existing tunnel is the largest repair in the 175-year history of DEP. See page 22 for more information about the aqueduct repair.

efficiencies from separate wastewater and stormwater programs and sequencing investments so that the highest priority projects come first. The area around Jamaica Bay is a prime example of DEP's integrated planning between the distinctly combined (CSO) and separate (MS4) sewer areas ***(Figure 3)***. In order to integrate stormwater planning in the Jamaica Bay Watershed, DEP has taken steps to ensure that investments are maximized, and agency resources are utilized strategically. DEP has mapped and analyzed impervious area cover, as well as vetted projects with other agencies in both the combined and separate sewer areas. Further discussions with partner agencies, site visits and stormwater modeling will also be completed to assist in prioritizing sites for green infrastructure retrofits.

DEP has achieved real progress in implementing the goals of the Clean Water Act, and in carrying out our mission to protect public health and the environment. In the future, DEP will continue to draw heavily on this integrated planning framework to facilitate additional water-quality improvements in our waterbodies while allowing us to adapt to new challenges. As the largest combined water and wastewater utility in the country, we remain dedicated to our leadership role in enhancing the environment in and around New York City, and are committed to successfully maintaining one of the most extensive municipal water systems in the world.

Vincent Sapienza, P.E., is the Commissioner of the New York City Department of Environmental Protection. For questions about this article, contact April O'Neil at aoneil@dep.nyc.gov.

The Bureau of Wastewater Treatment:

Evolving Resource Recovery to Meet Future Needs

by Pamela Elardo

New York Harbor has made a significant comeback and the signs are all around. New York City's most recent Harbor Survey Report shows that the harbor is cleaner now than at any time in the last 100 years. Continued improvements to wastewater conveyance and treatment are chiefly responsible for improved water quality, which have led to increased recreational opportunities for people, ecological advancement for aquatic life, and even a greater presence of whales in our waters.

Here in the New York City Department of Environmental Protection's (DEP's) Bureau of Wastewater Treatment (BWT), we are celebrating this achievement by looking back at our progress to date. At the same time, we look forward to the next challenges to continue this legacy and take greater strides for environmental stewardship and sustainability.

Wastewater Treatment in New York City Today

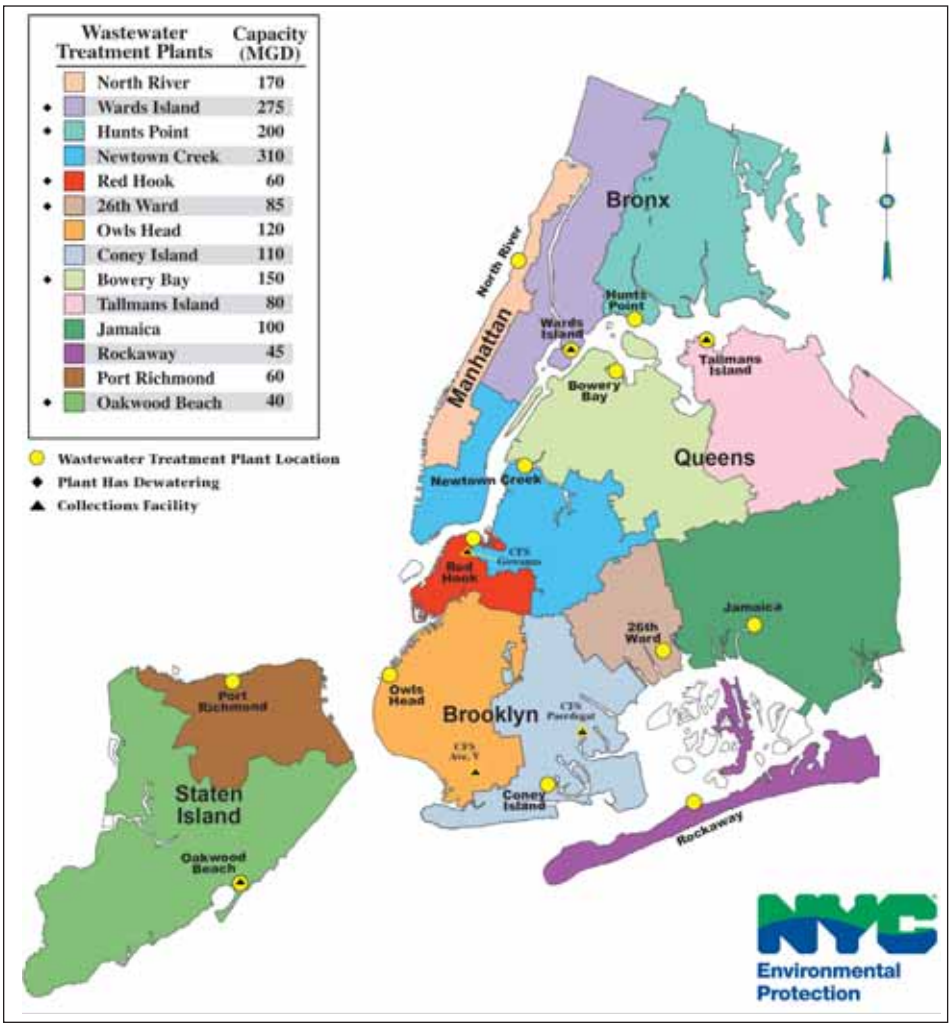
Today BWT, with a staff of about 1,800 employees, protects public health and enhances the environment in the New York metropolitan area by providing high-quality and effective treatment to wastewater collected from all five boroughs. Starting in 2018, BWT has also taken steps to more fully embrace its identity as an environmental leader. In fact, DEP anticipates expanding BWT's reach into resource recovery and the branding of its wastewater treatment plants in the near future.

DEP's wastewater system is the largest in the country and includes:

- 497 Regulators
- 96 Pumping Stations
- 14 Wastewater Treatment Plants (WWTP)
- 6 Sludge Dewatering Facilities
- 5 Sludge Vessels
- 4 Combined Sewer Overflow Retention Facilities
- 426 Combined Sewer Overflow Outfalls

New York City's WWTPs have the combined capacity to treat dry weather flows of 1,805 billion gallons per day (BGD). This number can easily double during wet weather events, while on an average day we treat 1.3 BGD.

Our WWTPs provide all the unit processes for preliminary, primary and secondary treatment followed by disinfection. The treatment process creates valuable resources, with our top product being clean water that ensures the city's high-quality waterways continue to improve. These facilities have served the city for decades and have prepared the city to become leaders in further environmental improvement.



New York City's 14 WWTPs, shown here with locations, drainage areas, and dry weather capacities.
New York City DEP

Recent Advances in BNR, CSO Control and TRC

Following implementation of the upgrades to the WWTPs that were required by the Clean Water Act, DEP continued to make strides to improve water quality. In more recent decades, we have gone further for the environment by providing Biological Nitrogen Removal and abating Combined Sewer Overflows impacts. More recently, we have worked on a plan to lessen potential impacts for residual chlorine toxicity by improving our process to reduce effluent levels of Total Residual Chlorine (TRC).

Biological Nitrogen Removal (BNR)

More than two decades ago, scientists discovered the link between excess nutrients – particularly nitrogen – and algal growth in marine waters. Excessive algal growth can result in hypoxia, or lack of oxygen, when algal die-off triggers bacterial consumption of the dead algae. The East River and Jamaica Bay have exhibited areas of hypoxia, and in response DEP has been working to reduce nitrogen discharges to these receiving waters. New York City has invested over $2 billion in strategic research, focused planning, detailed designs, and construction of BNR facilities to reduce effluent nitrogen discharges.

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Energy savings pay for the mixing project

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These facility upgrades to BNR included modifications to the treatment process to encourage the growth of the bacterial populations that are essential to nitrogen removal. Enhanced equipment and instrumentation for process optimization and monitoring, as well as supplemental chemicals such as carbon (glycerol), were put in place to support overall nitrogen removal.

As part of an agreement with the New York State Department of Environmental Conservation (NYSDEC) and the New York State Attorney General, DEP committed to reducing the combined nitrogen discharges from its WWTPs located along the East River by 58.5 percent by January 2017, and at its WWTPs discharging to Jamaica Bay by installing BNR upgrades. DEP met this commitment, successfully implementing BNR and reducing nitrogen discharges to the East River by over 60 percent, which exceeded the requirement and met the permit limits. In Jamaica Bay, DEP's actions have reduced nitrogen discharges by almost 50 percent and is below the current nitrogen discharge limit by over 1.5 million pounds of nitrogen discharged per year.

DEP is continuing its efforts to improve water quality by constructing BNR facilities at two additional Jamaica Bay WWTPs: Coney Island and Rockaway. These facilities will be operating with BNR by 2022. A focused water-quality monitoring program in Jamaica Bay is also ongoing to determine the extent of the effect of BNR upgrades on the health of Jamaica Bay.

Combined Sewer Overflow (CSO) Control

The majority of New York City's extensive sewer system is combined, which means it is used to convey both wastewater and stormwater flows. The city's collection treatment systems are unable to handle intermittent high flows that occur under certain storm conditions. When these events occur, upstream flooding must be prevented, and the public protected from contact with sewage. To achieve these goals, a ratio of about 80/20 (80 percent stormwater and 20 percent untreated wastewater) is discharged directly into waterways at CSO outfalls. CSOs are a concern because of their potential effect on overall water quality and recreational uses in local waterways during and for 48 hours after these discharge events.

To date, DEP has spent over $1.8 billion on controlling CSO discharges. Recent DEP construction projects have included upgrades in key wastewater treatment facilities, storm sewer expansions and the construction of several large CSO retention tanks.

CSO retention tanks are large facilities that capture CSO discharge during a wet-weather event and pump it back to a WWTP after the storm when there is capacity in the sewer system. New York City has four existing CSO tanks located at Alley Creek, Flushing Creek, and the Jamaica Bay tributaries Paerdegat Basin and Spring Creek. BWT operates and maintains these facilities, which were upgraded or came online between 2007 and 2011. Taking on these new CSO facilities required extensive planning and training, as well as coordination with the receiving WWTP.

Paerdegat Basin CSO retention facility. *New York City DEP*

Upgrades to our plants and sewers have allowed BWT to capture a greater amount of overall flow, from about 30 percent in the 1980s to over 72 percent today, and overflows are more dilute, with the percentage of sanitary waste decreasing from 30 percent to about 12 percent today.

Total Residual Chlorine

To eliminate the chance of potential chlorine toxicity to marine life in our waterways, DEP assessed the operations and receiving water dynamics at the outfalls of each plant and determined the need to construct dechlorination facilities at five WWTPs. Construction is underway at the Coney Island, North River and Newtown Creek WWTPs while dechlorination facilities at the Owls Head and Oakwood Beach WWTPs are currently under design.

DEP implemented operational modifications and optimization of existing systems and processes at all plants. For the Bowery Bay, Wards Island and Jamaica WWTPs, we are able to stay below chlorine toxicity thresholds in the receiving water standards without building additional infrastructure. This was a significant accomplishment for BWT.

The development of scientifically defensible and representative site-specific, water-quality-based effluent limits (WQBELs) by DEP (in coordination with NYSDEC) was the key driver and major achievement in supporting the ever-evolving effluent water-quality objectives.

The Hard Work Is Paying Off!

Under DEP's Harbor Survey Program, BWT tests the New York Harbor waters and sediments at 37 locations year-round, taking weekly samples from May through September and monthly samples from October through April. Typical tests measure bacteria, turbidity, temperature and the level of dissolved oxygen in the water. BWT uses the results to assess the effectiveness of all the city's water-quality programs and to monitor water-quality trends.

BWT's primary ocean vessel for sampling the New York Harbor waters is the *Osprey,* which is equipped with a small laboratory. Since 1909, DEP has monitored water quality in New York Harbor, the East River and the Hudson River. The results are published annually in its *New York Harbor Water Quality Report,* which is available on DEP's website.

According to our most recent *New York Harbor Water Quality Report,* the harbor is cleaner now than at any time in the last century. This is a direct result of BWT's ability to take on continued improvements to wastewater conveyance and treatment.

Looking Ahead

Although we have reached a place where improvements in our wastewater treatment are paying big dividends daily, we face myriad old and new challenges that can be broadly divided into three categories: state-of-good-repair, sustainability and regulatory compliance. These challenges often conflict in terms of funding, staffing, physical space and energy consumption.

State-of-Good-Repair

All the work we do for the public and for the environment depends on our ability to operate, maintain, repair and replace our base wastewater infrastructure. Keeping all the equipment and systems in a "state-of-good-repair" (SOGR) is critical to our ability to keep the public safe, be good neighbors to our communities, meet permit requirements, and achieve aggressive sustainability goals.

DEP's network of 14 WWTPs and 96 pumping stations have been in operation for several decades, with some structures at their century-mark. A significant amount of equipment throughout the system is still in operation despite being well past its useful life. We carefully plan upgrades, replacements and repairs to these systems; however, competing needs from new regulatory requirements and other investments can delay the best strategies for optimal performance. Thus, we find ourselves often in a "reactive mode," dealing with unfortunate equipment failures rather than engaging more fully in preventive and predictive maintenance activities.

Investing in a mature asset maintenance, repair, and replacement program does not always create a lot of excitement, nor result in shiny new projects. These essential business practices can also be easily misunderstood or devalued from the budgeting perspective. However, a robust asset management and maintenance program, which operates from the shop floor and wrenches up to the planning and budgeting spreadsheets, is the only way to support operations and continue to meet water quality, permit and community expectations. Awareness and commitment to SOGR needs to come from all stakeholders in our wastewater system, including elected officials, regulators, community organizations, non-profits and the general public.

To support the success of operations and meet the growing challenges of sustainability and increased regulation, BWT is embracing data-driven analysis and advancing to a more sophisticated and proactive asset management program. For example, we are advocating for more projects that are comprehensive and target a systems-level rather than an equipment-based focus. Assets identified by systems will allow for comprehensive maintenance planning, improved capital investment, and more cost-effective service to our ratepayers.

Sustainability

Both DEP and New York City have established policies and objectives in the last decade related to comprehensive sustainability planning. These are documented in sweeping plans starting with *PlaNYC* (2007) and, more recently, *OneNYC* (2014).

The BWT, as the owner, operator and maintainer of WWTPs, is an essential leader for the city and for the region in meeting energy and sustainability goals. We are finding new ways to reduce consumption from our energy-intensive processes. We are green-energy producers making valuable products from the waste stream, including biogas, heat, and electricity. We are utilizing and expanding solar cells while assessing even more alternatives. We are lowering greenhouse gas emissions through smart investing and optimizing operations. Moreover, we are poised to advance our role in carbon sequestration.

While you will find these topics covered in many of the articles in this issue of *Clear Waters* magazine, one area where BWT can make a significant impact to both environmental and fiscal sustainability is biosolids.

When ocean disposal of sludge ended as an option in 1992, New York City spearheaded a wide variety of programs for biosolids management. Generating an average of 1,200 wet tons per day of material required a diverse mix of vendors and destinations to ensure reliable removal of cake solids from the plants every day. Over the years, the city has composted (both on-site and remotely), heat-dried and directly land-applied processed solids.

In the last decade, however, it has been much more cost effective for DEP to dispose of biosolids to landfill. Currently, we direct dewatered cake solids to landfills in Pennsylvania, New York, Georgia, Virginia, Alabama and Ohio. Additionally, the city has an intergovernmental agreement with the Passaic Valley Sewerage Commission in New Jersey to accept thickened liquid sludge by barge. This material is then managed through the Zimpro® process and used as landfill cover.

As part of *OneNYC*, DEP has made a commitment to stop landfilling biosolids by 2030. Advanced technologies such as thermal hydrolysis, low-temperature drying, and pyrolysis are becoming commercialized and offer more efficient processes to transform cake solids into higher quality products. These products improve soil health and sequester carbon, making a significant contribution to New York City achieving its carbon neutrality goals. As part of the DEP's commitment, BWT recently hired a Biosolids Program Manager to focus on our biosolids future and move toward 100 percent beneficial use.

Regulatory Compliance

Permit limits change when new challenges emerge, and the definition of environmental quality continues to evolve. At the same

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time, we constantly look for "new and better ways to tackle old problems."

This is evident in our BNR program where, in addition to significant investments in process upgrades to the secondary treatment aeration systems at the WWTPs, we increased performance by separating treatment of the ammonia-rich side stream (centrate) from the biosolids dewatering process.

Since 2009, DEP has been operating the SHARON® (Single Reactor System for High Ammonia Removal Over Nitrate) Process, at the Wards Island WWTP. SHARON® quickly breaks down ammonia-nitrogen in the centrate stream at less cost and with a smaller carbon footprint than traditional technologies. The process is estimated to reduce the load by 10,000 pounds of nitrogen per day.

DEP continues to advance innovation to meet our nitrogen limits by evaluating what other utilities in the United States and abroad are doing to maximize treatment in limited footprints and reduce operating costs. DEP is now pursuing a de-ammonification-based Moving Bed Bioreactor (MBBR) process in the existing SHARON® reactors.

DEP will use a non-proprietary MBBR technology for de-ammonification, and we will be conducting a small-scale demonstration project to seed the MBBR. Successful demonstration of mainstream de-ammonification may allow DEP to eliminate the use of supplemental carbon at the WWTPs in the future.

Becoming a Wastewater Resource Recovery Facility of the Future

In BWT, our core mission to protect public health and enhance the environment both defines us and provides the basis for enhancing sustainability for our utility. We are advancing from simply handling wastewater for the purpose of meeting permit conditions to being progressive leaders in sustainable operations and resource recovery, seeking the best investments for environmental and social solutions.

Humpback whale seen in New York Harbor on September 27, 2017.
New York City DEP

Our work is gaining recognition as our WWTPs produce valuable products leading to local, regional, national and international sustainability. DEP and BWT will continue to be the leaders in improving water quality in New York Harbor, while striving to meet New York City's ambitious energy and sustainability goals.

Pamela Elardo, P.E., is the Deputy Commissioner of the New York City DEP Bureau of Wastewater Treatment. Questions regarding this article may be directed to Kathleen Esposito at kesposito@dep.nyc.gov.

The Bureau of Water Supply:

After 175 Years in Service, Waterworks Remain Marvel of Engineering

by Adam Bosch

When New York City residents turn the knob on a faucet, they are drawing water from a system of reservoirs and aqueducts that stretches far north of the city, into a wilderness of dense forests, rolling mountains and riffling streams.

New York City's water supply system is vast, storing a maximum of 580 billion gallons in 19 collection reservoirs and three controlled lakes located in the Catskill Mountains and the Hudson River Valley. They collect falling rain and melting snow from 1.2 million acres of watershed land, including some areas that sit more than 120 miles away from Manhattan.

Water from the reservoirs is conveyed to the five boroughs of New York City through more than 300 miles of aqueducts. These massive conduits are made of brick, concrete or steel, and each is large enough to carry a truck. The system was designed to convey its water by gravity alone, using the elevation difference between the mountainside reservoirs and the seaside city to deliver water without pumping. In fact, the pressure of gravity alone is enough to push water upward into the fifth or sixth story of buildings across almost every neighborhood in the city.

The New York City water supply system – the largest municipal water supply in the United States – is considered a marvel of modern engineers because of its size, scale and design.

Keeping the Structures in Good Repair

Now that its upland water supply is approaching two centuries of service, the New York City Department of Environmental Protection (DEP) is focusing much of its attention on maintenance projects. A number of large construction jobs are planned for the decades ahead – including some that have already begun – to keep the water supply system in a state-of-good-repair for the centuries ahead.

Most of these upgrades are focused on infrastructure that impounds and conveys water, including dams in the Catskills and both of the city's main aqueducts.

The Biggest Repair in New York City's Water Supply History

While upgrades or projects to rehabilitate existing water-supply infrastructure have been somewhat common, large-scale repairs to New York City's waterworks have been rare.

That is part of what makes the Delaware Aqueduct Bypass Tunnel project unique. It is the largest repair project in the history of the city's water supply – a huge effort to repair two leaks in the longest tunnel in the world.

The origins of the project date back to 1990. That year, a utility worker noticed water bubbling up from the western bank of the Hudson River at low tide. At the time, DEP was treating some of its Delaware Water System Supply reservoirs with copper sulfate, a chemical that knocked down algae. Water quality scientists from DEP tested the suspicious water bubbling up from the Hudson River and found that it tested positive for copper sulfate.

It was the first hint that the Delaware Aqueduct might be leaking. DEP soon used two high-tech machines – a remote-operated vehicle and an automated underwater vehicle – to meticulously comb the inside of the aqueduct, which had not been shut down for inspection since 1958. The inspections revealed a series of hairline cracks in the aqueduct in Newburgh (Orange County), where approximately 20 million gallons of water are escaping the tunnel and running into the river each day. A second area of leakage, farther to the north in Wawarsing (Ulster County), was also confirmed. Water in this area of the tunnel was leaking through three small holes in the grout lining of the tunnel, adding to an already-high groundwater table in the valley.

Both areas had presented challenges when the Delaware Aqueduct was originally constructed in the 1930s and 1940s. The Newburgh section was particularly difficult. Most of the aqueduct was drilled and blasted through very dense bedrock, but the geology alongside and under the Hudson River included crumbly limestone with fault lines. When work crews hit this formation during the original construction, as much as 2.5 million gallons of water each day, under huge head pressure from the river above, came barreling down on them. The crews bailed out and conjured a plan to deal with the water and support the tunnel. To provide the tunnel with structural support that the limestone could not provide, engineers coated about 1,900 feet of the Delaware Aqueduct in steel.

But the steel liner did not extend far enough. The hairline cracks in Newburgh formed just outside the limits of the steel liner, still within the limestone formation.

When first discovered, the leaks posed a serious dilemma for DEP. The Delaware Aqueduct delivers about 50 to 60 percent of New York City's drinking water on a typical day. At the time the leak was discovered, the city's demand for water was about 1.5 billion gallons each day. Engineers believed the aqueduct would need to be shut down for approximately four years to repair it from the inside, but the city did not have ample water in its other two systems – the Catskill and Croton – to withstand such a long shutdown of its main aqueduct.

Two breakthroughs yielded a solution. First, DEP assembled a

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The unique tunnel boring machine (TBM) was named "Nora" and will be used to build a 14-foot diameter bypass tunnel to repair leaks in the Delaware Aqueduct. *New York City DEP*

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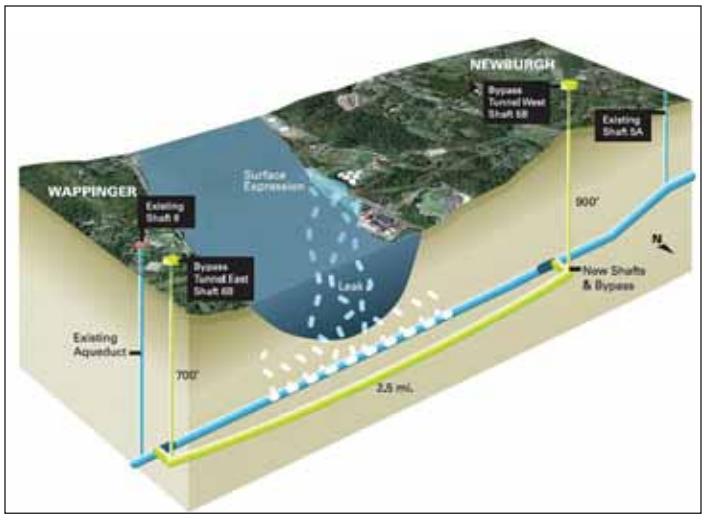

Schematic showing the 2.5-mile-long bypass tunnel under construction on the Delaware Aqueduct. *New York City DEP*

group of expert engineers from around the world to brainstorm a repair. That is when the concept of a bypass tunnel arose. The project would be like a bypass surgery for the water supply. Engineers would build a tunnel alongside the existing aqueduct, shut down the Delaware Aqueduct for a short time, and then connect the new tunnel to structurally sound portions of the existing aqueduct to convey water around the leaking section. The plan would reduce the shutdown time to only six months.

The second challenge, water demand, was met with creative solutions that focused on customer habits and modern fixtures. From 1990 to 2017, the population of New York City grew by 1.5 million people. But demand for drinking water in the five boroughs dropped by about one-third, to roughly 1 billion gallons each day. Demand was driven downward by the city's investment in modern-day metering, which changed people's water-use habits by billing them based on their consumption for the first time. Prior to this, water customers were billed based on road frontage. Demand was driven even lower by technology as the market was flooded with low-flow toilets, showerheads, dishwashers and other household appliances that sipped water instead of guzzling. In recent years the city took additional actions to reduce water consumption. It replaced thousands of outdated toilets in public schools, installed timers on showers in city parks, and issued a voluntary challenge to some of its largest restaurants and hotels to cut their water use by 5 percent.

Lesser demand for water in the city meant that the Catskill and Croton systems could now support the five boroughs for a shutdown of the Delaware Aqueduct.

In 2010, DEP announced a plan to address the leaks by building the $1 billion bypass tunnel around the leaking portion of the aqueduct in Newburgh, and also sealing the smaller leak in Wawarsing. The 2.5-mile-long bypass tunnel will run 600 feet under the Hudson River from Newburgh to Wappinger (Dutchess County). It will be located parallel and just north of the existing aqueduct. Once the bypass tunnel is finished, DEP will shut down the Delaware Aqueduct for six months, beginning in the fall of 2022, so that the bypass can be connected to structurally sound portions of the existing tunnel. The leaking portion of the aqueduct will be plugged and abandoned in place forever. The leak in Wawarsing will also be grouted closed during the six-month shutdown, and the entire aqueduct will be inspected for the first time in more than 60 years.

The project began in 2013 with the excavation of two vertical shafts in Newburgh and Wappinger to gain access to the subsurface. These shafts, 845 and 645 feet deep respectively, were completed in 2016. During the summer of 2017, workers completed an underground chamber at the bottom of the Newburgh shaft

Ashokan Reservoir, created in 1915, covers 8,315 acres and is a major component of the Catskill water supply system. *New York City DEP*

Shaft 5b, in Newburgh, New York, was constructed using drill and blast techniques as part of the Delaware Aqueduct repair project. This shaft will serve as the TBM launch site. A similar shaft at Wappinger, New York, will serve as the TBM retrieval site. *Kristen Artz, New York City DEP*

The interior lining of the 74-mile-long Catskill Aqueduct is being scrubbed to decrease friction, which will increase the tunnel's capacity by approximately 30 to 40 million gallons of water each day. *New York City DEP*

– akin to a large, underground factory room. The chamber serves as the staging area for the tunnel boring machine (TBM), and the spot from which pulverized rock will be lifted to the surface. Several railroad cars will run between the shaft and the TBM, delivering workers and supplies to the machine, and taking excavated rock back to the shaft.

The tunnel will be driven by a unique TBM that measures 21.6 feet in diameter, stretches 475 feet long, and weighs upwards of 2.7 million pounds. Because workers met huge inflows of water during construction of the original aqueduct, the TBM was built to withstand more head pressure than any tunneling machine ever built. It can withstand 290 PSI of pressure, a quantity equal to 10 times an average garden hose or about 8.5 times the amount of pressure in a car tire.

The TBM will take about 20 months to drive the entire 2.5-mile-long tunnel. The machine will grout concrete segments against the rock face as the tunnel is driven. Then DEP will install steel liners to provide structural support for the tunnel – except this time the steel will extend beyond the limestone. A total of 9,200 linear feet of steel will line the tunnel, nearly five times the length that was used during original construction of the aqueduct. The steel will then be coated in a second layer of concrete to achieve the bypass tunnel's finished diameter of 14 feet.

The massive repair project is expected to finish in 2023. And although it's the largest repair in the history of New York City's water supply system, residents of the five boroughs are not expected to see any change in their service.

Catskill Aqueduct Cleaning

Before the Delaware Aqueduct can be shuttered for six months in 2022, DEP needs to make sure that all other parts of the water supply are chugging at their maximum capacity to sustain the city.

The first part of that equation was the completion of the $3.6 billion Croton Water Filtration Plant in the Bronx, which was put online in 2015. The filtration plant can process and deliver a maximum of 290 million gallons of water each day from the city's Croton System reservoirs in Putnam and Westchester counties. That system had been shut down for nearly two decades while the filtration plant was designed and constructed.

The city's Catskill and Delaware supplies remain unfiltered because they meet the stringent regulatory criteria to avoid filtration. Combined, they are the largest unfiltered water supply in the United States. But the Croton Supply could no longer meet those standards, due to increased development within its watershed over the past 175 years.

With the Croton System ready and working, engineers also needed to be sure that the original Catskill System could deliver an ample supply of water to support the Delaware Aqueduct shutdown.

In this case, the Catskill Aqueduct is due for a cleaning.

When it was constructed the aqueduct could deliver a maximum of approximately 660 million gallons per day. More recently, however, it can only convey a maximum of about 595 million gallons per day. Engineers found that an accumulation of biofilm had reduced the aqueduct's capacity in recent decades.

Biofilm is comprised of harmless, filamentous bacteria that feeds off the naturally-occurring iron and manganese in the water. The bacteria attach themselves to the aqueduct lining, creating a rough surface along the smooth concrete. The roughness of the biofilm causes friction or drag inside the aqueduct, slowing the water down and reducing the conduit's capacity.

To solve this, DEP intends to shut down the Catskill Aqueduct for 10 weeks annually in the years 2018 through 2020. During those shutdowns, workers will climb down into the aqueduct and scrape the biofilm from the walls. Pilot tests thus far show that a flat metal scraper, similar to an industrial squeegee, is most effective for removing the biofilm. This cleaning will happen across 59 miles of its length.

To prevent biofilm from re-growing in the aqueduct, DEP is taking a lesson from Winnipeg, Canada. Winnipeg owns a cut-and-cover aqueduct that is nearly identical to the Catskill Aqueduct, but smaller. It also dealt with an accumulation of biofilm that was removed from the aqueduct lining. To prevent future growth, Winnipeg treated the aqueduct with a dose of chlorine for one shift, one day each week. The chlorine choked off the bacteria by oxidizing their food source.

Before the Catskill Aqueduct is cleaned, DEP will re-establish

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Gilboa Dam at the Schoharie Reservoir before rehabilitation, May 2010. *New York City DEP*

Gilboa Dam after rehabilitation, July 2015. The steps help to dissipate the energy of the water. *New York City DEP*

chemical feeds at an intake chamber for the Catskill Aqueduct, where chemical addition used to occur until the 1970s. A small dose of sodium hypochlorite or sodium dioxide will be added to the water periodically to keep iron and manganese away from the bacteria.

This $150 million cleaning of the Catskill Aqueduct also includes the replacement of more than 30 century-old valves along the course of the aqueduct, and the repair of a few small leaks along its cut-and-cover sections.

Experts predict the project will restore some of the aqueduct's historic capacity, allowing it to convey an additional 40 million gallons each day.

Comprehensive Rehab at Schoharie Reservoir

As DEP forges ahead with work on its aqueducts, it has also invested money to rehabilitate many of its dams. Most of the oldest dams in the Croton System were upgraded in the 1990s and early 2000s to meet modern dam-safety standards.

Now the city is working on some of its longest tenured dams in the Catskill System.

Gilboa Dam, built between 1919 and 1927, impounds Schoharie Reservoir, the northernmost reservoir in the city's water supply system. Schoharie Reservoir diverts its water through the 18-mile Shandaken Tunnel, which discharges into Esopus Creek where it travels another 11 miles before entering Ashokan Reservoir.

In 2014, the city completed a $138 million reconstruction of Gilboa Dam. The project included the addition of more than 500 massive spillway slabs, approximately 234 million pounds of concrete molded and dyed to resemble the original bluestone face of the dam, and upgrades to the abutment walls that support the dam.

DEP sharpened its focus on the dam after a comprehensive review of all its dams in the Catskill Mountains. Engineers in 2005 found that Gilboa Dam had a marginal factor of safety for flooding conditions similar to its then-record flood of 1996, which overtopped the dam by 6.7 feet. The review found that a similar flood could potentially cause the dam to fail.

Following that report, DEP moved immediately to make emergency repairs to the dam and protect the 8,000 residents who lived downstream. In 2006, a 220-foot-long by 5.5-foot-deep notch was cut from the top of the westernmost portion of the dam to control water spilling from Schoharie Reservoir and allow for the installation of 80 anchoring cables into the top and outer face of the dam. These post-tensioned anchors significantly improved the safety of the dam by pulling it tighter to the bedrock below. Temporary siphons were also installed to remove water from Schoharie Reservoir, over the dam's spillway and into the creek below, providing DEP with more control over the level of water storage in the reservoir.

Gilboa Dam is 2,024 feet long, 155 feet high, and more than 150 feet wide at its base. Several new features were added to the dam during its rehabilitation, including an inspection gallery inside the dam that runs its entire length. The gallery – which also includes instruments to constantly measure stress on the dam – allows engineers to visually inspect the inside and outside of the dam on a regular basis. The dam was also designed with 3-, 6- and 12-foot steps that dissipate the energy of water as it spills from the reservoir. The east and west abutment walls that support Gilboa Dam were also strengthened through the installation of 40 post-tensioned anchors, or steel cables that pull them tight to the bedrock.

The rehabilitation was completed ahead of schedule despite a nine-month setback in the wake of Hurricane Irene, which inflicted historic damage upon the Catskills and the city's water supply. The powerful storm sent roughly 8 feet of water over the dam's spillway, destroyed much of the staging area for construction, along with access roads and work platforms.

The Gilboa Dam project was part of a $400 million program to build and improve facilities at Schoharie Reservoir. Engineers are currently overseeing a $142 million element of that program, which will build a tunnel to release water from the reservoir into Schoharie Creek downstream of the dam. These near-release works are also meant to comply with modern dam safety standards. The ability to release water from Schoharie Reservoir will help DEP facilitate dam maintenance, respond to potential emergencies, mitigate flood risk for downstream communities, and enhance downstream habitat for fish and other wildlife. The release works are expected to be finished in 2020.

DEP began construction of the release works in July 2015. Thus far, the city has essentially completed excavations for an intake at the bottom of the reservoir and a release outlet near the creek.

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Work crews in the spring of 2017 lowered a micro-tunneling machine down a 82-foot-deep gate shaft that serves as the starting point for tunneling. The 9.5-foot-diameter machine will drive two tunnel sections that total 2,118 feet, running as deep as 185 feet below the surface. The first leg of the tunnel, which is nearly finished, will run 1,188 feet from the gate shaft to a valve chamber on the eastern bank of Schoharie Creek. The valve chamber – which acts as the portal that releases water into the creek – will include two valves capable of releasing about 65 to 1,550 million gallons of water each day. A third, smaller valve will be capable of smaller releases up to 65 million gallons per day. A second leg of the tunnel, stretching 930 feet, will run from the gate shaft to the intake crib at the bottom of Schoharie Reservoir, several hundred feet from the northern shore of the reservoir.

The Ashokan Century Program

New York City's very first reservoir in the Catskill Mountains is also scheduled to get an overhaul. In July 2017, DEP announced the Ashokan Century Program, a $750 million plan to upgrade water supply infrastructure at the reservoir. The multi-year capital program will include upgrades to the dam, dikes, chambers, and other facilities at Ashokan Reservoir. The program will comprise the largest public works project in the Catskills in more than 50 years.

Ashokan Reservoir is somewhat unique among its companion reservoirs in the New York City water supply system. The reservoir includes more chambers, dams and other infrastructure than any of the others. For example, the waters of Ashokan Reservoir are impounded by more than 29,000 linear feet of dam and dikes – a quantity that is more than all the other reservoirs of the Croton, Catskill and Delaware systems combined.

Investigative work to support the engineering designs, such as soil and bedrock sampling, began in 2017. Engineers will begin to design the projects in 2018. Construction is expected to begin sometime around the year 2023.

While exact details on each project will not be available until design work is completed, the overhaul of New York City's second largest reservoir is expected to last 10 years. It will include some of the following work.

- **Olive Bridge Dam and Ashokan Reservoir dikes:** DEP will perform a number of tasks at the Olive Bridge Dam, which is the main dam that impounded the Esopus Creek to form the reservoir, along with the many dikes that hold water in smaller valleys and coves. This will include structural upgrades, the installation of modern drainage and monitoring equipment such as piezometers, and the clearing of undesirable vegetation.
- **Ashokan Reservoir spillway:** DEP will reconstruct the spillway and spillway channel. The configuration of the spillway may be reworked to ensure the reservoir can pass the maximum conceivable flood.
- **Dividing Weir bridge:** Ashokan Reservoir is the only collection reservoir in the city's water supply that includes two basins. Engineers designed it that way to deal with episodic turbidity that happens during times of unusually high runoff. The West Basin was designed to retain murky water while suspended sediments settled out, and the reservoir's East Basin was intended to hold clear water that could be conveyed to the Catskill Aqueduct. The two basins are separated by a dam, known as the Dividing Weir, that contains 15-foot-tall gates. These gates can be lifted to transfer water from west to east. The Dividing Weir is also a bridge that carries a road over Ashokan Reservoir. That bridge will be completely reconstructed to include two travel lanes, shoulders, and a pedestrian/bike lane that will connect it to an existing network of recreational trails.
- **Ashokan Reservoir headworks:** The headworks are three masonry buildings that contain valves, gates and tunnels that convey water from Ashokan Reservoir into the Catskill Aqueduct. Under this program the superstructures will be rehabilitated, and many of the gates and valves will be replaced with modern equipment or refurbished in place.
- **J. Waldo Smith Monument:** The monument was used as a triangulation tower during construction of Ashokan Reservoir, allowing surveyors to take thousands of accurate measurements. The stone tower was later rededicated as a monument to J. Waldo Smith, the chief engineer who oversaw construction of the entire Catskill Water Supply System. The monument and its adjacent lands will be rehabilitated as a central location for public education and recreation.

As the New York City water supply looks toward its second century in operation, projects like these aim to fulfill the goal of those who designed and built a system that would "last the ages".

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2017 Highlights from the Watershed

The Bureau of Water Supply continued to send high-quality water to New York City every minute of all 365 days last year. Here are just a few numbers to highlight 2017:

- **334 billion** … total gallons of drinking water sent from the reservoirs to customers in New York City.
- **40 billion** … total gallons of drinking water consumed by communities in Westchester, Putnam, Orange and Ulster counties that are connected to the city's water supply.
- **219 billion** … gallons sent from the Delaware System.
- **143 billion** … gallons sent from the Catskill System.
- **12 billion** … gallons sent from the Croton System.
- **50,300** … water samples collected by BWS water quality scientists, both in the watershed and in the city.
- **617,000** … laboratory analyses performed on those samples by chemists, microbiologists, and other BWS staff.
- **1.2 million** … water quality analyses performed by the growing network of robotic monitoring buoys in the watershed.

Source: New York City DEP Weekly Pipeline, January 9, 2018, Volume IX, Issue 418.

The Water Systems that Support New York City

by Doug Greeley

The mission of the Bureau of Water & Sewer Operations (BWSO) is to provide New York City with reliable, environmentally sustainable and cost-effective distribution of high-quality drinking water, collection of wastewater, and management of stormwater while assuring the integrity and adequate capacity of water and sewer infrastructure now and for the future.

But what does this really mean?

BWSO operates and maintains a considerable portfolio of assets including: 6,800 miles of sewer mains; 7,500 miles of water mains; 109,000 hydrants; 149,000 catch basins; 100 miles of water tunnels with 73 supply shafts and distribution chambers; three manned booster pumping stations; two reservoirs; 68 groundwater wells; and 3,000 curbside rain gardens. Over the last decade, BWSO has embraced a data-driven, proactive approach to operating and maintaining the water and sewer system to improve efficiency. This look to the future is especially challenging as we must still operate and maintain a significant portfolio of older infrastructure.

Operations

BWSO is responsible for maintaining and operating the water distribution and sewer collection systems to ensure that residences and businesses in New York City have an adequate and continual supply of water as well as a properly functioning wastewater collection system.

The BWSO also spearheads enhanced programs and procedures, and leverages innovative technology to increase performance and improve efficiency, which include:

- An aggressive Pressure Reducing Valve (PRV) re-build and maintenance program and implementation of telemetry at the BWSO's remote sites to monitor pressures upstream and downstream of over 500 PRVs.
- Expansion of the BWSO's SCADA system that allows for remote monitoring of the entire water distribution system, which is equipped with operational alarms that allow the BWSO's Engineering Staff to respond and monitor emergencies in real time.
- Sewer Operations and Analysis Program (SOAP), which fosters proactive maintenance and requires the flushing of a city sewer when a reported sewer backup is confirmed.
- Degreasing program to identify problematic hotspots prone to residential grease discharge, and schedule cleanings based on severity of each location – monthly, quarterly or annually.
- Systematic and proactive sewer inspection; looking for evidence of surcharge, debris or any infiltration that could potentially obstruct flow.
- A comprehensive catch basin cleaning program, in which we proactively inspect all the city's catch basins once a year, and schedule cleaning and repairs as necessary. In Fiscal Year 2016, all of the city's catch basins were inspected and 96 percent were found to be functioning properly.
- Installation of flow monitors to alert field crews when an elevated flow level in a sewer pipe is detected. This technology allows staff to perform inspections and preventative maintenance, which enhances system capacity and improves the flow of wastewater.

With the implementation of these programs, we have improved the level of service citywide and achieved a significant reduction in complaints reported in key areas such as water main breaks, sewer backups, and response times.

Since 2012, the time to resolve sewer-related issues has fallen significantly, with sewer backup resolution times falling by 33 percent and catch basin-related complaints by 26 percent. In that same period, the BWSO increased proactive sewer inspections and cleaning by 133 percent.

In Fiscal Year 2016, 71 percent of sewer backups were related to grease; during the same period, total sewer backup complaints fell by 25 percent and confirmed sewer backup complaints fell by 49 percent.

In 2015, the BWSO conducted a survey of water main breaks in other major cities around the country. New York City had the lowest water main break rate for cities surveyed, with 8.3 per 100 miles, which is a 54 percent below the average of other surveyed cities and 67 percent below the national average. We believe this is primarily attributable to a regulator maintenance and telemetry system, which allows us to better monitor diurnal pressures throughout the system.

Capital Programs and Project Delivery

Planning includes updating and expanding in-city water distribution and sanitary/storm water collection systems. To achieve this, the BWSO manages a 10-year Capital Plan of more than $9 billion, and coordinates with other city agencies including the Department of Design and Construction, Department of Transportation, Department of Parks and Recreation and Department of City Planning so that all the city's competing needs are reconciled into one cohesive project.

In addition to some notable large-scale programs discussed below, BWSO focuses on capital water and sewer projects which:

- Support the build-out of the city's sewer system in accordance with the master drainage plan and the city's water supply system in accordance with the master trunk main plan.
- Ensure the long-term sustainability of the three city water tunnels, two in-city reservoirs, drinking water pumping stations, groundwater well stations and chlorination facilities.

Southeast Queens

DEP has initiated a comprehensive program to improve drainage conditions in Southeast Queens by investing $1.7 billion over the next ten years. The program will target chronic roadway flooding in large areas of low-lying, flat terrain with streets that have poor drainage design.

Southeast Queens has a complicated geography and history. Post-World War II expansion resulted in rapid development of these areas that significantly outpaced storm sewer development. In addition, the former Jamaica Water Supply groundwater-based distribution system in this area, now the responsibility of the DEP, was laid out in a radial rather than grid-based pattern. This complicates water system replacement projects.

In order to target those areas most in need, the BWSO examined complaint data from 2010 through 2014 and identified those areas with the highest density of wet weather flooding complaints.

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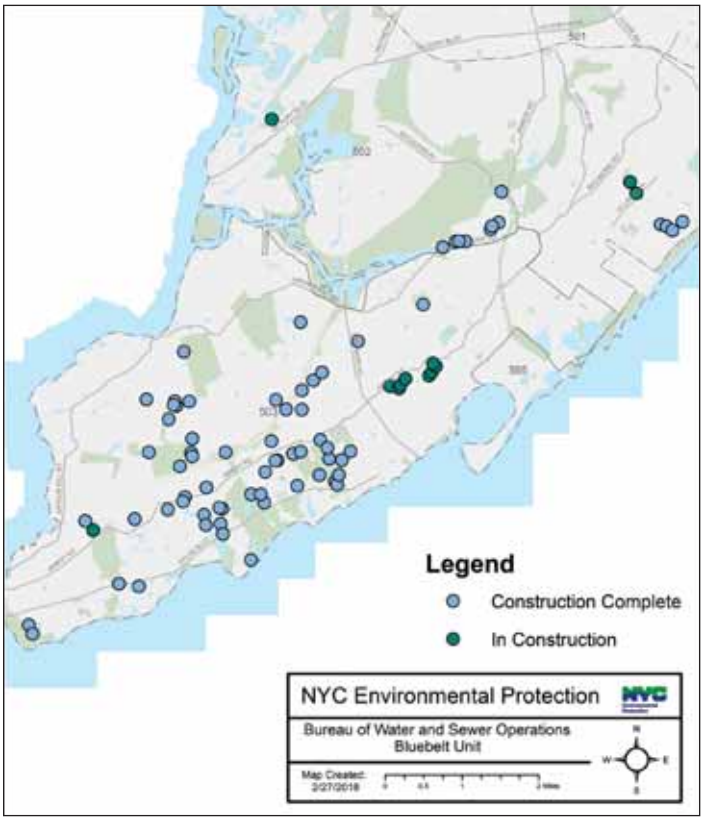
Twin Ponds Bluebelt, Queens, New York. *NYC Water*

Blue Heron Park Bluebelt Detention Basin, Staten Island, New York. *NYC Water*

This method yielded 50 priority grid areas. Teams of engineers then inspected each of the top priority grids during wet and dry weather to catalog street flooding, ponding conditions and existing infrastructure. The data was mapped block by block for each grid. This information was utilized in developing site-specific solutions.

While the program targets delivery of new storm sewers, it will also deliver upgrades to sanitary sewers, combined sewers, and water mains. Some of the water mains being replaced are former Jamaica Water Supply mains. The new mains will be integrated into the newer, surrounding water distribution system. The program also includes the development and expansion of the Bluebelt system within Twin Ponds, Brookville Triangle and Baisley Pond.



Bluebelt Stormwater Management Staten Island Installations. Many other Bluebelt projects are in planning for Staten Island and beyond. Other installations are already in place in Queens and the Bronx.

NYC Water

Approximately two-thirds of the funding will go towards the construction of key sections of large trunk spines that will discharge into Bergen and Thurston basins. This will include parts of the 150th Street, Guy Brewer Boulevard, Springfield/Laurelton and Farmers Boulevard spines. This work will take place through approximately 11 separate projects, and will be the basis for long-term future flooding relief. The rest of the funding will support dozens of smaller local sewer projects, which will connect neighborhoods to trunk sewer spines where existing capacity is available. These local sewers will bring shorter-term relief for those experiencing chronic flooding.

The award-winning Bluebelt system is a cost-effective program that preserves natural drainage corridors, such as streams and ponds, and optimizes their stormwater carrying capacity to help control and filter the runoff. On Staten Island, Bluebelts receive drainage from approximately one-third of the island's land area. In the South Richmond and mid-Island areas, the city has purchased over 400 acres of property to create the Bluebelts, providing drainage for 19 watersheds covering over 14,000 acres. To preserve our natural heritage, the Bluebelts are landscaped with native vegetation that also serve to maximize its functionality. The catch basins receive road drainage via new storm sewers. Water directed to Bluebelt wetlands and detention ponds is naturally filtered prior to discharge into local waterways. The complete Bluebelt system manages stormwater from over 15,000 acres of land between 26 watersheds. In 2017, the Institute for Sustainable Infrastructure (ISI) recognized the recently completed Sheldon Avenue Bluebelt project with its *Envision Silver Award,* just the second New York City project to receive the award.

We hope to incorporate Bluebelt thinking into drainage improvement projects in the other boroughs, to improve the water quality of stormwater discharged to our surrounding waterways as well as enhance the quality of both community and ecological health in the vicinity of our projects.

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Integrated Hydrologic and Hydraulic Modeling for Coastal Resiliency Planning

by James Garin, Gregory Mayes, Sandeep Mehrotra, Charles Wilson and Caitlin Fedio

Coastal Resiliency in New York City

Managing extreme storm events is a challenge for many coastal cities and towns. As climate change increases the threat of extreme events, municipalities search for ways to adapt and protect their critical infrastructure and vulnerable populations from the risk of heavy rainfall and storm surges. Damage left in the wake of Hurricane Sandy exposed New York City's vulnerability to coastal storm events and resulted in an estimated $19 billion in damage due to overland storm surge inundating low-lying areas. Climate change and sea level rise are projected to further increase the city's risk of flood damage during future coastal storm events.

The East Side Coastal Resiliency (ESCR) Project – which proposes a series of berms, floodwalls, and deployables – is the first large-scale flood protection project undertaken to protect New York City from storm surge. Generally running parallel to the East River coastline in Manhattan and extending approximately 2.4 miles from East 25th Street to Montgomery Street, the ESCR Project is designed to reduce the risk of inland flooding during extreme storm events like Hurricane Sandy. ***(Figure 1***). Since the inception of the ESCR Project during the city's Rebuild by Design Competition in 2014, several other resiliency studies and design projects have begun.

Coastal Resiliency Goals and Need for Interior Drainage Analysis

Coastal resiliency projects must do more than keep floodwaters from storm surge and rising tides at bay. Cities such as New York City are also concerned with surge waters impacting the existing sewer system's functionality during extreme storm events. Most of the city's sewers are combined sewers, meaning that stormwater runoff and sanitary flows are conveyed in the same pipes. During a rainfall event, excess flow generated due to runoff is relieved as combined sewer overflows (CSO) through outfalls along open water bodies. However, under a storm surge condition, the tide gates on the combined sewer outfalls are closed by high tidal elevations, limiting or preventing CSOs. Without relief provided to the system via outfalls, combined flow can back up in the sewer system, causing sewers to surcharge and potentially flood streets, a process referred to herein as inland flooding ***(Figure 2)***.

Figure 1. New York City 100-year floodplain and ESCR project area.
Floodplain data courtesy the Federal Emergency Management Agency. Aerial imagery courtesy ESRI. Graphic prepared by Hazen and Sawyer.

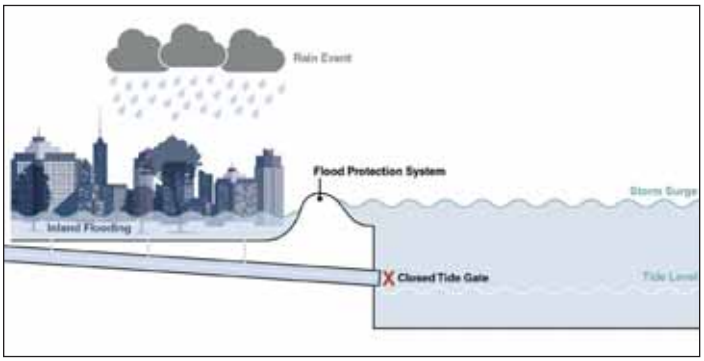

Figure 2. CSO outfalls can be held closed under storm surge conditions, causing inland flooding. *Hazen and Sawyer*

Flood protection barriers, like the one proposed for the ESCR Project, will reduce the risk of overland flooding from tidal surges. However, residual inland flooding due to drainage infrastructure capacity limitations, which can occur with or without such barriers, becomes more noticeable with the presence of a coastal barrier that prevents overland surge flooding. To holistically reduce flooding risk during extreme storm events, which often consist of coincident rainfall and tidal surges, municipalities must assess the risk of inland flooding occurring and provide drainage management solutions in conjunction with surge protection measures.

Available Modeling Tools for Analysis

As part of the ESCR Project, significant hydrologic and hydraulic modeling efforts were undertaken to evaluate the risk of inland flooding and determine feasible drainage management strategies. To accomplish this, the movement of surge waters, stormwater runoff, and combined sewer flows were analyzed, both in the sewer system and overland. Software with hydraulic and hydrologic modeling integration (a two-dimensional model) is best suited for simulating complex flow patterns and the relationship between the hydraulic grade line (HGL) in the sewers and overland surge flooding. Unlike a traditional one-dimensional hydraulic model, which can quantify above-grade flooding volumes (not depths), a two-dimensional model is also able to quantify overland flow velocities and flooding areas and depths. Two-dimensional models link the topography to the sewers and manholes of a modeled area. This allows flows to be simulated as they move overland and around ground surface obstacles and buildings, providing a more realistic aereal extent of flooding risk.

Various software programs are available to perform two-dimensional modeling for a coastal resiliency project. The programs most commonly used for New York City projects include Mike Urban and InfoWorks Integrated Catchment Model (ICM); however, other software programs, such as USEPA's Storm Water Management Model (SWMM) have similar modeling capabilities.

Model Development

Once modeling software is selected, the integrated model must be assembled and calibrated. This involves delineating the project drainage area, building out the hydraulic pipe-node model to represent the existing sewer and drainage infrastructure, and defining appropriate drainage subcatchment areas for the sewer network. Field data, such as tidal levels and sanitary flows, should be collected and incorporated into the model. Once completed, the two-dimensional model must be calibrated and verified against field data for historical wet-weather events.

The ESCR Project model was developed from an existing InfoWorks Collection System (CS) network, maintained by the New York City Department of Environmental Protection (DEP), and upgraded to InfoWorks ICM to provide two-dimensional flood modeling capabilities. The network of sewer pipes and manholes was significantly expanded to include virtually all infrastructure within the project's drainage area, increasing the resolution of the sewer system to include sewers as small as 18 inches in diameter for maximum modeling accuracy ***(Figure 3)***. In conjunction with the pipe network build-out, the model's drainage subcatchment areas were subdivided and refined to improve the collection system modeling resolution.

To equip the hydraulic base model with hydrologic modeling capabilities for each subcatchment area, it must be provided with high-resolution above-ground topography data (such as LIDAR), building footprints, and other surface details, such as roadway curb cuts. These surface inputs form the two-dimensional surface to which the sewer system is linked. It defines the available overland flow paths for sewer surcharge and flood waters on the ground surface ***(Figure 4)***. Runoff coefficients were assigned to each drainage subcatchment area based on ground cover types.

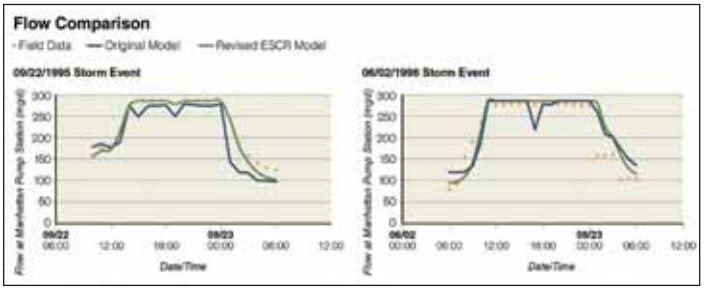

Figure 5. Model validation plots confirm the performance of the model under historic wet-weather events compared to collected field data.
Hazen and Sawyer

To confirm the validity of the model after its enhancements, it was verified against measured field data. For the ESCR Project, flow data was collected at DEP's Manhattan Pump Station during dry and wet weather in 1995 and 1996. Four unique storm events were isolated from the data and simulated with the original one-dimensional model and the updated two-dimensional model. The revised model results compared favorably with the actual observed flow from Manhattan Pump Station as well as the original model results, indicating that the model inputs were valid and that the model is appropriate for further drainage analysis ***(Figure 5)***.

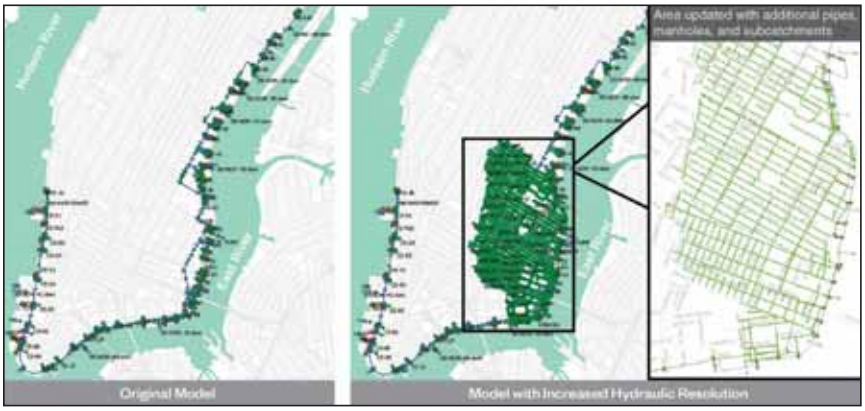

Figure 3. Enhanced pipe network resolution increases the resolution of the modeled hydraulic results.
Hazen and Sawyer

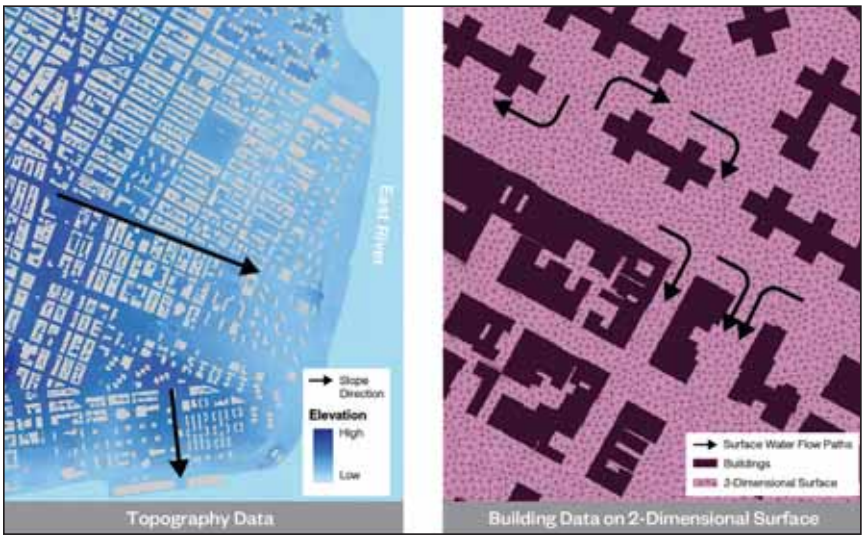

Figure 4. Topography data routes flow across ground surface from high elevations to low elevations. Building footprint data completes the two-dimensional surface to dictate available surface water flow paths.
Hazen and Sawyer

Design Parameters

The design parameters for a coastal resiliency project must establish the design storm conditions for which the project will provide risk reduction. The design storm is defined as the maximum coincident rainfall and surge severity. The probability of a hazard occurring is commonly described in terms of return period, or the time interval of average recurrence, and is given in terms of years. However, this is often misinterpreted as the number of times an event will occur during a given time period, e.g., a 100-year storm occurs once every 100 years. As such, the Federal Emergency Management Agency (FEMA) describes flood events in terms of annual exceedance probability, which is described as a percentage. For example, a 100-year storm surge has a one percent chance of recurrence in a given year. For the ESCR Project, the design flood elevation was established as a one in 100-year surge event plus a high estimate of 2050s sea level rise (approximately 30 inches).

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To model rainfall concurrent with a 100-year surge, the ESCR Project analyzed two design storms, as defined by the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 10 guidance (NOAA 2015), to establish a range of protection levels. The NOAA 2-year and 5-year, 24-hour, 2nd quartile (median) design storm distributions were used to assess drainage management requirements for the project area. Total precipitation depths for the NOAA 2- and 5-year design storms as recorded by the NOAA Central Park rain gauge are 3.5 and 4.6 inches, respectively. The two design storms were carried through the ESCR modeling process to bracket a reasonable range of estimated flooding risks and their associated drainage management requirements. For each storm, the peak rainfall intensity was aligned with the peak tidal elevations to provide the most conservative result as the coincident peak represents the point at which CSO capacity would be most limited.

In addition to the surge and rainfall modeled parameters, wave overtopping of the flood protection system and overland and/or sewer flows from areas outside of the project area should be isolated or incorporated into the model, as applicable.

Development of Drainage Management Alternatives

Once the model is verified and the design parameters are set, the coastal flooding risk analysis can begin. The first step in the analysis is to establish baseline sewer HGLs for the design rainfall event under existing sewer system and mean high-water tidal conditions. The project should aim to maintain the baseline sewer HGLs once the flood protection system is in place. For the ESCR Project, the modeled peak HGL was tracked at locations in the collection system for each modeled storm surge simulation as a metric for comparison between scenarios. The model should be simulated for the design storm (the design surge conditions coincident with the design rainfall event) to determine the HGL response to the storm conditions and, subsequently, the drainage management needed to restore the HGLs to the baseline levels.

When the design surge conditions were applied to the ESCR model, the simulations revealed that HGLs exceeded the established 2-year and 5-year baseline conditions, resulting in above-grade, inland flooding within the project area.

Two-dimensional models can be a tool to determine the volumes and locations of drainage management required to mitigate the observed surcharging and flooding areas, depths and durations and to verify the effectiveness of proposed drainage management alternatives. For the ESCR Project, a weir with unlimited overflow capacity was modeled at each of the project area regulators to determine the volume and peak flow rate of overflow under the design rainfall and surge conditions that was required to restore the HGLs to the baseline levels. The flow rates and volumes over the weirs are analogous to the flow to the CSO outfalls under non-surge tidal conditions.

Once the required drainage management flow rates and volumes are established, various drainage management strategies can be incorporated into the model to evaluate their effectiveness. Drainage management strategies include constructing upstream controls (such as retention basins and blue roofs) to capture wet-weather flow before it reaches the combined sewer system; increasing pumping capacity to discharge excess sewer flows to the outfalls under surge conditions; and/or wet-weather storage facilities to hold excess flow during a storm event. In addition, leveraging the capacity of existing drainage infrastructure, via inline storage or increased conveyance capacity, can provide effective solutions.

Critical Considerations for Drainage Management Alternatives Assessment

The drainage management alternatives must be evaluated with respect to their hydraulic benefits as well as constructability, cost, schedule, and operations and maintenance requirements. Socioeconomic impacts to public spaces, project stakeholders, and adaptability to future risk (such as sea level rise) must also be considered. For example, urban areas typically have extreme space constraints and extensive utility conflicts, often complicating the siting of new large infrastructure. Similarly, prior to and during extreme storms, operations teams are likely to be busy working to minimize the effects to the infrastructure and their customers, so drainage management strategies that require minimal operational effort during a storm event are generally preferred. These considerations must be at the fore as proposed drainage management strategies are refined, modeled, and ultimately selected.

The ESCR drainage analysis determined that sufficient drainage capacity exists at the Manhattan Pump Station to manage all wet-weather flow from the ESCR Project area for the design storm conditions, assuming the project area is isolated from surge waters in tributary areas upstream of the protected area. Hydraulic limitations in the project area's sewer system, upstream of the interceptor that conveys flow to the facility, were determined to be the cause of the elevated HGLs predicted by the model.

Additional conveyance capacity that would be activated only in response to a forecasted storm surge event was proposed as the primary drainage management strategy for the ESCR Project. Additional conveyance capacity would relieve upstream hydraulic limitations identified in the branch interceptors and lateral sewers within the project area and would allow the full capacity of the existing interceptor and Manhattan Pump Station to be employed. This approach allows the majority of new infrastructure to be sited in the right-of-way, which requires less capital and operations investment and can be implemented faster than larger scale pumping and storage infrastructure. Additional conveyance capacity also requires limited operation and monitoring during a storm event with fewer long-term maintenance concerns.

The city determined that in the future, additional inland flooding risks posed by climate change and future sea level rise can be mitigated through investments in additional infrastructure, as needed.

Drainage Management Refinement and Verification of Performance

Once a preferred drainage management strategy is selected, its performance must be confirmed for the design storm conditions. The last step is to model the performance of the drainage management strategy during historical storm events. The reason for this is three-fold: (1) the rainfall and surge distributions for actual storm events often include multiple peaks, as opposed to a single concentrated peak used for many synthetic design storm events; (2) to assist managers and elected officials in preparing emergency operation and preparedness plans; and (3) to assist public outreach and engagement by depicting project effectiveness in terms of familiar historical events.

For the ESCR Project, a suite of historical extreme storms, as

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Table 1: Modeled Storm Events for ESCR Drainage Management Assessment

Storm Event*		Rainfall Total (in)	Peak Rainfall Intensity (in/hr)	Peak Storm Tide (ft Manhattan Sewer Datum)
Design Parameters	2-year NOAA with 100-year surge	3.5	0.4	9.6
	5-year NOAA with 100-year surge	3.6	0.5	9.6
Historical Events	Sandy	1.0	0.1	9.5
	Irene	6.9	0.9	5.1
	1992 Nor'easter	3.2	0.2	6.6
	Floyd	6.8	1.2	3.1
	Donna	2.7	0.3	5.6
Extreme Synthetic Events	Donna rain with 50-year surge	4.5	0.6	8.4
	10-year rain with 50-year surge	5.5	0.6	8.4
	100-year rain with 50-year surge	8.7	0.9	8.4

*Note: *Rainfall data from Central Park rain gauge, except for the Extreme Synthetic Event "Donna rain with 50-year surge," which uses actual Donna rainfall depth and peak intensity from the Elizabethport, New Jersey, rain gauge. Tidal levels were recorded at the Battery tide gauge.*

well as some additional synthetic design storms, were simulated with the proposed drainage management strategy in place to evaluate its effectiveness. The historical storms included Hurricane Sandy (2012), Hurricane Irene (2011), Hurricane Floyd (1999), Hurricane Donna (1960), and the 1992 Nor'easter. The additional synthetic storms were a 10-year and a 100-year rainfall, each coincident with a 50-year storm surge, as well as a Hurricane Donna rainfall with 50-year storm surge. These storms effectively tested the drainage management system under a wide range of possible coastal storm risks, from high surge and low rainfall (e.g., Sandy) to low surge and high rainfall (e.g., Floyd) ***(Table 1)***.

The modeling results indicated that the preferred drainage management strategy could mitigate the effects of inland flooding under the design parameters ***(Figure 6)***. However, the modeling also revealed that even with the proposed interior drainage infrastructure in place, extreme storm events (with lower probabilities of occurring than the design storm) are anticipated to cause sewer surcharge and inland flooding that cannot be fully managed. These scenarios include events with a moderate rainfall and coincident moderate storm surge severity, such as Hurricane Irene. Additionally, significant inland flooding may occur during unprecedented storm events, like the modeled synthetic events.

Due to the significant capital funding required and difficulty of siting infrastructure that would be necessary to mitigate these low-probability events, the city recommended that such events be addressed through operational and emergency management measures rather than permanent infrastructure. Such measures may include deployment of emergency pumps or street closures in flood prone areas, as appropriate.

Figure 6. Sample two-dimensional modeling outputs indicate surface flooding benefits of drainage management for inland flooding during a coastal storm surge event. *Hazen and Sawyer*

Success Found in Coastal Resiliency Modeling

Integrated two-dimensional hydrologic and hydraulic modeling has successfully been used to predict sewer hydraulics and overland flow for urban coastal resiliency studies including, but not limited to, the ESCR Project.

The modeling software is a useful tool for communicating information, engaging project stakeholders, and generating detailed flood maps and videos that animate the system response. The model data provide designers with crucial design inputs such as sewer flow rates and depths, as well as flooding volumes, durations and depths. By far, the most significant benefit of high-resolution, two-dimensional modeling is that it can be used to provide a visually illustrative demonstration of the level of risk mitigation that can be provided by a flood protection project through evaluating performance under a multitude of scenarios.

The modeling and analyses developed for the ESCR Project translate well to similar coastal planning applications, allowing for the simultaneous analysis of above- and below-grade stormwater and sewer flows for optimized resiliency planning.

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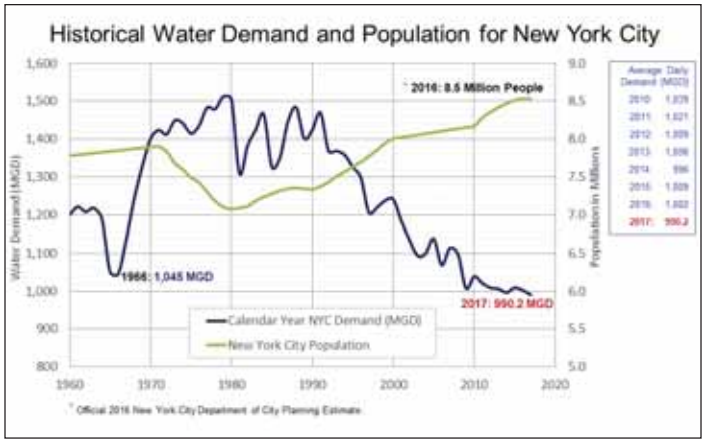
Demand Management: Innovative Programs to Save Water for New York City

by Ben Huff, Erin Morey and Alan Cohn

New York City's drinking water demand is the lowest it has been in more than 50 years, even as the city's population has increased. Reducing drinking water demand readies the city for water shortages, offsets energy and greenhouse gas emissions associated with pumping and treatment and reduces flow to sanitary and combined sewer systems. The New York City Department of Environmental Protection (DEP) is the lead agency not only for delivering drinking water, but for ensuring its sustainable use.

Beginning in the early 1990s, DEP began monitoring leaks in the Delaware Aqueduct, which supplies approximately 50 percent of New York City's daily water supply. After a decade of studying and assessing the problem, DEP launched the Water for the Future Program to repair the leaks and secure the future performance of the aqueduct. Under the program, DEP is currently constructing a tunnel parallel to the aqueduct to bypass the leaks and, once construction is completed, will shut down the aqueduct for a six- to eight-month period, allowing DEP to repair the leaks.

In support of the Water for the Future Program, DEP released the 2013 Water Demand Management Plan, launching the agency's comprehensive Water Demand Management Program. Demand management was chosen as a cost-effective alternative to connecting to an adjacent water system to provide backup supply water during the planned shutdown. DEP's Water Demand Management Program is also beneficial to the city by reducing non-revenue water, optimizing metering infrastructure, and reducing losses in the distribution system through monitoring and improvement efforts.



New York City's drinking water demand is the lowest it has been in more than 50 years. Part of this reduction in demand is a result of DEP's Water Demand Management Program, initiated in 2013.

New York City DEP

Water Demand Management Plan

Since releasing the 2013 Water Demand Management Plan, the city has invested millions of dollars in implementing DEP's Water Demand Management Program, including six key initiatives:

- Strategy 1 – Municipal Water Efficiency Program, involves retrofits of city-owned properties through partnerships with city agencies.
- Strategy 2 – Residential Water Efficiency Program, includes the Toilet Replacement Program for multi-family buildings and other residential properties, and distribution of home water-savings kits.
- Strategy 3 – Non-Residential Water Efficiency Program, promotes collaboration with private-sector organizations including hotels, restaurants, and hospitals.
- Strategy 4 – Water Distribution and System Optimization, includes system repairs and upgrades, managing water pressure, and refining water meter accuracy and leak detection.
- Strategy 5 – Water Shortage and Supply Management, entails the review and revision of plans to prepare for drought and other water shortages.
- Strategy 6 – Upstate Wholesale Customers Demand Management Program, added in 2014, targets demand management planning and implementation for wholesale customers north of the city.

Demand Management Strategies in Action

As part of the Municipal Water Efficiency Program, DEP partnered with the Department of Education (DOE), Department of Parks and Recreation (NYC Parks), Fire Department of the City of New York, and City University of New York. DEP also prioritized water reduction in its own facilities and identified wastewater treatment plant efficiencies to reduce consumption.

The DOE is the largest public education system in the United States. With over 1,400 buildings, the majority of which were built prior to the 1970s, DEP recognized a significant opportunity for plumbing upgrades. Partnering with DOE, DEP has funded the replacement of over 30,000 toilets and urinals with WaterSense®-

DEP, in partnership with NYC Parks, has installed 400 spray showers with push-button timer activation to save water in city parks.

New York City DEP

certified models in over 340 schools across all five boroughs. DEP anticipates that 500 schools will be retrofitted by 2020, accounting for 40,000 total fixture replacements.

DEP partnered with NYC Parks to retrofit spray showers with push-button timer activation located in city parks. Through this partnership, which concluded in summer 2017, DEP funded the retrofit of 400 spray showers citywide. The new spray showers require users to push the button to activate the play feature, instead of continuously running all day once initially activated by Parks staff. In addition to 400 spray showers, DEP also funded fixture replacement in nine NYC Parks recreation centers citywide.

DEP also completed Water Challenges at wastewater treatment plants to encourage water reductions in the agency's own facilities. During the challenges, DEP staff review operations and purchase new equipment to improve water efficiency. Staff have recognized that plant operators could benefit from hand-controlled spray nozzles for cleaning equipment to avoid water losses during this process. Staff have also worked to upgrade and repair pumps and pump seals to further reduce water losses. To date, of the 10 wastewater treatment plants that have participated in these challenges, five were able to achieve a 10 percent reduction from the previous year's baseline average. These projects alone have helped save the city over 4 million gallons of water per day.

As part of the Residential Water Efficiency Program, DEP launched a Toilet Replacement Program in May 2014. The program offers $125 vouchers to eligible residential multi-family building owners to replace old, inefficient toilets with high-efficiency, WaterSense®-certified models. DEP created a website portal to help customers through the voucher redemption process. All vouchers are tracked in DEP's billing system, and each customer's meter consumption is monitored to verify that water savings are achieved. DEP manages contracts with four toilet wholesale vendors to accept the vouchers and provide toilets to consumers. To date, over 930 vouchers have been issued, with estimated water savings of 490,000 gallons per day.

In the non-residential sector, DEP successfully launched three Water Challenges to three different commercial sectors: hotels, restaurants, and hospitals. Participants are encouraged to reduce their annual water consumption by an average of 5 percent from their baseline year (measured as the 12-month period prior to the beginning of the Water Challenge). DEP prepares monthly reports to help participants track their consumption and performance against the other benchmarked participants in the Water Challenge. To further support participants, DEP also hosts quarterly workshops with industry professionals to provide information on how to improve efficiency of their facilities. At the end of the challenge, lessons learned – including successes and obstacles for reducing water in the industry – are included in a manager's guide to water efficiency. These guides are posted on DEP's website and distributed at workshops and conferences.

Water distribution system optimization entails repairs and upgrades to the system, managing water pressure, and refining water meter accuracy and leak detection. For this effort, DEP uses advanced technology leak detection, including acoustic software, to detect leaks that are not visible. DEP also responds to reports of visible leaks that are relayed to the agency by members of the public through the city's NYC311 system. In addition, DEP has launched a program to replace 70,000 large meters (1.5 inches or greater), which account for a third of DEP's revenue. By replacing these meters, small errors that could cumulatively result in gross under-representation of water consumption are reduced. DEP also affords customers the ability to access their consumption information online through their *My DEP* account, where they can also sign up for leak detection alerts.

Finally, in 2014, DEP launched a Demand Management Program for wholesale water utility customers located in upstate communities. As of 2017, DEP is partnering with 10 of its largest wholesale customers, which constitute approximately 10 percent of the system's current consumption. DEP offers assistance to these utility partners to develop individual Demand Management Plans and implement the identified conservation strategies over a four-year contract period. The program goal is a 5 percent total reduction in consumption from an identified baseline for each partner. This partnership highlights the important relationship between DEP and its upstate customers, and DEP will continue to work with these partners as each community completes and implements their plan by 2022.

Recent Highlights

Several of DEP's recent projects feature innovative strategies that serve as a precedent for future demand-management programming in New York City. One of these projects is a newly-constructed 40,000-gallon storage tank and water recovery facility at the Fire Department of the City of New York (FDNY) training facility on Randall's Island. FDNY mandates testing and calibration of hose equipment on fire trucks, which requires significant water use. Through this reuse project, water used for calibration and testing is collected in an underground tank and reused within a closed-loop system, instead of draining to the sewer system or nearest open waterbody.

The New York City Water Challenge to Hospitals is another successful project completed in 2017, following two years of working with three city hospitals to reduce their baseline water consumption by 5 percent. Although not every hospital was able to reduce their

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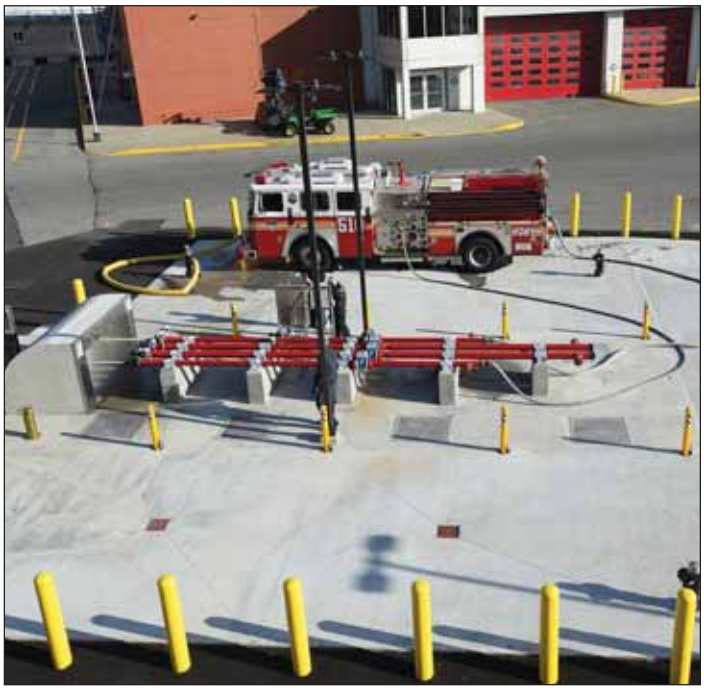

A 40,000-gallon storage tank and water recovery facility at the Fire Department training facility on Randall's Island collects used water in an underground tank and reuses it to calibrate equipment on fire trucks. *FDNY*

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consumption by 5 percent, all participants conducted water audits and have committed capital funding for efficiency upgrades. These audits have helped DEP understand the challenges and opportunities for water conservation in hospitals citywide.

Finally, DEP recognized a significant opportunity for sustainability by reusing porcelain from discarded toilets from school retrofits, which would have otherwise been sent to landfill. Working with the New York State Department of Conservation, DEP received two Beneficial Use Determinations for porcelain reuse, and was able to recycle thousands of fixtures. In Jamaica Bay, an artificial oyster reef was created with 6,500 discarded toilets. Combined with oyster and clam shells, the reef serves as home for 50,000 breeding oysters, with the crushed porcelain mimicking the shape of the oyster and clam shells for oyster spat to land and reproduce. Additionally, at Public School 120 in Flushing, Queens, 3,500 crushed fixtures were used to replace 110 cubic yards of crushed stone in a new playground, providing stormwater retention during rain events. These projects represent an integrated water management approach that DEP will continue to pursue as new opportunities arise.

The playground at Public School 120 in Flushing, Queens, uses 3,500 crushed toilets below its surface to provide stormwater retention during rain events. *New York City DEP*

Emerging Opportunities

DEP recently completed a study to expand its existing Water Demand Management Program, focusing on the Municipal Water Efficiency Program. As a result of this study, DEP plans to pursue new partnerships with NYC Health + Hospitals, which operates 11 public hospitals, and the Department of Citywide Administrative Services, which owns or leases over 50 public buildings. DEP also plans to expand existing partnerships with NYC Parks and DOE.

DEP is also promoting the uptake of water-saving technologies with the On-site Water Reuse Grant Pilot Program. This cost-sharing program is aimed at providing commercial, mixed-use, and multi-family residential property owners with incentives to install water-reuse systems, promoting construction of these systems at building and district levels by reimbursing up to $500,000 of efficiency technology capital costs. In addition, DEP's Comprehensive Water Reuse Program provides customers who install effective water-reuse systems a discount of 25 percent from their water and wastewater fee.

With a growing population, planned infrastructure repairs, and a changing climate, demand management is critical to the sustainability of New York City's water supply. In the last five years, daily water consumption has averaged approximately 1 billion gallons of water per day, and has twice dropped below 1 billion gallons per day. DEP's focus on demand management, including the successful creation of multiple partnerships to reduce water demand, has been critical to this downward trend of citywide water consumption and will continue to provide benefits to customers and the environment.

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Drivers for Sustainability at New York City DEP

by Erika Jozwiak

As the largest water and wastewater system in the nation, New York City is in a unique position to act as an example to other large municipalities as we pave a new path forward with sustainable infrastructure. The New York City Department of Environmental Protection (DEP) has a legacy of planning for the distant future and, thanks to this foresight in the past, has been able to meet the current challenges of an uncertain climate with innovative solutions. The city's infrastructure is historically built on the principles of lasting, resilient design. Long before sustainability became a popular buzzword in global industry, DEP was investing in the long-term future of its water-supply system, and pioneering advances in wastewater treatment.

Many challenges facing cities around the globe are exaggerated in New York City. As a coastal city and the most densely populated metropolis in America, the effects of climate change, waste generation, energy consumption and stormwater management are magnified. The challenges posed to the modern utility include an active and educated public, state-of-good-repair needs, and local, state, and federal regulation.

Inherent to the nature of the work performed, DEP is the second largest greenhouse gas emitter in the city, and the third largest consumer of energy. Considering the impact DEP has on the environment, the scale of our operations, and our established practice of planning for a variable future, we have the opportunity to make significant strides toward a truly sustainable system on a global scale.

Sustainability for water and wastewater utilities is uniquely defined. "Sustainable development" is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural-resource base essential for future development. Water and wastewater utilities are inherently linked to finite natural resources and water, so stewarding this asset responsibly is of utmost importance to DEP. As a public utility, DEP's most important obligation is to the ratepayers – the citizens of New York City who consume the water and rely on the effective disposal and treatment of their wastewater. The truly sustainable utility will deliver on the commitment to provide safe drinking water and clean waterbodies, in both the near and long term.

The incentive for meaningful integration of sustainability is being rapidly provided on a citywide level. Densely populated space with a history of environmental problems, continual urban sprawl, and associated demographic shifts create a scenario where social and environmental issues are inextricably linked. More than ever before, the current urban landscape motivates designers to place the triple bottom line of social, economic, and environmental considerations at the forefront of design. Mayor de Blasio's *OneNYC* and subsequent related Local Laws expand on the mainly environmental initiatives of Bloomberg's *PlaNYC* to include heavy emphasis on human rights and a higher quality-of-life for all New Yorkers. Ambitious environmental objectives, such as an 80 percent carbon reduction by 2050, are paired with a human element, such as fostering higher percentages of New Yorkers living within walking distance of a park. Resiliency preparation in the face of climate change-induced sea level rise is paired with an initiative to decrease flooding in vulnerable and often poor neighborhoods. The city can be seen as a microcosm for the flexibility and adaptability that will be required of America as we prepare the half of the U.S. population living within 50 miles of the coast for an indeterminate future.

DEP is uniquely poised, even among its partner city agencies, for incredible impact. *OneNYC* outlines four main tenants of sustainability for New York City:

- Vision 1: Our Growing, Thriving City.
- Vision 2: Our Just and Equitable City.
- Vision 3: Our Sustainable City.
- Vision 4: Our Resilient City.

Beyond individual energy targets and mandates is the understanding that the core vision of the *OneNYC* plan aligns with DEP's inherent missions as an agency. Several *OneNYC* initiatives target DEP directly, such as achieving net-zero energy at in-city wastewater treatment plants by 2050 and reducing the risk of stormwater flooding in most affected communities.

The New York City Local Laws that codify *OneNYC* ***(Figure 1)*** are valuable external incentives. However, nothing is a more powerful driver than the core mission of DEP: "to be the safest, most efficient, cost-effective, resilient, and transparent water utility in the nation." This is the true driver of sustainability as an entity, and what continues to develop our capital program. The external drivers serve as a mechanism to increase the pace of DEP's ongoing investment into becoming a truly sustainable utility in an environ-

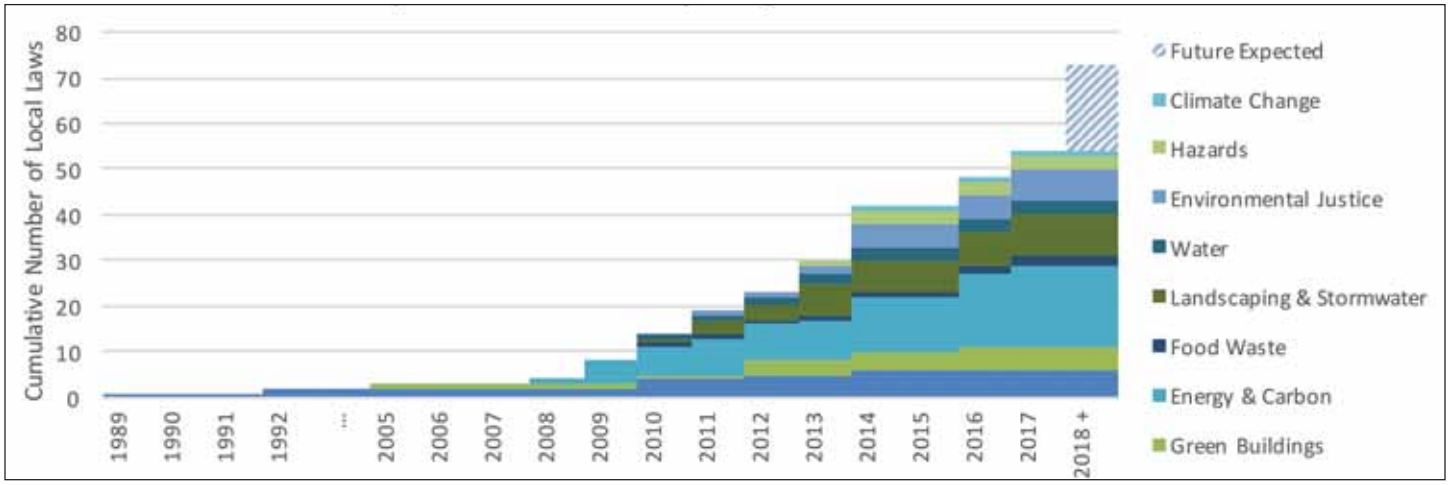

Figure 1. Sustainability related New York City Local Laws impacting water and wastewater treatment. *New York City DEP*

ment of competing economic needs.

DEP's response has been consistent with the mission and legacy of the agency. The Wastewater Resiliency Plan and Cloudburst Planning initiatives address the far-reaching impacts of climate change such as storm surge, sea-level rise, and intensified precipitation. The Green Infrastructure Program, Municipal Separate Storm Sewer System (MS4) Plan, and Staten Island Bluebelt initiatives work conjunctively to reduce combined sewer overflow and restore the landscape to more natural hydrologic conditions. Master planning and agency-wide solutions are effective strategies to mitigate the risks associated with a changing climate and, paired with embedded sustainability protocol, illustrate proven results.

The Bureau of Engineering, Design & Construction (BEDC) is the capital project delivery entity for the agency, developing capital projects for the three main operation bureaus. The Sustainability Section within BEDC serves to integrate sustainable design into each project in DEP's capital plan ***(Figure 2)***, tailoring lofty citywide initiatives into appropriate and effective methodologies. Operating full time within BEDC since 2014, the Sustainability Section provides training; maintains a working knowledge of regulatory changes and industry best practices; develops tools and guidelines; and takes on roles as necessary to assist project managers during the development of projects. The program utilizes several key performance indicators to create a lens by which to measure project sustainability:

- Energy – Energy usage and efficiency of equipment and systems.
- Emissions – Greenhouse gas emissions related to the final operating condition.
- Climate Change – Resiliency and adaptability of infrastructure to the changing climate.
- Environmental Impacts – Material selection of the built environment and waste-to-landfill reduction.
- Sustainable Sites – Stormwater management and landscaping functionality.

The Sustainability Section conducts design charrettes with project teams at two key junctions in design: facility planning and prior to 30 percent design. The outcome of the charrettes is a set of specific goals tailored to the project scope. This individualized approach allows for the adaptation of city strategies to a wide variety of infrastructure ranging from unmanned, subgrade pump stations to large-scale drinking water filtration plants coupled with community recreation areas.

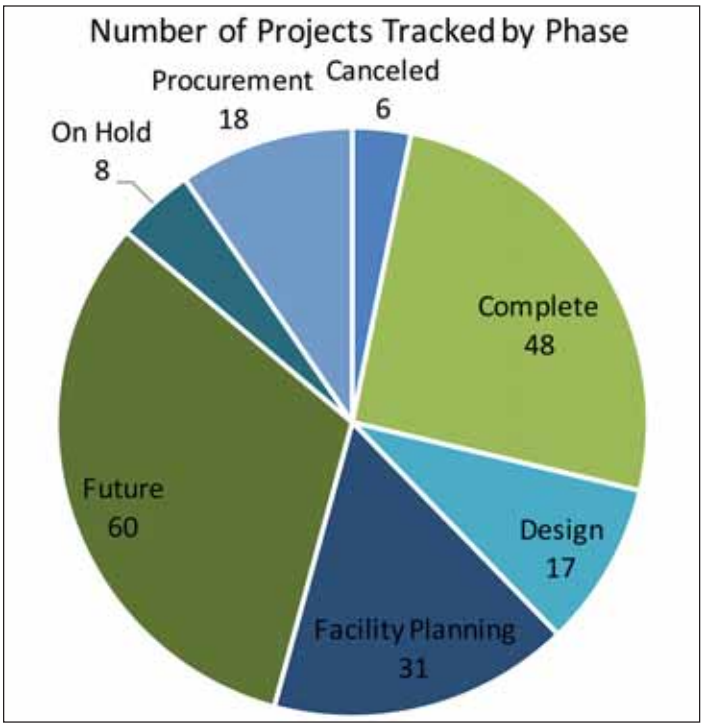

Figure 2: Number of projects tracked via the BEDC Sustainability Section, by project phase. *New York City DEP*

The Sustainability Section also endeavors to achieve full compliance with sustainability-related local laws. Laws 31 and 32 of 2016 particularly impact the BEDC, with new requirements for third-party certification (aka, LEED or *Envision* rating systems) for industrial infrastructure, and a 50 percent reduction in energy from non-process loads. Renewable energy is being actively incentivized as well: Local Law 6 of 2016 requires a geothermal feasibility assessment, and Local Law 24 of 2016 requires an assessment for solar. Under the new MS4 program, green infrastructure must be considered on all city projects for certain area thresholds. The BEDC sustainability program plays a vital role in keeping abreast of these policy changes, as well as providing guidance for compliance to project teams.

The tools developed by the Sustainability Section are the key to its ongoing success. Standard Operating Procedures (SOPs), design guidelines, specifications, contract language, employee education,

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Solar panel installation at Port Richmond Wastewater Treatment Plant in Staten Island. *New York City DEP*

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and staff support are some of the resources the Sustainability Section provides designers. SOPs have been developed for each of the aforementioned key performance indicators. Targeted and collaborative goal-setting by all stakeholders is critical for both the project delivery and educating BEDC staff. Embedding the sustainability program into the project delivery process and standardizing reporting requirements create the groundwork to foster innovative solutions on a project-specific basis.

Additionally, the *Envision* rating system has been adopted by the BEDC to assist designers in placing a quantifiable value to the "intangibles," (i.e., community quality-of-life). DEP infrastructure is, by design, unseen. Pump stations, wastewater treatment plants and drinking water treatment operations are not open to the public for safety and security reasons. The community should not interact tactilely with this infrastructure; therefore, it cannot be subject to traditional measurements of social impact. Designers as well are challenged to convey the indirect community benefit that can be gained from DEP projects. Visualizing how, for example, a small rain garden project can fit into the abstract concept of the "larger community" can be difficult and even more challenging to justify during early planning stages when critical design decisions are made. *Envision* adds quantifiable metrics to abstract parameters, and additionally aids the agency in compliance with new regulatory requirements – namely Local Law 32 of 2016. This legislation represents a new foray for industrial infrastructure into required green-building methodology.

A long-term, informed mindset has always been a guiding principle of DEP as a utility and has continuously driven success over the past 175 years. Our earliest engineers understood the value in planning for an uncertain future and we continue that legacy in our designs today. DEP's role in the changing climate cannot be understated and consequently our role in large-scale solutions and action cannot be underplayed. Today's requirements are numerous and stringent, and actively compel the agency in the direction of responsible, long-term design. The Sustainability Section is one of many evolving solutions. However, it is our own inherent ambition towards the better, the most reliable, the most resilient, the best investment for our customers – it is there that true sustainability is manifested.

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Programmatic Implementation of Resiliency Upgrades at New York City's Critical Wastewater Facilities

by Colin A. Johnson and Gabriel F. Giles

Hurricane Sandy raged across the Northeast in October of 2012 and impacted 10 of 14 New York City Department of Environmental Protection (DEP) wastewater treatment plants (WWTPs), and 42 of its 96 wastewater pumping stations. All of these facilities play a vital part in treating the wastewater for more than 9 million people in New York City. The impacts seen at the WWTPs and pumping stations were due to damage from floodwaters and/or power availability. The impacts of Hurricane Sandy provided DEP with the opportunity to advance programmatic implementation of resiliency at its wastewater facilities.

Program Overview

As part of New York City's commitment to planning for climate change and the impacts of extreme weather, DEP established the New York City Wastewater Resiliency Program (the Program). The Program is structured to manage the implementation of a portfolio of related work that will be partially funded by DEP and by two primary external funding sources: the New York State Storm Mitigation Loan Program and the Federal Emergency Management Agency (FEMA). The identified scopes of work have a principle goal of providing resiliency in the operation of DEP's wastewater facilities.

DEP has now started approximately $400 million in resiliency upgrades at New York City's critical wastewater collection and treatment facilities to help protect and recover more quickly from rising sea levels and storm events. The work is being implemented as a stand-alone program within DEP to achieve a coordinated, consistent approach to the work and meet funding reimbursement deadlines. The Program consists of a Program and Construction Management contract, four Task Order Contracts (TOCs) for design services, and eighteen Job Order Construction (JOC) contracts. The JOC contracts are pending advertisement.

Scope Development

Approximately half of the Program's work was defined in the *NYC: Climate Risk Assessment and Adaptation Study* (the Study), issued in 2013. The Study provides a detailed and comprehensive assessment of the risks that climate change poses to New York City's wastewater collection and treatment system. The Study, initiated in 2011 and expanded after Hurricane Sandy (2012), was based on an asset-by-asset analysis of the risks from storm surge under updated flood maps at all 14 treatment plants and 58 pumping stations, representing more than $1 billion in infrastructure assets. Without action, it was estimated that damage to the equipment from repeated coastal flooding at projected sea levels could exceed $2 billion over the next 50 years. The analysis originally recommended $315 million in cost-effective upgrades at these facilities to protect valuable equipment and minimize disruptions to critical services during future storms. The Study puts into action initiatives laid out in Mayor Bill de Blasio's *OneNYC: The Plan for a Strong and Just City.*

The Study also provided a guide to how New York City prepares for the impact of future storms. The Study, the first to assess coastal flooding risks based on fine resolution maps and detailed analysis of the elevation of individual components of the wastewater system, serves as a national model. The Study provides a scientific analysis of severe weather events and identifies more than 500 construction projects to strengthen the city's wastewater facilities, increase resiliency and, in turn, better protect the city's surrounding waters and public health for more than 9 million residents. DEP intends to further this initiative by applying a combination of the following general adaptation strategies at many of its wastewater facilities throughout the city:

- Installation of temporary and permanent barriers.
- Flood-proofing of buildings with the addition of sandbags and the flood-proofing of equipment.
- Raised elevations of critical equipment.
- Installation of emergency backup power.
- Sealing of buildings and control rooms.
- Electrical wire and conduit repairs and replacement.

The other significant Program scope funded by FEMA consists of electrical conduit and wire replacement at 15 DEP facilities. The scope of the Program's FEMA work was defined through assessments of the DEP facilities that sustained disaster-related damage as a result of Hurricane Sandy.

Contracting Approach

The Program's scope is geographically dispersed across 35 facilities throughout New York City's five boroughs. However, the similar types of work across the multiple locations lend to a programmatic approach to achieve efficiencies and consistency in implementation. DEP awarded a Program and Construction Management contract and four Task Order Design contracts for program management, design, and construction management services. DEP plans to advertise eighteen JOC contracts in 2018 for the Program's construction phase.

The Program Management and Construction Management contract serves as an extension of the function and responsibilities of the DEP's Bureau of Engineering, Design & Construction (BEDC). This includes the development and delivery of Program Management systems, creating a strategy for sequencing and assigning the scopes of work to be completed under the Program, forming design and construction contracting strategies as well as the establishment of Program Controls and a Program-specific Unit Price Book (UPB). Other services include stakeholder management, assistance with contract procurement, and coordination of funding reporting processes to meet critical funding reimbursement deadlines.

The detailed designs are being developed through four TOCs. These four firms competitively bid on assignments and provide design planning, detailed design to 100 percent biddable documents, construction procurement assistance, design services during construction, and project closeout services.

The Program involves a level of repetitious work that is typical of JOC programs. The scope of work is to replace or raise *in situ* equipment that was either damaged by Hurricane Sandy or determined to require improvements to resiliency against future weather events. It also includes the installation of waterproof doors, windows, hatches, and stop logs across all facilities. The repetitious nature of the work lends itself to a unit-price payment structure for construction activities.

DEP Wastewater Resiliency Program Resiliency Adaptation Strategies

Elevate Equipment
- Relocate electrical equipment, pumps and motors above the design flood elevations.

Seal Building
- Install watertight windows and doors.
- Raise louvers above the critical flood height elevation.
- Create elevated secondary access platforms.

Flood-proof Equipment
- Enclose electrical equipment in watertight NEMA boxes.
- Replace non-submersible pumps with submersible pumps.

Install Backup Power
- Allow for backup generator connections on-site at Pumping Stations.
- "Plug-and-Play" connections to temporary backup generators.

Install Static Barrier
- Static barriers or stop log barriers.
- Height equivalent to flood protection height.
- Length equivalent to the width of the specific flood pathway.

Conduit and Wire
- Elevate conduits and reroute conduits above design flood elevations.
- Upgrade to above-ground and below-ground conduit supporting structures.

Adapted from NYC: Climate Risk Assessment and Adaptation Study (2013)

The Program's UPB has been developed to be a Program-specific pricing mechanism that is customized to DEP work and utilizes New York City Union Rates, crew tables, and equipment prices from the New York City market. The UPB will be implemented by the TOC design firms across all stages of design to drive standardization and itemization of work across the Program.

Each JOC contract will be awarded based on a competitively bid multiplier to the Program-specific UPB. Each subsequent Job Order Assignment (Assignment), associated with the contract, will be issued for lump-sum price development at 100% design stage with notice to proceed assigned at the completion of a reconciliation of that value. It is the goal of the Program to engage the JOC Contractor during constructability review of each Assignment to reduce the level of uncertainty between the completion of design and the commencement of construction.

This combined TOC/JOC approach ensures critical-facility resiliency work occurs expeditiously. Construction assignments would start once the design is completed and the value of the assignment is agreed upon with the contractor.

Planning and Design Approach

FEMA's new advisory base-flood elevation maps for a 100-year flood event were selected as the baseline for the analysis. An additional 40 inches of flooding was added to this baseline to account for expected sea level rise by the 2050s, the high end of projections from the New York City Panel on Climate Change. Flood pathways at each DEP facility and the location of critical equipment were then compared to the anticipated flood elevation level to determine which infrastructure is potentially at risk. In determining the appropriate resiliency measures and the level of acceptable costs, DEP considered the value of each asset at wastewater treatment plants and pump stations, the population and critical facilities they serve, and potential impacts on nearby beaches and waterways. Cost-effective protective measures, such as elevating equipment, water proofing buildings, and replacing traditional pumps with submersible pumps, were then selected based upon cost and level of risk reduction. The result is a portfolio of strategies that will be implemented as part of future capital projects or as other funding mechanisms are identified.

Key to success of the Program's implementation is limiting the Maintenance of Plant Operations/Maintenance of Facility Operations impacts to each facility. This is achieved by ensuring the continuation of process area operations during construction and programmatic planning to ensure the work is assigned with a holistic view rather than separated into individual asset types. Individual assets types within a system process area have operational connections such as pipe manifolds (pump to pump), or electrical tie-ins (control panels to pumps), or auxiliary service systems that handle entire process areas. To maintain facility permit requirements, these system process areas must continue full functionality during all JOC activities.

Current Status

The Program has commenced design for approximately half of the Program scope with additional design assignments to be awarded in 2018. Construction is due to begin in the spring of 2019 with JOCs being advertised for bid in 2018. Resiliency work for DEP wastewater facilities outside the Program has already been completed at the Manhattan and Gowanus Canal Pumping Stations and is currently underway at the North River Wastewater Treatment Plant, where existing contracts were in a position to complete the identified work.

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Manhattan College Students in foreground (l-r): John Abbatengelo, Fezena Bacchus and April Weeks

William Nylic, left, and Robert Wither

President Paul McGarvey poses with NYWEA Scholarship winners (l-r): Elena Araya, Matthew Baideme, Agata Bugala, Mallory DeLanoy and Randall Novak. Congratulations, all!

Adam Zabinski, left, and Krish Ramalingam

Robert Hennigan, Jr. accepts the Water Hero Award posthumously for his father, Robert D. Hennigan. The award will be renamed the Robert D. Hennigan Water Hero Award.

Courtnay Anderson receives the Uhl T. Mann Award for maintenance.

President Paul McGarvey and NYWEA's Major Scholarship Winner from Columbia University, George Theodosopoulos

Lisa Derrigan, right, receives the Arthur Sidney Bedell Award from WEF Executive Director Eileen O'Neill.

Kristin Waller receives the Linn H. Enslow Memorial Award for her paper, "Fix It with Film: The Details of IFAS/MBBR Design and Construction".

William Nylic receives the Young Professional Award from President Paul McGarvey.

Lawrence Vulis, center, speaks on the City College Green Infrastructure presentation.

Navigating the Regulatory and Design Challenges of the Gowanus CSO Facilities

by Geoffrey M. Grant, Norman Bradley, Kevin Clarke, Lindsay Degueldre and Natalia Perez

Introduction

The Gowanus Canal, located in the borough of Brooklyn ***(Figure 1)***, has been an industrial center for New York City since the mid-1800s when the tidal marshes were filled in and the canal was channelized. The canal promoted the movement of goods and materials to and from the heavy industry that developed along it, including manufactured gas plants, coal yards, cement makers, soap makers, tanneries, paint and ink factories, machine shops, chemical plants and oil refineries.

Over time, these industrial operations contributed to the extensive contamination found in and around the canal. This was the primary reason why the United States Environmental Protection Agency (USEPA) added the Gowanus Canal to the Superfund Program's National Priorities List on March 2, 2010. The Superfund-designated remedy focused on the contamination associated with the manufactured gas plant (MGP), which was located near the head end of the canal, under the present-day Thomas Greene Park and Douglas-Degraw Pool.

Figure 1. Orthoimage of the Gowanus Canal and surrounding terrain in the borough of Brooklyn, New York.

Ortho image courtesy of the New York State GIS Clearinghouse

Record of Decision (ROD)

Following the addition of the Gowanus Canal to the National Priorities List, the USEPA issued its ROD in September 2013, which described the selected remedy for "in-canal" work associated with the Gowanus Canal Superfund Site. The ROD included:

- Stabilization and removal (dredging) of hazardous substance-contaminated sediments that have accumulated above the native sediments.
- Construction of a multi-layered cap to prevent the migration of polycyclic aromatic hydrocarbons (PAHs) and residual non-aqueous phase liquid (NAPL) from native sediments.
- Excavation and restoration of the 1st Street turning basin and a portion of the 5th Street turning basin.
- Implementation of institutional controls to protect the integrity of the cap.
- Periodic maintenance of the cap and long-term monitoring to ensure that the remedy continues to function effectively.
- Combined sewer overflow (CSO) controls to reduce solids loading to the canal, which is intended to prevent the re-contamination of the canal following the implementation of the remedy.

Responsibility for the implementation of the selected remedy was mostly borne by other potentially responsible parties (PRPs). However, under the ROD, New York City is required to construct two CSO facilities to reduce solids loading from CSOs to the canal.

In May 2014, USEPA issued an Administrative Order for Remedial Design to New York City (the Order) that contained a Scope of Work (SOW) further defining the portion of the selected remedy which requires the city to construct CSO tanks to control CSOs that currently discharge through outfalls RH-034 and OH-007 ***(Figure 2)***. The ROD preliminarily estimated that the CSO retention solution will need to provide a 58 to 74 percent reduction in CSO solids loading to the canal from the RH-034 and OH-007 outfalls in order to meet the ROD's preliminary remediation goals. A tank size of 8 million gallons (MG) and 4 MG were estimated to be required to reach the solids-load reduction targets at RH-034 and OH-007, respectively.

Siting Study

In response to the ROD and subsequent Order, the New York City Department of Environmental Protection (DEP), as the city's designated agent, conducted a series of technical evaluations to site and size the CSO facilities and coordinate planned work activities with the other parties involved with implementing the ROD.

The city retained an engineering consultant, Brown and Caldwell, to conduct a "Siting Study" to evaluate the requirements stipulated in the Order. The goals of this study were to:

- Identify appropriate storage volumes to attain the targeted solids-load reduction required by the ROD.

Figure 2. Present-day Gowanus Canal and CSO outfalls RH-034 and OH-007 to be addressed per the Record of Decision (ROD).

Brown and Caldwell

- Determine a reasonable footprint of the facilities, taking into consideration all the unit processes associated with a CSO storage facility.
- Identify parcels of land that would be suitable to construct and operate facilities of the requisite sizes.
- Estimate the construction cost to compare against the costs included in the ROD.

These evaluations established the technical basis for the facility layout and supporting the negotiations over the preferred locations for the two CSO facilities. Eventually, the results of the Siting Study advanced the design of the Red Hook facilities and contributed to the Settlement Agreement between USEPA and New York City.

Siting Study Methodology

The scope of the Siting Study included a series of assessments and evaluations necessary for proof-of-concept that the alternative proposed in the ROD was feasible and constructible. Key tasks of this study included:

1. Establishing Design Conditions, including CSO volumes and flow rates to be captured by the facility.
2. Facility Sizing and Performance Evaluation, to determine what was necessary to achieve the ROD requirements.
3. CSO Facility Requirements, including mechanical equipment and appearances that are needed for a functioning and compliant facility.
4. Land Search and Facility Siting, which endeavored to identify potential sites for the facility, based on the footprint requirements as established through the previous three tasks.

The Siting Study established the preliminary basis of design, which is now being advanced under a separate design contract.

1. Establish Design Conditions

An initial step of the study was to establish the CSO volume and flowrates that would be used to size key elements of the storage facility. While the ROD and Order did not specify the facility design conditions needed to meet the solids-load reduction, the DEP determined that the targeted performance should be based on typical-year metrics, consistent with the sizing of other CSO control measures across the city. Throughout the development of the CSO Long-Term Control Plan, the rainfall record from calendar year 2008 was selected as the most representative of annual average rainfall conditions over a 50-year record. Therefore, this data was used in sizing infrastructure to control the discharge from DEP CSOs.

Typical-Year CSO Volume

During wet weather, the Gowanus Canal receives CSO discharges from two distinct wastewater treatment plant (WWTP) sewershed areas (collection systems): the Red Hook and Owls Head WWTP sewershed areas (***Figure 3***). The collection systems serving each of these two WWTPs are represented by two distinct models, referred to as the Red Hook and Owls Head models. These models, developed using the InfoWorks CS software package, allow for robust representation of complex real-world systems in a mathematical framework that can be used for planning and design evaluations. To estimate flow conditions at two CSO discharge points – RH-034 and OH-007 – the study used predicted CSO volume data, calculated by both the Red Hook and the Owls Head models.

Apart from the Superfund ROD and the Order requirements, DEP is already implementing a series of projects to reduce wet-weather overflows from CSOs that discharge to the Gowanus Canal. These projects, implemented under the Waterbody Watershed

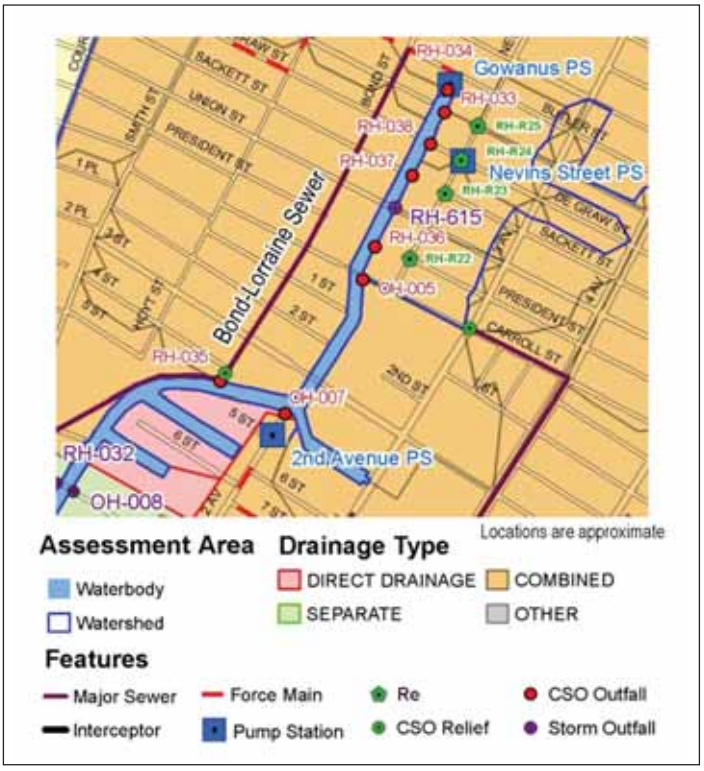

Figure 3. Gowanus Canal WWTP service areas and permitted CSO locations. *New York City DEP*

Facility Planning process with New York State Department of Environmental Conservation (NYSDEC), were not in-place during the Remedial Investigation phase of the Gowanus Superfund program. Nor will they have either been completed or likely be completed prior to the construction of the ROD remedy. These projects include the Gowanus Wastewater Pumping Station upgrade, Green Infrastructure, and the High-Level Storm Sewer improvements. These projects are anticipated to reduce total CSO volume to the Gowanus Canal by 44 percent. In addition, the Gowanus Flushing Tunnel and Pump Station reactivation reduces pathogen concentrations and increases dissolved oxygen in the canal, resulting in full compliance with designated state water-quality standards. Given the significant anticipated CSO reduction impact of these projects and associated reduction in solids loading, they are being considered as part of the remedial solution toward meeting the 58 to 74 percent estimated reduction in solids loading set forth in the ROD.

Typical-Year CSO Design Flow Rate

While the CSO volumes aided in sizing the tanks to achieve the solids-load reduction, the model-predicted peak-flow rates associated with the CSO events were used to size conveyance infrastructure. Additionally, the peak-flow rates were used to estimate head losses through the influent and effluent conduits and the basin. Understanding the head loss was critical to developing the hydraulic profile and confirming that the CSO facility would not adversely impact the hydraulic grade in the upstream collection system.

The peak typical-year flow rates of 306 million gallons per day (mgd) and 146 mgd for RH-034 and OH-007, respectively, were used as the basis of design. This conservative approach enables all typical-year CSO to be directed to the facility.

Aside from directing 306 mgd and 146 mgd to the RH-034 and OH-007 storage basins, the CSO regulator must still be able

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to bypass the five-year/two-hour storm to the canal to prevent adverse impacts in the upstream system, which include sewer backups, flooding, and surcharge. This was estimated to be 750 mgd for RH-034 and 250 mgd for OH-007. To accommodate these flow rates, the CSO structures need to be reconfigured to allow complete diversion of typical-year flows to the CSO facility to meet solids-load reduction requirements, as well as the ability to bypass excess flows to avoid upstream surcharge and flooding.

2. Facility Sizing and Performance Evaluation

The purpose of the CSO facilities is to reduce solids loading to the canal from CSO sources by capturing CSO volume, prior to discharge to the canal, and storing it until after the event so it can be sent to the treatment facilities. By intercepting CSO volume prior to discharge, solids loading to the canal will be reduced. To estimate the required size of the tank, both volumetric and pollutant-load reduction bases were used to calculate the required tank size to meet the solids-load reduction requirement.

The volume basis approach assumes that the solids-load reduction is equal to the reduction in typical-year CSO volume, a 1:1 ratio. By reducing the typical-year CSO volume by 58 to 74 percent, it is expected that the solids loading to the canal will be reduced by the same percentage. Considering that a significant portion of the solids loading typically occurs during the beginning of a wet-weather event and is either carried to the WWTP or contained in the storage tank, this approach likely results in a more conservative estimate of the required tank volume than other methodologies.

In parallel, a pollutant-load reduction calculation was also completed. Since the tank is designed to be a flow-through facility, whereby CSO volume that exceeds the storage volume of the tank is discharged from the facility, some degree of primary (Type I) settling is expected to occur as the flow passes through the tank. The settling of solids, considered in this approach, resulted in higher solids capture for the tank than the volume basis approach.

The 8 MG and 4 MG facilities for RH-034 and OH-007, noted in the ROD, exceed the higher end of the required solids-loading reduction ***(Table 1)***. To achieve the targeted range of solids-load reduction of 58 to 74 percent, the required storage volume could be reduced to either 3.1 or 5.7 MG for RH-034 and either 1.4 or 2.5 MG for OH-007.

Table 1. Typical-Year Solids-Loading Reduction, by Tank Volume

RH-034		OH-007	
Tank Volume	Reduction in Typical Year Volume	Tank Volume	Reduction in Typical Year Volume
8.0 MG	82%	4.0 MG	87%
5.7 MG	74%	2.5 MG	74%
3.1 MG	58%	1.4 MG	58%

Under the pollutant-load reduction calculation, the solids-load reduction for an 8 MG and 4 MG basin exceeded 90%.

3. CSO Facility Requirements

As a preliminary step in developing the conceptual requirements and layouts of storage solutions for the CSO facilities, the team conducted a desktop benchmarking evaluation of wet-weather storage facilities installed in other cities across the United States. The purpose of this high-level assessment was to identify common features of storage facilities, as well as to identify innovative layouts or unit processes that were either proven or believed to enhance performance, reduce operations and maintenance challenges, and provide abatement of noise and odors. Information was collected from a variety of sources, including conversations with engineers who were involved with the planning, design, or construction of the facilities; Internet research; and informal discussions with utility staff that own or operate the storage facilities. In addition to this high-level benchmarking exercise, two of DEP's CSO storage facilities were toured to study the layout, understand operational challenges with the existing facilities, and identify improvements that the operations staff would recommend for future installations.

After collecting information from the review of wet-weather facilities, the project team developed a series of recommendations for preferred unit processes and sizing criteria based on the design flow rate conditions and required storage volumes. These recommendations enabled selection and sizing of the mechanical and electrical equipment, based on the targeted flow rates and tank volumes. Collectively, this information was used to develop a workable facility layout that considered DEP's operational preferences, redundancy requirements, and requirements for setbacks and clear space for safe operation of a CSO facility.

An outcome of developing the site plan layout was a better understanding of the footprint required for the facility. This analysis indicated that a 4 MG tank at OH-007 will require approximately 60,000 square feet and an 8 MG tank at RH-034 will require approximately 100,000 square feet.

4. Land Search and Facility Siting

After the conceptual facility layouts were developed and the footprint requirements were defined, the team embarked on a review of property near the RH-034 and OH-007 regulators that were of suitable size to construct and operate a CSO storage facility.

A two-step process was used to identify potential locations for the CSO facility. An initial screening was conducted on available properties that were of a suitable size and were within a quarter-mile radius around RH-034 and OH-007. Short-listed sites that resulted from the initial screening were then subject to a more detailed short-list evaluation.

<u>Initial Identification and Screening</u>

A total of 86 sites were initially identified. These properties were scored against three main screening criteria, effectively considered "fatal flaw" analysis. The criteria included:

- Size of Properties. Evaluated the sites to determine if a 100,000 square-foot 8 MG facility or a 60,000 square-foot 4 MG facility could fit on the property or a combination of adjacent properties. If not, the location was dropped from the list.
- Hydraulic Analyses and Effective Capture of the CSOs. Hydraulic analyses conducted during the conceptual layout phase determined that diverting flow to storage downstream of the CSO weir resulted in a better level of control than diverting CSO to storage upstream of the tank, within the tributary collection system. Sites that were located upstream of the CSO regulators or sites that were not within close proximity to the CSO regulator were eliminated from the list.
- Current or Planned Land Use. Because there is significant development occurring around the Gowanus Canal, research was conducted to identify properties among the 86 sites which had planned or permitted development. These sites, as well as sites under construction or slated for redevelopment, were eliminated from the list.

Because very few properties met the minimum size requirements on their own, several properties were combined into potential sites

meeting the square footage requirements for the CSO facilities. The remaining 14 sites met the minimum size needed for the tanks and facilities; the availability of construction set-back and staging areas was evaluated in more detail in the next step of the screening process.

Evaluation of Short-listed Sites

The 14 sites identified from the preliminary screening were further evaluated and ranked using a multi-criteria analysis that allowed for the application of numerous qualitative screening factors to each potential site, resulting in a quantitative ranking. The screening factors consisted of both engineering criteria and land use/environmental criteria. The initial screening for land use and environmental considerations was based on the analysis categories in the City Environmental Quality Review (CEQR) Technical Manual.

The final list of eight screening factors used for this analysis was selected as follows:

A. Engineering Criteria
   1. Size.
   2. Proximity to existing infrastructure.
   3. Utility relocation.

B. Land Use and Environmental Criteria
   1. Current/planned surrounding land uses (applicable to land use, air quality, noise, construction and neighborhood character considerations), including community disruption.
   2. Historic and cultural resources.
   3. Known contamination/hazardous materials.
   4. Property acquisition.
   5. Proximity to potential staging areas.

Assigning impact scores for each of the eight criteria were completed through workshops and meetings between the Siting Study team and DEP. The outcome of the effort was a prioritized list of available sites in which the highest-ranked sites (two sites for RH-034 and two sites for OH-007) were advanced in the study. Detailed facility layouts were developed for the highest-ranked sites so cost estimates and construction schedules could be developed.

Outcomes of the Siting Study

The Siting Study helped DEP better quantify the size of the facility required to meet the obligations outlined in the ROD, as well as help determine a site for the facility, based on the estimated footprint. The information obtained through the Siting Study was used to develop an AACE Class IV cost estimate which determined the total program (RH and OH tanks) to cost more than $1 billion in 2015 dollars, significantly greater than the $77 million estimated by USEPA in the ROD.

Settlement Agreement

In June 2016, USEPA and New York City entered into an "Administrative Settlement Agreement and Order for Remedial Design, Removal Action, and Cost Recovery" which uses findings from the Siting Study to establish DEP's requirements to complete two parallel designs of an 8 MG CSO retention tank at the RH-034 CSO overflow. The Owl's Head obligations remain under the 2014 Order. The city is proceeding with the project and has retained a consultant team (Hazen and Sawyer with Brown and Caldwell) to complete the design of the CSO facilities.

Detailed Design

Detailed design of the CSO facilities began in July of 2016, initially with a series of design workshops culminating with the Facility Plan and Basis of Design Report, which was completed in December 2017. This preliminary design work built off the findings from the Siting Study and advanced key design alternatives, such as fine influent screening, degritting the pumped effluent to prevent redeposition in the collection system, and a robust odor control system to address the proximity of the facility to residential areas.

The detailed design of a CSO facility in a congested neighborhood in Brooklyn presents many challenges, many of which continue to be evaluated as part of the design. One of the more complex considerations is the requirement that the city complete the removal action of contaminated sediments within the footprint of the facility within 24 months. Per the Settlement Agreement, the city must remove and handle all the soil within the footprint of the tank, while other PRPs will handle hot spot contamination outside of the tank footprint.

Based on the facility footprint at the head-end site RH-034, an estimated 71,000 cubic yards of material needs to be handled during excavation. Site characterization identified soils with a high moisture content and chemical impacts, primarily attributed to the MGP waste found on the site. These conditions suggested that the soil needs to be stabilized after excavation. To work within the 24-month removal action requirement, the design team endeavored to optimize the time needed to construct a robust support of excavation (SOE), while still providing sufficient time to remove and handle the spoils. A range of SOE options were evaluated by the design team that considered cost and time to construct. The outcome of the analysis was a deep SOE to bedrock, with minimal bracing. This option provides an SOE that minimizes cross-lot bracing and creates minimal conflicts with excavation equipment, leading to a more efficient process of removing the soil. In addition, a deep SOE eliminated the risk of a weak jet grout plug, caused by the MGP waste reacting with the grout. Construction of the plug was anticipated to take a long time to overcome the reaction with the MGP waste, potentially leading to an overrun on the 24-month schedule.

This is one of many examples the complexities of designing a CSO facility that is located in the middle of a Superfund site.

Summary

CSO facilities are typically constructed in response to Clean Water Act requirements – and even under these circumstances, there are regulatory and design challenges that need to be addressed and overcome. The overlay of Superfund has created new challenges that need to be effectively managed, namely the requirements stipulated in the ROD and Settlement Agreement, and the specific requirements for remediation of the soil under and around the proposed CSO facility. DEP continues to advance this design, balancing technical needs for an operable facility and sensitivity to the community during construction, with the aggressive remediation schedule dictated by USEPA. In addition, DEP is exploring opportunities to make the Gowanus program synergistic with other needs in the draining area, including climate change, resiliency, growth, and quality of life.

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Achieving Environmental, Health and Safety Excellence: The DEP Experience

by Persis Luke

DEP has a robust environmental, health and safety (EHS) program, but we don't look at EHS as only a "program." We strive to instill safety and environmental compliance as an organizational core value. The most important factor in making this a reality is to combine a strong program with committed leadership to carry the message and "walk the walk." EHS commitment exists at all levels of the organization – from the Commissioner to the Catch Basin Machine Operator.

What are the basic tenets for EHS leadership and success at DEP?

- EHS Expectations.
- EHS Education.
- Listening to Employees.
- Promoting Safety Ownership.
- Measuring Performance – "Record the Good Stuff Too".
- Safety by the Numbers.

EHS Expectations

DEP has a strong EHS program that has as its backbone a cadre of 50 written policies and guidelines covering both environmental compliance and employee safety. Policies incorporate all applicable regulatory requirements as well as procedures and standards to ensure that these requirements are understood by all. These policies, procedures and standards provide a platform for success for employees at worksites and facilities. Roles and responsibilities for each policy are clearly defined and employees, supervisors and managers are educated on each one. Our policies cover everything from Lockout/Tagout to Workplace Violence Prevention.

DEP has a robust EHS internal and external auditing program that assesses how well we comply with regulatory requirements and with our own policies and procedures. This process assists our operations to sustain compliance and move towards best management practices.

DEP regularly monitors the EHS regulatory environment to ensure that we will be ready to comply with emerging requirements at the federal, state and local level.

EHS Education

At DEP, EHS education goes beyond perfunctory regulatory training. We also do extensive skills training, professional development and strive to communicate openly about EHS successes and challenges. For example, the Bureau of Water and Sewer Operations (BWSO) has a "Field Training Center" where our Water and Sewer Construction Laborers and Apprentice Construction Laborers learn to perform infrastructure repair and maintenance tasks, such as water main repairs and valve repair. These laborers also master how to safely use equipment, enter confined spaces, perform hot work, and work safely on busy New York City streets.

Employees in DEP's Bureau of Water Supply (BWS), which has full responsibility for the watershed lands, infrastructure, water quality and drinking water treatment operations, also have extensive skills and safety training in relevant work tasks. Similar to the metropolitan operations, BWS also has a structured field-training program for employees engaged in work that presents safety or environmental compliance risks. For example, certain designated

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At the Bureau of Water and Sewer Operations Field Training Center, the Apprentice Construction Laborers learn how to set up a safe work zone. *New York City DEP*

An Apprentice Construction Laborer learns how to safely enter a confined space. *New York City DEP*

Safe operation techniques for using a jackhammer are practiced by an Apprentice Construction Laborer. *New York City DEP*

continued from page 57

DEP employees are part of a "Tree Task Force" that is mobilized for both routine and emergency level tree work. They go through extensive practical training in chainsaw safety, tree felling and tree climbing.

Finally, on the wastewater treatment side, DEP's Bureau of Wastewater Treatment (BWT), the largest bureau, with 1,800 employees, also has an extensive training program for its Sewage Treatment Workers (STWs), Electricians, and Stationary Engineers (Electric) (SEE). All new sewage treatment workers receive initial operational training over a period of several weeks, which incorporates all safety training necessary for them to perform their tasks safely. Of particular importance for BWT's workforce is competence in Lockout/Tagout, Confined Space, Electrical Safety, Personal Protective Equipment, FDNY (Certificates of Fitness) and Spill Prevention, just to name a few. Additionally, wastewater treatment employees receive Wastewater Treatment Grade Certification classes (to grades between 2 and 4 depending on their title and responsibility levels). BWT also has specialized equipment training and boat safety training.

An Apprentice Construction Laborer learns safe operation techniques for operating a circular saw. *New York City DEP*

A member of the Tree Task Force uses his extensive safety and operations training, as well as his experience, to complete a task *New York City DEP*

For DEP, hands-on, structured skills training which incorporates safe work practices helps to reinforce why safety is important for that specific task. It also provides employees with the opportunity to ask questions in an open environment of learning rather than in an operational setting where other pressures are present.

Listening to Employees

In addition to having a good understanding of DEP's EHS policies and procedures, experienced employees are very knowledgeable about inherent risks in their regular work tasks. They should be important collaborators in developing the best safe work practices, standard operating procedures, operational improvements, equipment training and process improvements. This should not be the purview of EHS or operational management alone.

Employees need to be engaged directly in addressing safety challenges and driving improvements within the organization and be recognized for important contributions. DEP continues to offer such opportunities, including participation in EHS Labor Management committees, Process Safety/Risk Management (Chlorine Safety) committees, and honoring the expectation and opportunity to identify near-misses and unsafe conditions. Employees are engaged in myriad safety improvement initiatives and are frequently consulted in the development of important EHS and operational procedures. DEP also regularly communicates safety messages and initiatives through the agency's weekly *Pipeline* newsletter, DEPtv, *EHS Matters* (Case Studies), and regular "Lessons Learned" publications.

DEP recognizes employee contributions through the *Always Creating Excellence* ("ACE") recognition program, where employees are honored for EHS excellence in a quarterly ceremony.

It is also important for an organization to keep its finger on the pulse of how employees think about safety. Do they understand safety expectations? Do they feel they receive adequate training? Do they believe that the organization communicates and is transparent when it comes to safety challenges and results? Are employees self-directed when it comes to safety? These factors can be assessed by ongoing Safety Perception surveys, which help identify areas for improvement. DEP performs ongoing surveys every few years to "listen" to employees' perceptions about DEP's commitment and practices towards reducing risks for employees and the environments in which we operate.

Promoting Safety Ownership

Safety ownership at all levels in the organization is accomplished by going beyond just monitoring and dictating from management to staff. Safety ownership is about EHS collaboration and problem solving. Monitoring still needs to occur through regular evaluations but should evolve into a more collaborative and self-directed process. How do we move employees from being "other-directed" (e.g. following edicts) to being self-directed (e.g., engaging in preventive behavior without being instructed to do so)? This is challenging and represents a significant culture change for many organizations, including DEP. As is the case for water utilities, we work in a heavily-regulated environment so it's a natural mindset for us to be "other-directed" and reactive. Recent efforts to turn safety inspec-

From left to right: Deputy Commissioner Zoe-Ann Campbell, EHS Specialist Lal Sarju, EHS Director Fred Chyke-Okpuzor, Machinist Glenn Corwin, and Assistant Commissioner Persis Luke. Machinists Glenn Corwin, Arthur Batson (not pictured) and Steve Brie (not pictured) were recognized for re-designing a breaking bar to include a safety handle. This was done to reduce the risks for hand injuries from a sledgehammer. This exemplifies excellent collaboration between EHS staff and Operations. *New York City DEP*

tions, audits, near-misses or even incident reviews into learning opportunities or problem-solving opportunities have been bumpy, but it is a beginning. The use of safety teams is also an effective way to encourage self-direction and safety ownership.

DEP has recently initiated a new EHS reporting process and procedures, which includes the reporting and review of near-misses and unsafe conditions. This provides an opportunity for employees to be involved in suggesting corrective actions or recommendations for prevention in an environment that is not entwined in a full-bore investigation (as would be the case with a serious accident or injury). Engaging employees in this way fosters more involvement, self-direction and motivation for taking responsibility for prevention of future incidents.

Measuring Performance – "Record the Good Stuff Too"

The widely-used measurement for evaluating safety performance in organizations has traditionally been the recordable injury incidence rate. This rate reflects the number of recordable injuries normalized for the number of hours worked by employees over the course of time (usually a year). This is a standard "lagging" indicator that measures adverse outcomes. On the other hand, "leading" indicators measure an organization's efforts to ***prevent*** adverse outcomes. In an ideal situation, an uptick in leading indicators would result in a decrease in lagging indicators. For example, an organization that sees increases in positive safety activities (e.g. safety inspections, trainings, near-miss reports or unsafe condition reports, safety interventions, safety engagement and recognition) should ideally experience a decrease in the lagging indicators, or negative outcomes (e.g., injuries, fatalities, violations, regulatory enforcements and grievances).

We cannot measure the health of our safety program on lagging indicators alone. For example, DEP's Bureau of Engineering Design and Construction (BEDC) has been a leader in this area. They are responsible for $10 billion of active construction contracts and regularly use leading indicators in their measurement portfolio. They measure positive safety activities like the number of inspections, site visits by managers, trainings, the development of job hazard assessments, audits, unsafe conditions and near-miss reporting.

As such, the corresponding incidence rate for BEDC contractor injuries has decreased from 3.42 in 2014 to 1.87 in 2017, a 46% decrease.

Safety by the Numbers

DEP as a whole has seen a significant decrease in its total recordable injury rate over the last several years ***(Figure 1)***.

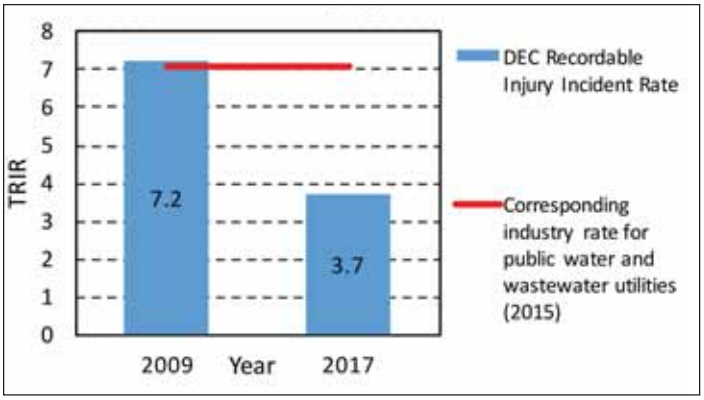

Figure 1. The recordable injury rate is a standard used by OSHA and Bureau of Labor Statistics to standardize injury data. The Total Recordable Injury Rate (TRIR) is calculated as the number of OSHA recordable incidents times 200,000, which is then divided by the total number of hours worked. *New York City DEP*

The recordable injury rate is a standard used by OSHA and Bureau of Labor Statistics to standardize injury data. The corresponding industry rate for public water and wastewater utilities for 2015 is 7.1 (the red line in ***Figure 1***). As such, DEP is now significantly better than the industry average. With continued implementation of a strong program of prevention, we expect this rate to continue its downward trend. Other important EHS metrics for DEP are shown in ***Table 1***.

Table 1. Other Important EHS Metrics for DEP.

Performance Indicator	2009	2017	% Change
# of Recordable Injuries	402	189	-53%
Recordable Incident Rate	7.2	3.7	-49%
# of EHS Audit Findings	4,719	135	-97%
Regulatory Violations	40	13	-68%
Environmental Releases	228	87	-62%
Permit Exceedences	394	98	-75%
Preventable Motor Vehicle Collisions	219	221	+1.0%

In addition to enhancing opportunities for employee engagement, one of DEP's current EHS challenges is to reduce the number of preventable motor vehicle collisions. This is one of the few metrics in which we have seen significant stagnation. Although most of DEP's collisions are minor in terms of damage amounts and injuries, there are opportunities for driver improvement, distracted driver prevention and improved accident review.

DEP – with its solid EHS foundation, knowledgeable and committed employees, and strong leadership – is poised to continue to improve its ability to assess current and emerging risks in the work environment and address them in a positive and collaborative way.

Persis Luke is the Assistant Commissioner with the New York City DEP Bureau of Environmental Health and Safety. She may be reached at LukeP@dep.nyc.gov.

Women in STEM Working for New York City – Then and Now

New York City's water and wastewater agencies have benefitted from the contributions of women in the STEM fields (Science, Technology, Engineering and Mathematics) since the city's earliest years of water management. Two examples are civil engineer Nora Stanton Blatch Deforest Barney and Deputy Commissioner Pam Elardo, P.E. Although the life experiences of these two women seem worlds apart, they share a common interest in engineering and water resources management.

Civil Engineer Remembered

by Adam Bosch

The Tunnel Boring Machine (TBM) being used for the Delaware Aqueduct Bypass *(see page 22)* was named "Nora," after Nora Stanton Blatch Deforest Barney, the first woman in United States history to earn a college degree in civil engineering. Nora worked for the city's Board of Water Supply from 1906-1908. As a draftsperson, she designed some of the original infrastructure for Ashokan Reservoir and the Catskill Aqueduct.

Nora was also noted for her work in the women's rights movement. Her involvement was something of an heirloom passed down by her grandmother and mother. Her grandmother, Elizabeth Cady Stanton, authored the "Declaration of Sentiments" that was presented at the Seneca Falls Convention of 1848, marking the start of an organized push for women's rights and women's suffrage in the United States. Nora's mother, Harriot Stanton Blatch, was also a noted suffragist who injected new energy by broadening the movement to include working-class women in New York City, and by organizing parades up Fifth Avenue, protests at Carnegie Hall, and lobbying efforts at the State Capitol in Albany.

Nora continued in that tradition. She founded a suffrage club at Cornell, became president of the Women's Political Union in 1915, and led the charge for an Equal Rights Amendment to the U.S. Constitution that would have guaranteed women equal rights in the workplace. The amendment was not ratified, but it has been debated in Congress almost annually since first introduced.

Saving Lives with Clean Water

by Toby Siegman

Pam Elardo, Deputy Commissioner New York City DEP Bureau of Wastewater Treatment

If you were asked to decide what was the greatest medical advance of the past 200 years, what would you choose? When the prestigious British medical journal *The BMJ* posed that question to its readers, who are mostly physicians, the survey's final outcome was surprising: the winner was sanitation, or human waste management.

"Sanitation is Life" was the underlying theme of a riveting presentation by Pam Elardo, Deputy Commissioner of the New York City Department of Environmental Protection Bureau of Wastewater Treatment, before the NYWEA Women's Initiative group. The presentation, titled "Making Your Impact: Saving Lives with Clean Water," explained how we can empower communities to protect their health and environment through the sustainable use of water resources.

Ms. Elardo discussed how her passion for the environment evolved, beginning with her early childhood fascination with wastewater treatment and progressing to the national and international arena. The breadth of her career includes volunteer work in the U.S. Peace Corps water and sanitation sector in Nepal, a role in implementing the Clean Water Act regulation, and director of the King County Wastewater Treatment Division in Seattle. She has also been engaged internationally on water and sanitation issues with Asia Development Bank, the World Bank, the Living Earth Institute, and other non-profit organizations.

Ms. Elardo challenged the attendees to reflect on what inspires them to perform their individual work, and what they consider to be their personal vision and role in the future. To achieve one's ultimate vision, she quipped, "You don't only need confidence – you need courage."

Over 55 people attended the meeting from a dozen different companies, including Arcadis, AECOM, Arup, AKRF, Brown and Caldwell, CH2M, Hazen and Sawyer, HDR, Nova Consulting, Mott MacDonald, Marine Tiger Technologies and Tetra Tech. Also in attendance were staff from DEP and students from City College of NY.

The purpose of the NYWEA Women's Initiative is to further women's career development, provide mentoring opportunities and networking opportunities, and to encourage involvement by women in NYWEA.

Toby Siegman, P.E., is an Administrative Engineer with the New York City DEP Bureau of Engineering, Design & Construction. She may be reached at TSiegman@dep.nyc.gov.

Operator Quiz Test No. 119 – Definitions & Process Troubleshooting

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. Mineral-type compounds that are generally nonvolatile, not combustible and not biodegradable are called:
   a. Inorganic
   b. Organic
   c. Volatile solids
   d. Struvite
2. The process of removing soluble components from aqueous solution by contact with highly adsorptive granular or powdered carbon is known as:
   a. Charcoal filtering
   b. Activated carbon adsorption
   c. Activated carbon absorption
   d. Sand filter treatment
3. When a pump is obstructed due to air entrapped in a high point restricting the free flow of water, the pump is said to be:
   a. Plugged
   b. Cavitating
   c. Air-bound
   d Short-circuiting
4. A valve, when opening or closing, consists of a disk that rotates about a spindle supported by the frame of the valve. At the full open position, the disk is parallel to the axis of the conduit. This is known as a:
   a. Butterfly valve
   b. Gate valve
   c. Ball valve
   d. Pinch Valve
5. The amount of heat necessary to raise the temperature of 1 gram of 15°C water by 1°C is called:
   a. Calorie
   b. BTU
   c. Celsius
   d. Thermophilic range
6. A device with V-notch, trapezoidal or rectangular geometric configuration that is used to measure and control the flow of liquid is called a:
   a. Flow meter
   b. Control valve
   c. Venturi
   d. Weir
7. The unit of electromotive force that, if steadily applied to a circuit having a resistance of one ohm, will produce a current of one ampere is called a:
   a. Volt
   b. Amp
   c. Load
   d. Diode
8. The amount of solids applied to a treatment process per unit time per unit volume is known as:
   a. Chemical loading
   b. Solids loading
   c. Solids inventory
   d. Total suspended solids
9. The oxygen used during biological oxidation, typically expressed as mg O_2/L/h in the activated sludge process is called:
   a. Oxygen transfer
   b. Oxygen utilization
   c. Oxygen reduction potential
   d. Oxygen uptake rate
10. The oxidation of ammonia nitrogen to nitrate nitrogen in wastewater by biological or chemical reactions is called:
    a. Nitrification
    b. Denitrification
    c. Redox
    d. Fermentation
11. A primary clarifier is experiencing black and odorous septic wastewater and sludge. Which of the following statements is true regarding this scenario?
    a. The probable cause is a malfunctioning collector. Inspect sludge collectors and run them continuously.
    b. The probable cause is improper sludge removal pumping cycles. Check sludge density and add chemicals to influent flow.
    c. The probable cause is a plugged withdrawal line. Check sludge pump output and clear the line.
    d. The probable cause is septic waste hauler dumpers. Review operator logs and add chemicals to influent flow.
12. An operator observes clouds of billowing homogeneous sludge rising and extending throughout a secondary clarifier. Mixed liquor settles slowly and compacts poorly in a settling test, but the supernatant is fairly clear. Which of the following statements is most accurate regarding this scenario?
    a. Improper dissolved oxygen concentration is a result of RAS rate. Increase dissolved oxygen by increasing RAS rate.
    b. A microscopic exam shows a normal distribution of activated sludge organisms. Chlorinate influent flow to reduce the amount of filamentous bacteria in this distribution.
    c. Low dissolved oxygen, less than 0.5 mg/L, is noticed in the biological reactor. Check DO concentrations throughout the entire reactor and increase DO levels to between 1 and 3 mg/L.
    d. The pH in the biological reactor is less than 6.5. Monitor effluent flow and add alkaline agent to raise pH.
13. A rotating biological reactor is experiencing an increase in snail growth. Which of the following is the most accurate statement regarding this?
    a. Lowering organic loading will prevent snail growth.
    b. Periodically slowing down the RBC speed will help eliminate snail growth.
    c. Snail growth is not an issue experienced in RBC operation.
    d. Periodic chemical cleaning is necessary for conditions prone to snail growth.
14. A lagoon is experiencing an increased growth of weeds. Which of the following is the most accurate statement?
    a. Weeds in a lagoon are favorable and help to control insect population.
    b. An insufficient water depth will not allow weeds to grow.
    c. Poor circulation and maintenance is the probable cause of weed growth.
    d. Weeds in a lagoon are favorable so herbicides are avoided as a means of control.
15. An operator is experiencing an increase in effluent solids in a dissolved air flotation thickener. Which is the best explanation for this?
    a. The unit is overloaded.
    b. The polymer dosage is too high.
    c. The skimmer is running on a timer.
    d. A decrease in septic sludge on bottom of unit.

Answers on page 62.

Questions for this exam compiled from Operation of Water Resource Recovery Facilities MOP 11. 7th ed.

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: 1A, 2B, 3C, 4A, 5A, 6D, 7A, 8B, 9D, 10A, 11C, 12C, 13D, 14C, 15A

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

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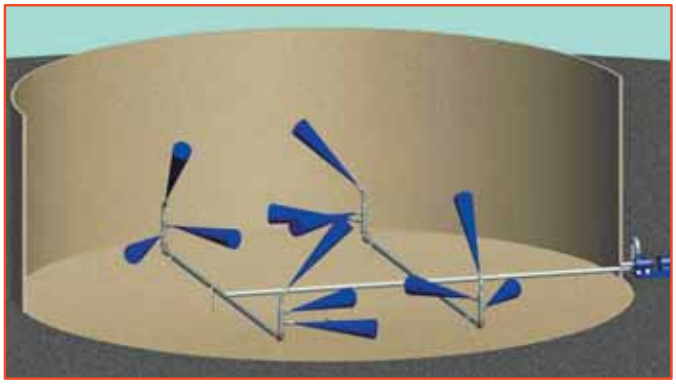
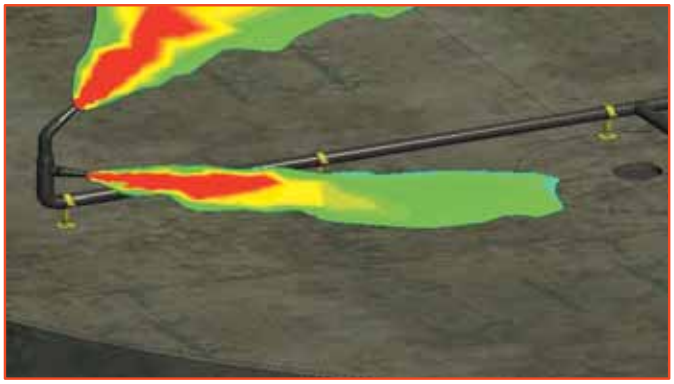


MULTIPLE ZONE SLUDGE MIXING



CFD ANALYSIS

JET MIXING IN EQUALIZATION TANKS

MIXING AND AERATION IN pH CONTROL TANK

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