Paerdegat Basin, Jamaica Bay

Credit: Mylan Cannon/The New York Times

Water and Wastewater

Newtown Creek Wastewater Treatment Plant in Greenpoint, Brooklyn

Credit: DEP

New York's water and wastewater system is an engineering marvel of massive scale. Every drop of water that comes out of the city's taps has traveled through a complex network of aqueducts and tunnels, some dating back more than 150 years, from sources that extend more than 125 miles from the city and across a 2,000-square-mile watershed. Water that enters the city's drains is conveyed through 7,500 miles of sewers and returned to New York City waterways.

With more than 8 million residents and many more daily commuters and visitors in New York City, merely ensuring that they all have the essentials—including uninterrupted water and wastewater services—requires a constant choreography that is as complex as it is invisible to its users. Whether turning on a tap to get a drink, running a bath, watering a lawn, flushing a toilet, or fighting a fire, New Yorkers rightly expect their water and wastewater system to work for them—all the time, no matter the conditions.

But the Department of Environmental Protection (DEP) and the water and wastewater system it manages accomplish much more than just supplying the essentials. DEP does not just provide drinking water; it provides clean, mostly unfiltered water from distant, carefully protected and managed watersheds—thereby eliminating the need for billions of dollars in filtration plant investments that would otherwise be required. DEP does not just carry and treat wastewater; it helps to protect a harbor and waterways that are cleaner than they have been in over a century.

Moreover, DEP's system is able to function even under extraordinary conditions. In the wake of storms that cause disruptions to one or several of its reservoirs, system operators are able to draw from other parts of the system, thereby maintaining an uninterrupted flow. While on average, New York's wastewater facilities treat about 1.3 billion gallons of wastewater per day, on a wet day they can treat twice as much as they do on a dry day.

Of course, even a system as effective as this one has its limits. Sandy, though it was not a significant rain event, came with a surge that affected some of DEP's assets in low-lying areas, knocking out electrical grid power and critical equipment at key wastewater facilities located along the waterfront. As a result, DEP resorted to its onsite and portable backup power systems and mobilized portable pumps.

As Sandy demonstrated, the city's water and wastewater system has vulnerabilities to extreme weather that must be addressed, particularly as climate change increases the likelihood of storm surges and heavy rains that can result in overflow of untreated sewage into the city's waterways. To prepare for the future, DEP began implementing climate change resiliency measures early, in 2008, when it issued the Climate Change Assessment and Action Plan. Prior to Sandy, DEP was already in the process of performing a detailed climate change study for representative wastewater treatment plants, pumping stations, and drainage areas to determine the potential likelihood and severity of various risks, including storm surge. After Sandy, DEP expanded that study to include all of its wastewater infrastructure across the city to systematically determine risks and resiliency measures to help prevent future disruptions.

Beyond this, DEP invests billions of dollars—from revenues generated by the water and sewer assessment charged to every New York building—to upgrade and maintain the system, thereby safeguarding efficient performance during all conditions.

However, some extreme weather events are likely to become more severe and, in some cases, more frequent. In keeping with the goals of this report, where possible and reasonable, the City will work to mitigate the impacts of climate change to the water and wastewater system. Meanwhile, for those times when impacts do occur, the City will enable rapid recovery by building resiliency into this system. To that end, the City will protect wastewater treatment facilities from storm surge, improve and expand drainage infrastructure, and invest in projects that increase the redundancy and flexibility of the water supply system.

How The Water and Wastewater System Works

DEP manages a complex system that begins with reservoirs located over 125 miles away from the city and ends at the city's 14 wastewater treatment plants with the release of treated effluent into New York Harbor. Although the system is integrated, it is best explained by separating it into two primary components: the city's water supply and distribution system, and its collections and treatment system. (*See chart: The Water and Wastewater System in New York City*)

Water Supply and Distribution

The New York City water supply system provides drinking water to almost half the population of the State of New York—8 million people in New York City and 1 million people in Westchester, Putnam, Orange, and Ulster Counties—plus the tens of millions of commuters and tourists who visit the city throughout the year. Overall, the system has a total storage capacity of 580 billion gallons, and consumption is more than 1 billion gallons each day.

The Croton watershed was the city's first Upstate water supply and is located entirely east of the Hudson River in Westchester, Putnam, and Dutchess Counties, with a small portion in the State of Connecticut. Historically, 10 percent of the city's average daily water demand has been provided by the Croton system, although in times of drought, it may supply significantly more water. As of the writing of this report, the system is offline temporarily while the City constructs a water treatment plant to filter the Croton water supply. Once completed, Croton water will be filtered and disinfected before flowing into Jerome Park Reservoir in the Bronx.

The Catskill system consists of two reservoirs—Schoharie and Ashokan—located west of the Hudson River in Ulster, Schoharie, Delaware, and Greene Counties. Water leaves Schoharie Reservoir via the 18-mile Shandaken Tunnel, which empties into the Esopus Creek and then travels 22 miles through the Esopus to Ashokan Reservoir. Water leaves Ashokan Reservoir via the 75-mile-long Catskill Aqueduct, which travels to Kensico Reservoir in Westchester County. The Catskill system provides, on average, 40 percent of the city's daily water supply.

The Delaware system consists of four reservoirs west of the Hudson River: Cannonsville, Pepacton, and Neversink in the Delaware River basin, and Rondout in the Hudson River basin. The outflow from the first three reservoirs arrives in Rondout via three separate tunnels. Water then leaves Rondout and travels to West Branch Reservoir in Putnam County via the 90-mile Rondout/West Branch Tunnel. Water from West Branch subsequently flows through the Delaware Aqueduct to Kensico Reservoir. The Delaware system provides, on average, 50 percent of the city's daily demand.

Because waters from the Catskill and Delaware watersheds mix at Kensico Reservoir, they are frequently referred to as one system: the Catskill/ Delaware system. DEP has completed construction of an Ultraviolet Disinfection Facility to improve and ensure high-quality water for the Catskill/ Delaware system. This facility provides secondary disinfection for Catskill and Delaware water before it flows to Hillview Reservoir in Yonkers.

Water is distributed from Hillview Reservoir and Jerome Park Reservoir to end users throughout the city via more than 7,000 miles of water mains and pipes at pressures that, in most cases, only require privately owned electric pumps for buildings taller than six stories. The 7,000 miles of water mains and pipes that distribute water throughout the five boroughs are buried and pressurized, preventing water from infiltrating. Furthermore, there is necessary redundancy built into the system so that water supply can be diverted to different pipes within the system to ensure the constant flow of water.

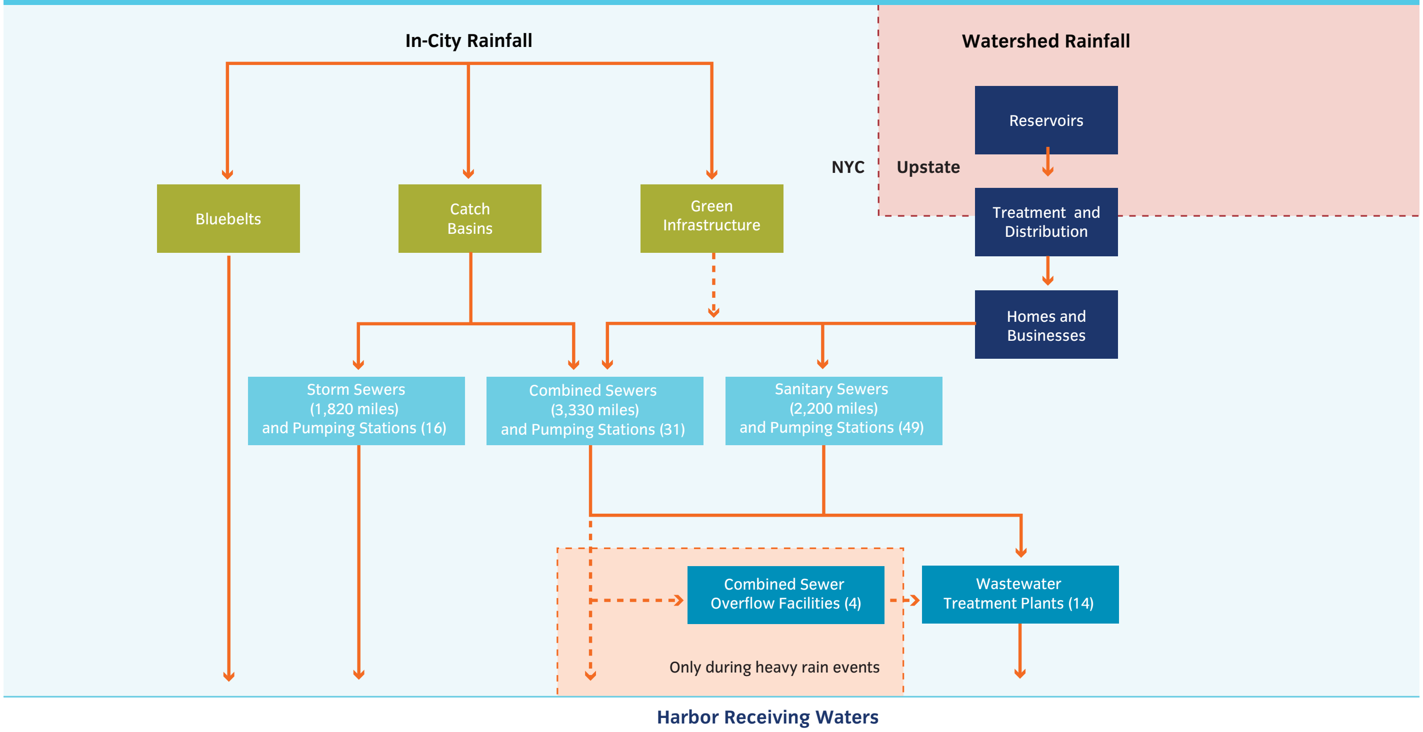
Despite this flexibility, the water supply remains vulnerable to heavy rain events. The events of the summer of 2011 illustrate this vulnerability. In late August, Hurricane Irene arrived in the Northeast, bringing with it wind and heavy rain. Although Irene weakened to a tropical storm as it moved over New York City, it nonetheless brought torrential rains, particularly Upstate, which saw more than 16 inches fall in parts of the Catskill System, and up to 10 inches in a 12-hour period in many other areas of the watershed. Twenty-three US Geological Survey stream gauges in the Catskill and Delaware watersheds recorded new maximum flow readings, and the flooding caused catastrophic damage to watershed communities, washing out many roads and bridges, damaging many homes, and causing widespread power outages. DEP responded to the resulting elevated levels of turbidity (murkiness resulting from stirred sediment) in reservoirs through various operational measures, including daily treatment and reduction of the flow of water from the Catskill system.

Just 10 days later, Tropical Storm Lee affected the same area, bringing with it more heavy rain and further affecting water quality conditions in several reservoirs. Once again, DEP responded with operational measures and maintained an adequate supply of high-quality drinking water for the city. The combination of two heavy rain events in a 10-day period led to unprecedented operational measures—including a record 260-day treatment regime for the Catskill system.

Wastewater Collection and Treatment

Every day, the City treats 1.3 billion gallons of wastewater and helps restore and maintain water quality in New York Harbor. Although the city uses a sanitary sewer system that carries only sewage, it, like other older urban centers, largely is served by a combined sewer system where stormwater and sanitary waste are carried through a single pipe. Stormwater enters the collections and treatment system from catch basins that direct flow to the city's sewer system. Sanitary waste enters the sewer system through direct connections from buildings. From there, wastewater flows by gravity through sewers, about 60 percent of which are combined sewers. In low-lying areas, the city has 96 pumping stations that lift wastewater and stormwater to a higher elevation and help continue its journey.

The Water and Wastewater System in New York City



Kensico Reservoir in Westchester County, NY

The combined sewer and sanitary sewer systems convey wastewater to the City's 14 wastewater treatment plants. At these plants, wastewater undergoes five major processes: preliminary treatment; primary treatment; secondary treatment; disinfection; and, finally, sludge treatment. Preliminary treatment screens debris and litter to protect the main sewage pumps and other equipment. The main sewage pumps then lift the wastewater to the surface level for primary and secondary treatment. Primary and secondary treatments remove on average between 85 and 95 percent of all pollutants from wastewater (up to 40 percent removed in primary treatment and up to another 60 percent in secondary treatment). Once the treated water is disinfected, it is returned to the city's waterways. Meanwhile, the remaining sludge is treated, with the resulting material, known as biosolids, frequently shipped elsewhere for disposal in landfills, or for use as compost or fertilizer.

All of the city's 14 wastewater treatment plants are located along the waterfront at relatively low elevations. Waterfront locations significantly reduce the cost and environmental impact of treating wastewater in New York City, making it easier for flow to arrive by gravity and providing nearby waterways to discharge treated effluent. Secondarily, but also importantly, the waterfront location further allows sludge to be transported efficiently by boat to DEP facilities for additional treatment.

Under normal conditions, system capacity is adequate to perform full treatment for the combined volume of sewage. During periods of rainfall when flow exceeds two times dry weather capacity, the combined volume of sewage and stormwater quickly can exceed the capacity of the wastewater treatment plants. The system is designed to discharge a mix of stormwater and wastewater—called combined sewer overflow or CSO—into nearby waterways to drain the city quickly and prevent the biological processes at the wastewater treatment plants from becoming compromised, which could lead to extended service outages.

In response to these CSO events, the City has invested billions of dollars. Recently, however, the City restructured its approach to implement innovative strategies to absorb rain before it can enter sewers, and, in the process, create systems of greenery that shade and beautify the city. In September 2010, Mayor Bloomberg launched the NYC Green Infrastructure Plan, a comprehensive 20-year effort to meet water quality standards, and in March 2012, the plan was incorporated into a consent order with the State that will eliminate or defer $3.4 billion in traditional investments and result in approximately 1.5 billion gallons of CSO reductions annually by 2030.

The City's Bluebelt program complements its Green Infrastructure program. Bluebelts are natural areas that often enhance existing drainage corridors (such as streams, ponds, and other wetland areas) and convey, treat, and retain stormwater in place of traditional "grey" infrastructure. Bluebelts engineer these natural elements to slow the flow of water and use vegetation and other elements to absorb and filter impurities. DEP's Bluebelt program started in Staten Island (with almost 10,000 acres now in place) and is now expanding in Staten Island and into other parts of the city, including Southeast Queens.

What Happened During Sandy

While Sandy's impact on the water supply was minimal, impacts on the wastewater system were more significant—predominantly as a result of storm surge and the loss of electrical power.

Sandy passed to the south of the Catskill/Delaware watershed and, therefore, brought minimal rainfall and did not affect the city's water supply substantially. All of New York City's drinking water treatment and distribution facilities remained operational and supplied potable water throughout the storm. Kensico Reservoir in Westchester County, part of the Catskill/Delaware System, did experience a spike in turbidity. The turbidity at Kensico was the result of high winds that caused erosion on the reservoir's edge, sending natural materials into the reservoir. However, DEP was able to adjust water supply operations at Kensico so that water supply distribution and quality in the city were not affected. The city's robust water quality testing system, which takes more than 500,000 samples per year, sampled locations in the watershed and nearly 1,000 stations across the five boroughs during and after Sandy, and confirmed water quality.

Although the system fared well overall and drinking water remained safe during Sandy, there were some localized impacts on water supply. Many high-rise buildings throughout the city were unable to pump water to residents on upper floors due to the loss of power to their pumping systems. Meanwhile, in Breezy Point, a private community on the Rockaway Peninsula in Queens, fires caused significant disruption to the neighborhood's private water distribution system, which draws its supply from City-owned mains. Finally, while some City-owned water main breaks were reported, there was no significant spike citywide, and in these individual cases it took DEP an average of five hours to restore water service.

However, Sandy did impact the city's wastewater treatment plants, which are along the waterfront and at low elevations, and are thus particularly vulnerable to storm surge. To address these impacts, DEP worked tirelessly to ensure that the system would perform its core functions without significant disruption.

During Sandy, 10 of DEP's 14 wastewater treatment plants were damaged or lost power, and released untreated or partially treated wastewater into local waterways. Three of these facilities were non-operational for some time as a result of the storm: Coney Island for two hours, North River for seven hours, and Rockaway for three days. The other facilities maintained at least partial treatment, including removal of pollutants and disinfection of effluent before water from these plants was discharged into waterways. Although, collectively, wastewater treatment plants operated at more than twice their normal flow rate at the height of the storm, approximately 560 million gallons of untreated sewage mixed with stormwater and seawater was released into local waterways, equivalent to approximately half a day's worth of normal wastewater treatment. (*See chart: Volume of Wastewater Treated During Sandy*)

Most of the damage to wastewater facilities involved electrical systems and equipment, including substations, motors, control panels, junction boxes, and instrumentation. Sandy's floodwaters inundated the lower levels of facilities, where much of this equipment is located. Even where electrical systems were not damaged during Sandy, utility power outages forced many facilities to operate on emergency generators for up to two weeks.

Where shutdowns occurred, DEP worked quickly to mitigate impacts. For example, the Rockaway Wastewater Treatment Plant (WWTP), which treats approximately 1 percent of the city's wastewater, suffered severe flooding—as did the upstream sewers and the surrounding community—and was shut down during and immediately after the storm; just three days later it was providing partial treatment, and two weeks later, it was fully back online.

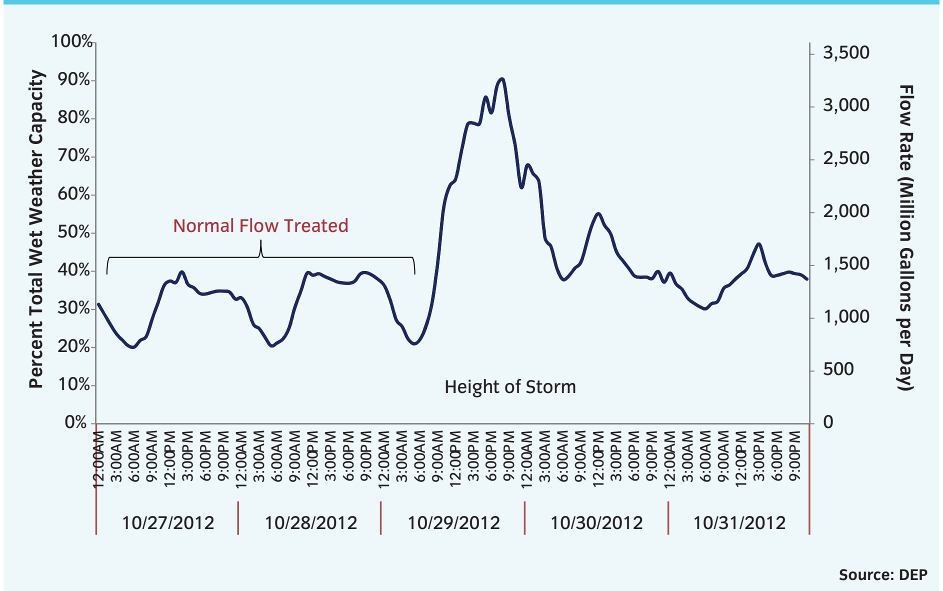
Many of DEP's wastewater treatment plants, however, performed well throughout the storm. For example, the Oakwood Beach plant in Staten Island was able to treat 80 million gallons of wastewater during the storm—twice its normal level—despite being surrounded by Sandy's surge and incurring some damage. This performance is attributable at least in part to the elevation of critical systems during a facility upgrade that took place more than three decades ago—and the dedication of the workers who stayed and continued operations even while the plant was surrounded by water.

In addition to affecting treatment facilities, Sandy also affected pumping stations. Forty-two of 96 such stations were damaged or lost power. Power outages were responsible for roughly half of the impacts, with storm surge inundation responsible for the other half—primarily in coastal communities in Staten Island, Brooklyn, and Queens. At inundated pumping stations, many of which are underground, recovery required not just pumping floodwaters out of the stations, but also repairing damage caused by the corrosive impact of seawater on electrical equipment. (*See map: Pumping Stations Affected By Sandy*)

Thanks to an immediate response by DEP employees, most affected treatment plants and pumping stations were running again shortly after Sandy's floodwaters receded. Within four days of Sandy, 13 of 14 wastewater treatment plants and most pumping stations were fully operational, treating 99 percent of New York City's wastewater.

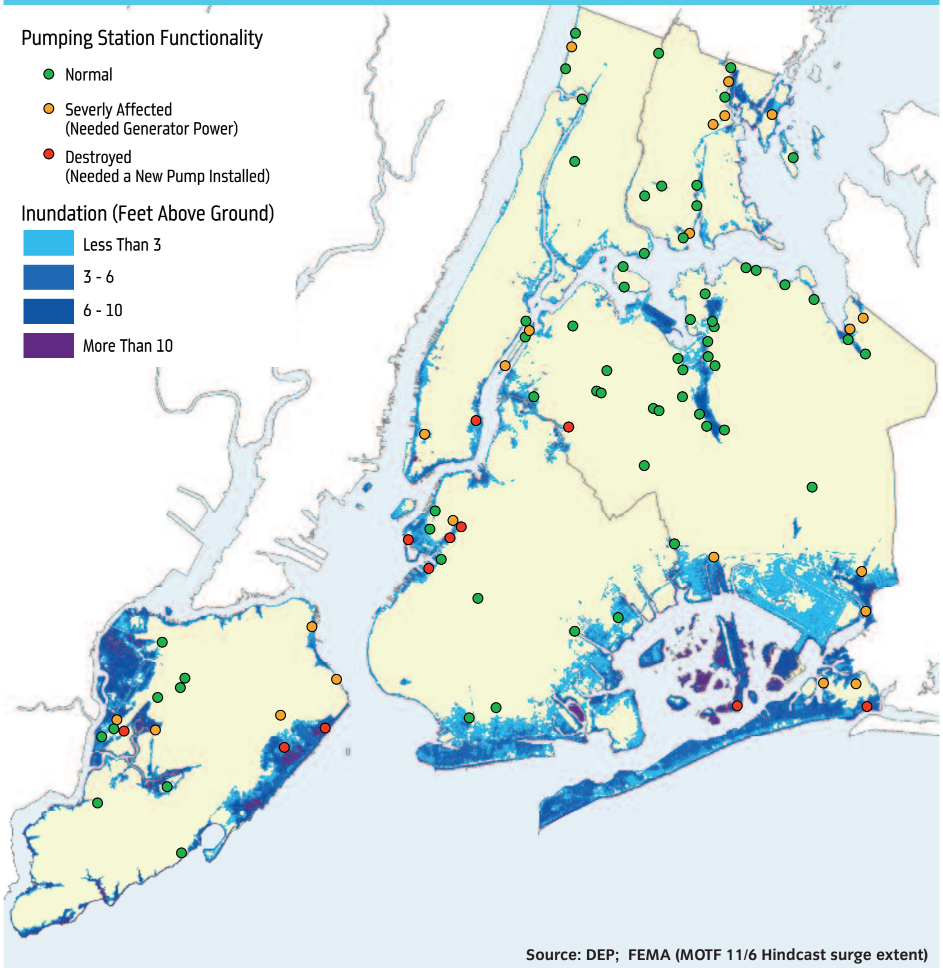
Despite the rapid response, Sandy's surge led to the release of wastewater into New York's waterways. As DEP reported, approximately 560 million gallons of untreated combined sewage, stormwater, and seawater from

Volume of Wastewater Treated During Sandy



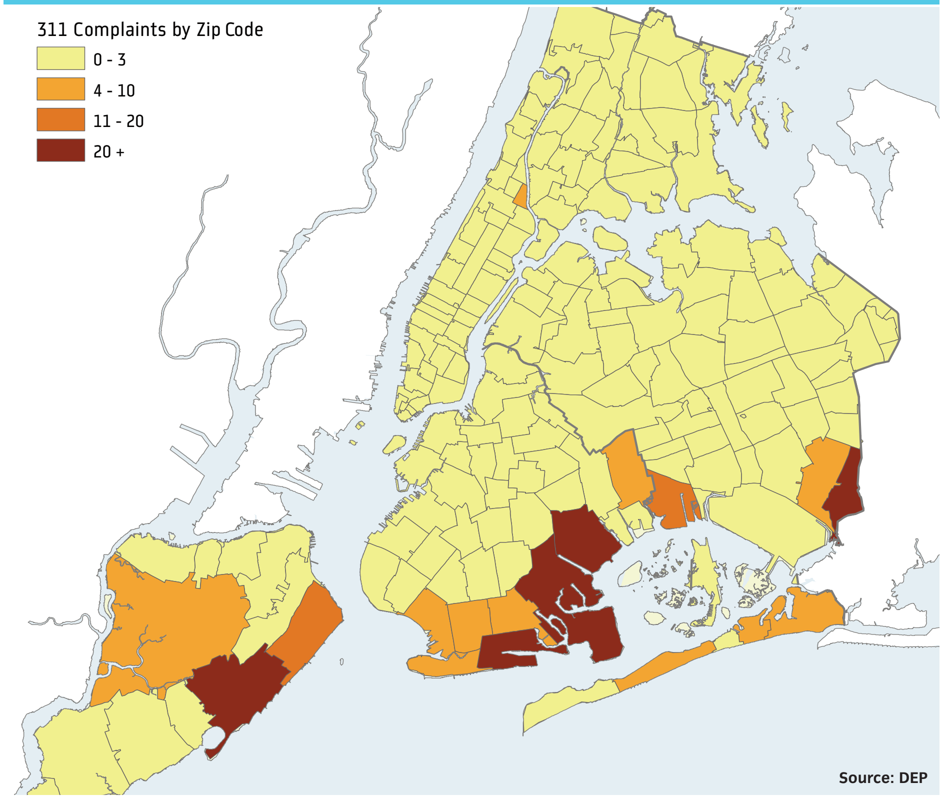
Source: DEP

Pumping Stations Affected By Sandy



Source: DEP; FEMA (MOTF 11/6 Hindcast surge extent)

Confirmed Sewer Backup and Street Flooding Complaints Oct. 30 - Nov. 1, 2012



sewers, and another approximately 800 million gallons of partially treated and disinfected wastewater, were released into waterways. After Sandy, DEP collected samples of water quality throughout the harbor. Data from these samples showed that water quality in New York Harbor was not affected significantly by the storm. Some localized and limited exceptions were attributable, at least in part, to damage at wastewater treatment facilities in other regional municipalities outside of DEP's jurisdiction. These third-party impacts were concentrated in waterways near Raritan Bay and the Narrows.

Part of the reason that Sandy's impact on water quality was so limited was likely Sandy itself. The same high volume of seawater that affected some DEP assets also helped to dilute the discharge of untreated or partially-treated sewage. Nonetheless, as a precautionary measure, two days after Sandy, the City issued a recreational water body advisory for the Hudson and East Rivers, New York Harbor, Jamaica Bay, and the Kill Van Kull. The advisory remained in place for 30 days and was lifted after DEP testing confirmed that the waterways were safe.

Another impact of Sandy was sewer backups, which occurred in some coastal areas. Sandy's surge inundated properties and the sewer system through catch basins, manholes, and storm drains in the streets. While ultimately, the city's drainage systems helped to drain floodwater after the storm surge receded, the surge also deposited sand and debris in and around drainage systems, which slowed the drainage process. Recorded complaints for sewer backups and flooding, received through the City's 311 service, were concentrated in highly developed areas near the waterfront. DEP inspected the areas of all recorded complaints and performed any necessary work. DEP crews cleaned more than 3,500 catch basins and flushed more than 190,000 linear feet of sewer lines in the three weeks following the storm, and accompanied other City agencies in additional cleanup efforts. *(See map: Confirmed Sewer Backup and Street Flooding Complaints Oct. 30 - Nov. 1, 2012*)

What Could Happen in the Future

The greatest climate change-related risk to the city's water supply is runoff from heavy downpours affecting water quality in reservoirs. By contrast, the greatest risk faced by the city's wastewater system is storm surge inundation of critical assets, potentially leading to release of untreated or partially treated wastewater.

Major Risks

Heavy downpours pose a significant risk to the city's water supply system. They produce increased runoff, which causes high pathogen and contaminant levels in reservoirs, increases turbidity due to the underlying geology of land near the reservoirs, and affects the drinking water disinfection process. These conditions are particularly challenging if extreme rainfall events happen one right after another, before the impacts of a previous event have been controlled fully. This vulnerability of the water system, particularly the Catskill system, is expected to be tested with greater frequency through the 2050s with increases in heavy downpours in the New York region.

Storm surge, on the other hand, poses a major risk for the city's wastewater treatment plants and pumping stations, as Sandy demonstrated. Floodwaters from the surge can damage equipment and disrupt the power supply at these facilities; consequently, partially treated or untreated sewage can spill into waterways around New York City.

This vulnerability only will increase as the climate changes. Given their waterfront locations, according to a recent DEP study, by the 2050s, all of the city's 14 wastewater treatment plants will have at least some of their equipment located below the Base Flood Elevation (BFE), or the height to which floodwaters are expected to rise during a "100-year flood" (a flood with a 1 percent or greater chance of occurring in any given year). As sea levels rise, expected flood heights will also increase, putting a greater percentage of treatment facility equipment at risk of flooding and increasing the likelihood that surge from a coastal storm would disrupt or even shut down DEP facilities. The percentage of critical equipment that is estimated to be below expected flood heights, based on New York City Panel on Climate Change "high end" sea level rise projections for the 2050s, varies by facility from as little as less than 1 percent at Jamaica WWTP to potentially as much as 70 percent at Hunts Point WWTP.

Meanwhile, of the city's 96 pumping stations, 37 are located in the 100-year floodplain indicated in the Federal Emergency Management Agency (FEMA) 2013 Preliminary Work Maps. That number is expected to grow over time—to 48 by the 2020s and 58 by the 2050s. (*See sidebar: Reducing Flood Risk to Key Wastewater Infrastructure*)

Other Risks

The city's wastewater system is also at risk from gradual sea level rise—without storm surge. Sea level rise itself may cause flow to back up during heavy rain and limit the ability of some wastewater treatment plants to operate at full capacity, leading to CSO events and release of partially treated sewage into area waterways.

Increased precipitation and heavy downpours alone, regardless of sea levels, also could lead to CSO events. Furthermore, heavy downpours can overwhelm the sewer system and cause

Risk Assessment: Impact of Climate Change on Wastewater

Major Risk   Moderate Risk   Minor Risk

	Scale of Impact			
Hazard	**Today**	**2020s**	**2050s**	**Comments**
Gradual				
Sea level rise				At higher water levels, wastewater treatment plants may not be able to operate at full capacity during heavy rain events, leading to releases of untreated or partially treated sewage into waterways
Increased precipitation				Combined sewage and stormwater could exceed the capacity of wastewater treatment plants, leading to releases of untreated or partially treated sewage into waterways
Higher average temperature				Minimal impact
Extreme Events				
Storm surge				Asset damage and power disruption could lead to releases of untreated or partially treated sewage into waterways
Heavy downpour				Combined sewage and stormwater could exceed the capacity of wastewater treatment plants, leading to releases of untreated or partially treated sewage into waterways Sewer system capacity may be exceeded more frequently, leading to street flooding and sewer backups
Heat wave				INDIRECT: Utility power outages could lead to reduced treatment levels and sewage bypass
High winds				Minimal impact

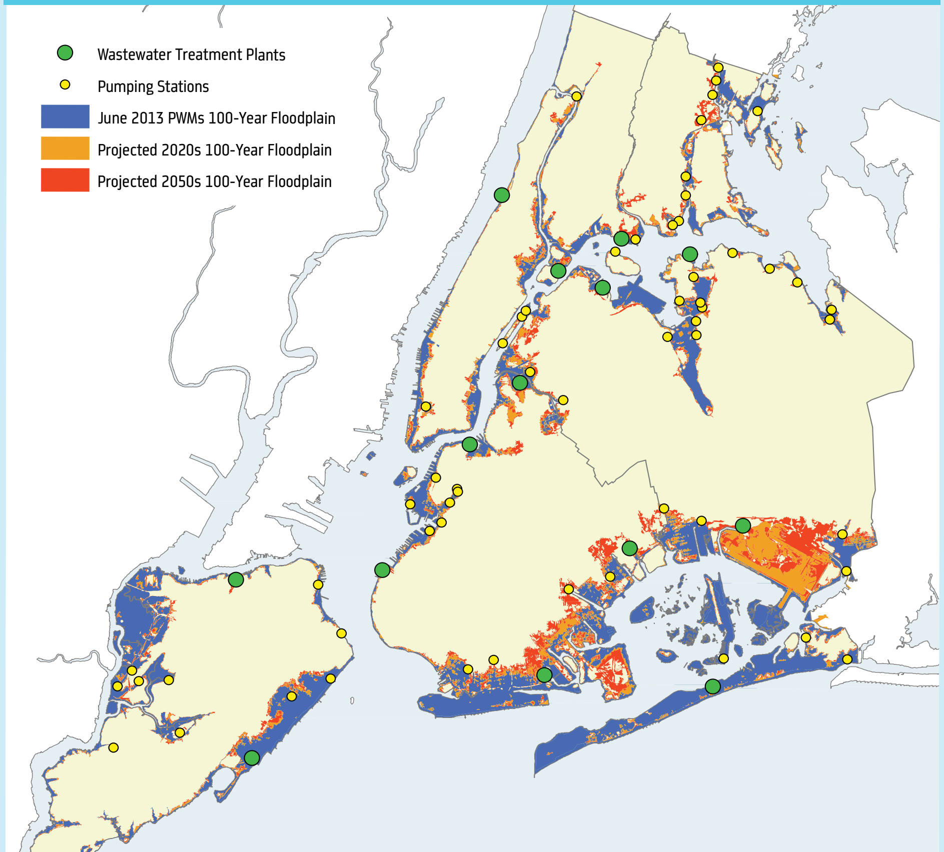
Risk Assessment: Impact of Climate Change on Water Supply

Major Risk   Moderate Risk   Minor Risk

	Scale of Impact			
Hazard	**Today**	**2020s**	**2050s**	**Comments**
Gradual				
Sea level rise				Minimal Impact
Increased precipitation				Increased turbidity, pathogen, and contaminant levels could require treatment and challenge disinfection process
Higher average temperature				Reduced snowpack, drought, and higher demand could stress water supply Increased algae growth could affect water color and taste and challenge the disinfection process
Extreme Events				
Storm surge				Minimal Impact
Heavy downpour				Increased turbidity, pathogen, and contaminant levels could require treatment and challenge disinfection process
Heat wave				Reduced snowpack, drought, and higher demand could stress water supply Increased algae growth could affect water color and taste and challenge the disinfection process
High winds				Minimal impact

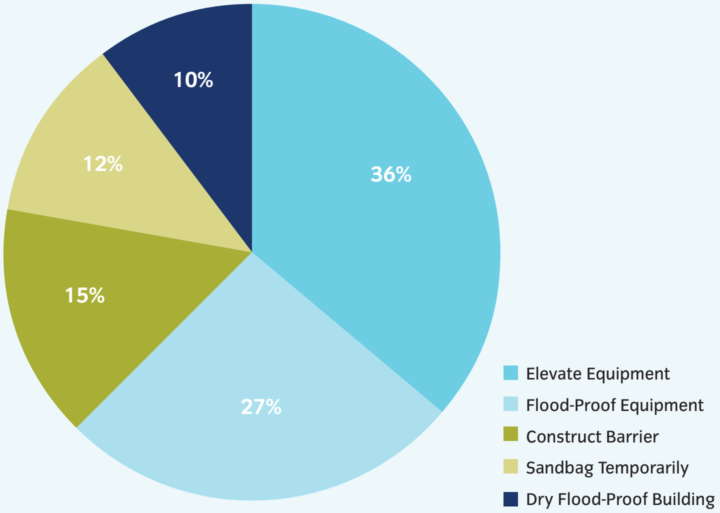
Reducing Flood Risk to Key Wastewater Infrastructure

Wastewater Facilities at Risk of Storm Surge Inundation



Source: DEP; FEMA; CUNY Institute for Sustainable Cities

Recommended Adaptation Strategy Allocations for Wastewater Facilities



Source: DEP

Many of New York City's 14 wastewater treatment plants and 96 pumping stations are susceptible to flood damage from storm surge, as seen during Sandy. With climate change, the vulnerability of these facilities likely will increase in the future. Accordingly, DEP has undertaken a detailed facility risk assessment and adaptation study to identify which wastewater infrastructure is and will be most at risk of flooding during extreme weather events, and to recommend adaptation strategies to address these risks.

To make its determination of vulnerability, DEP undertook site visits, engineering analyses and interviews with facility personnel. Common flood pathways that DEP examined included doorways, outfall pipes, bulkheads, windows, vents, conduits, and facility tunnel systems. Facility assets were determined to be at risk if they fell below expected flood heights based on "high end" sea level rise projections for the 2050s developed by the New York City Panel on Climate Change.

According to the study, all 14 wastewater treatment plants have assets that are at some level of risk. In fact, of the almost 47,700 total assets at these facilities, about 4,000 that are necessary for primary treatment and 10,600 other facility assets were shown to be vulnerable. Meanwhile, 58 of the 96 pumping stations were shown to be vulnerable.

DEP also analyzed a projection of its financial exposure to the aforementioned vulnerability. Again assuming high end sea level rise projections, the City's potential exposure was estimated to be $900 million at wastewater treatment plants and $220 million at pumping stations. This exposure excluded any costs associated with loss of service or environmental impacts. Based on the potential costs alone, DEP has concluded that there is a clear need for a robust set of protective measures.

To determine which protective measures to prioritize, DEP looked at a portfolio of strategies, including dry flood-proofing buildings with watertight windows and doors, elevating equipment, making pumps submersible and protecting electrical equipment with watertight casings, constructing external flood barriers, installing temporary sandbagging, and providing backup power generation to pumping stations (wastewater treatment plants are already so equipped).

DEP also looked at operational, environmental, social, and financial metrics in deciding how to prioritize its investments. These metrics included historical flooding frequency, proximity to beaches and sensitive water bodies, population served, number of critical facilities such as hospitals affected, and scheduled improvements in DEP's 10-year capital plan.

Based on the foregoing (as well as studies of site feasibility and cost-benefit analyses) a combination of recommended strategies was selected for each facility. Generally, for assets critical to meeting a minimum required level of service, strategies that would result in the highest resiliency levels were selected, while, for other assets, DEP sought to strike a balance between resiliency and return on investment.

The bottom line of the study is that a strategic mix of protective strategies could avoid almost 90 percent of risk citywide to wastewater treatment plants and ensure continuous service at pumping stations. In this way, the study set forth a cost-effective strategy for reducing damage to infrastructure and safeguarding public health.

Turbid water spilling from the Cannonsville Reservoir, Delaware County, NY, June 2006 Credit: DEP

Drought conditions at the Cannonsville Reservoir, Delaware County, NY, Dec. 2001 Credit: DEP

flooding and backups. The city's drainage systems, however, are designed to handle heavy rainfall, with capacity for rainfall intensity of 1.5 inches per hour in most areas of the city, where sewers were built prior to 1960, and 1.75 inches per hour in locations with sewers built after 1960.

While increases in temperature can have an effect on water quality in reservoirs, such as increased algae growth which can lead to changes in water color and taste and challenge the disinfection process, it can also lead to more severe water quantity impacts, including droughts. As of the writing of this report, New York City designates the 1963–1965 drought as the "drought of record," or the city's anticipated worst-case scenario. Though precipitation in the New York City area generally is expected to increase going forward, the City does need to monitor drought patterns, and changes in winter snowpack which may limit the ability of reservoirs to refill sufficiently to meet summer demand.

Finally, potential disruptions to power supply resulting from heat waves are another challenge that the city's water and wastewater systems may face going forward as the climate changes. However, many facilities have backup generators. Wastewater treatment plants, for instance, are required to have backup generators and maintain partial treatment during a blackout or brownout, thereby limiting the net impact of this risk.

This chapter contains a series of initiatives that are designed to mitigate the impacts of climate change on New York's water and wastewater system. In many cases, these initiatives are both ready to proceed and have identified funding sources assigned to cover their costs. With respect to these initiatives, the City intends to proceed with them as quickly as practicable, upon the receipt of identified funding.

Meanwhile, in the case of certain other initiatives described in this chapter, though these initiatives may be ready to proceed, they still do not have specific sources of funding assigned to them. In Chapter 19 (*Funding*), the City describes additional funding sources, which, if secured, would be sufficient to fund the full first phase of projects and programs described in this document over a 10-year period. The City will work aggressively on securing this funding and any necessary third-party approvals required in connection therewith (i.e., from the Federal or State governments). However, until such time as these sources are secured, the City will proceed only with those initiatives for which it has adequate funding.

Uninterrupted access to high-quality drinking water and continuous treatment of wastewater are critical to the viability of New York City as the climate continues to change. Though, as Sandy demonstrated, the city's water and wastewater systems are already highly resilient due to investments over many decades, the city cannot function without either system. DEP, therefore, will accelerate its resiliency efforts across a range of initiatives, including both existing and new efforts. DEP's strategies will include protecting wastewater treatment facilities from storm surge, improving and expanding drainage infrastructure, and investing in the projects which increase the redundancy and flexibility of the water system.

Strategy: Protect wastewater treatment facilities from storm surge

The City's investments in wastewater treatment over many years have resulted in dramatic improvements in the waterfront's ecological conditions, making the area a safer place to live and enhancing opportunities for public recreation. However, a substantial number of critical wastewater treatment assets are located, by design, in low-lying areas at risk of flooding in an extreme weather event. To minimize disruptions to its wastewater systems and protect its waterfront, the City must protect its vulnerable facilities from flooding impacts that may occur from future storms. Owners of other such facilities along area waterways also must undertake similar protective measures.

Initiative 1
Adopt a wastewater facility design standard for storm surge and sea level rise

Sandy damaged wastewater treatment plants and pumping stations even though the design of City wastewater facilities has taken into account the highest historically recorded water height of nearby water bodies or the BFEs identified in FEMA maps. The City, therefore, will adopt an increased level of protection for design and construction of all wastewater facilities based on the latest FEMA maps, modified to reflect sea level rise projections for the 2050s. The design for upgrades to DEP's Gowanus Canal facility, for instance, will protect any critical equipment that is located at or lower than 2.5 feet above the best-available BFE. DEP will adopt the new design guidelines in 2013.

Initiative 2
Harden pumping stations

Many of the city's pumping stations are located in low-lying areas and are necessary to convey wastewater and stormwater out of communities; however, their location also increases their vulnerability to storm surge. Therefore, subject to available funding, the City will retrofit these pumping stations for resiliency. These protective measures include raising or flood-proofing critical equipment, constructing barriers, and installing backup power supplies. Preliminary estimates indicate that there are currently 58 at-risk pumping stations, of which several already are scheduled for capital improvements. DEP will pursue implementation of resiliency projects at these pumping stations in conjunction with repairs and planned capital work, and as appropriate based on the level of risk, historical flooding, and potential community impacts, among other criteria. The goal is to begin implementation in 2014.

Initiative 3
Harden wastewater treatment plants

All 14 of the city's wastewater treatment facilities are located along the waterfront and are therefore at risk in the event of a coastal storm. Subject to available funding, the City will protect these critical treatment facilities by raising or flood-proofing assets that are critical to the treatment process, constructing barriers, improving waterfront infrastructure, or implementing redundancy measures to avoid failure of these critical treatment systems. DEP will target initially facilities that have been identified as either most at risk or as having the largest implications for adjacent communities and waterways, based on the findings of DEP's in-depth study. These facilities include the Oakwood Beach, Coney Island, 26th Ward, Hunts Point, Rockaway, and Jamaica WWTPs. The goal is to begin implementation of adaptation measures for these and other facilities in 2014 as part of repairs and other planned capital projects.

Initiative 4
Explore alternatives for the Rockaway Wastewater Treatment Plant

The Rockaway WWTP was one of the most heavily damaged wastewater facilities during Sandy. However, prior to investing significant funds to

Rendering of cogeneration facilities at North River Wastewater Treatment Plant in Manhattan Credit: DEP protect the plant from future storms, the City will consider converting it to a pumping station, which would be less expensive to protect, and potentially transferring its treatment responsibilities to a less vulnerable wastewater treatment facility elsewhere in the city. The City will conduct a feasibility study to consider all options. In addition to potentially decreasing future operations and maintenance needs, the conversion of this treatment plant would provide the opportunity to incorporate protective measures that would help avoid the failure of critical systems in future extreme weather events, and the potential impacts to water quality that could come with such failure. DEP will initiate the feasibility study in 2014 and, based on the results and subject to available funding, will consider moving forward with the conversion while incorporating additional resiliency measures.

Initiative 5

Develop cogeneration facilities at North River Wastewater Treatment Plant

The North River WWTP, in Upper Manhattan, had to cut off its electrical power supply when waters threatened the plant's internal substation. While, like other wastewater treatment plants, the facility was able to run on generators, it did have to power down for several hours. The City will continue to enhance the reliability of this critical facility by installing cogeneration equipment there while hardening electrical assets. Using methane generated by the wastewater treatment process itself, cogeneration will produce electric power to keep wastewater treatment processes at North River online during power outages or during peak summer load periods, when Con Edison may request that the facility reduce its power usage. The project will replace the existing engines at the treatment plant with new, efficient motors and a cogeneration system that will generate electricity sufficient to meet base electrical demand and recover heat for the treatment plant's entire process and building needs. DEP projects that design of the cogeneration project at North River WWTP will be completed by 2015, with construction timeline pending design specifications.

Initiative 6

Explore opportunities to expand cogeneration and other energy measures

Although all city wastewater treatment plants maintain backup power supplies, there are other measures that will improve the ability of wastewater treatment plants to operate reliably during disruptions to the electrical grid. The City will explore the feasibility of expanding cogeneration and other energy-related reliability measures to other wastewater treatment plants in the city besides North River, including the Wards Island WWTP. These measures, which could include energy efficiency, increased generation and use of renewable energy supplies such as methane gas and solar energy, and cogeneration, would improve the ability of wastewater treatment plants to operate reliably during disruptions to the electrical grid while also enabling significant reductions in DEP greenhouse gas emissions. Over the long term, DEP will continue to plan and design new and improved wastewater treatment facilities with the ultimate goal of recovering and producing all energy on site, where feasible. DEP will begin a feasibility study for cogeneration at Wards Island in 2013, with implementation and other efforts to follow based on results and subject to available funding.

Stormwater running into a green infrastructure bioswale

Credit: DEP

Initiative 7

Encourage regional resiliency planning

Even if the City protects its wastewater treatment assets, the water quality at certain locations in New York Harbor may still be at risk should non-City facilities discharge sewage at a large scale—as happened during Sandy. The City, therefore, immediately will call upon nearby utilities in New York and New Jersey to take measures to protect their wastewater facilities from storm surge and sea level rise. Through regional resiliency planning, the City and neighboring municipalities alike can protect our shared Harbor.

Strategy: Improve and expand drainage infrastructure

Increased rainfall and heavy downpours may contribute to increases in street flooding, sewer backups, and combined sewer overflows. Improving the city's sewer systems will enhance the ability of the existing infrastructure to cope with environmental changes. To this end, DEP will continue to implement a number of its programs that are already under way and, where opportunities exist, will seek to expand these programs.

Initiative 8

Reduce combined sewer overflows with Green Infrastructure

As climate change brings increasing rainfall volume to the New York area, the city may also experience shifts in the frequency and volume of CSOs. The City will continue to implement its Green Infrastructure Plan and CSO Long-Term Control Plans (LTCPs) to reduce such CSOs. For this purpose, DEP, working with the Department of Parks & Recreation and Department of Transportation (NYCDOT), will continue to pursue its plan to capture the first inch of runoff in 10 percent of impervious surfaces citywide in areas within the combined sewer system by 2030. At the same time, DEP also will continue to develop LTCPs to evaluate long-term solutions to reduce CSOs and improve water quality in New York City's waterways. DEP will issue an LTCP for Alley Creek in Queens in 2013, with nine additional water body-specific LTCPs and one citywide LTCP to follow by 2017—including plans for Coney Island Creek, the Gowanus Canal, Newtown Creek, and Jamaica Bay.

Initiative 9
Reduce combined sewer overflows with high-level storm sewers citywide

While the construction of new, green infrastructure is an effective solution to manage rainfall and reduce CSOs in some locations, in other areas, it will be more cost-effective to enhance the city's existing sewer system. The City will augment existing combined sewers with high-level storm sewers in certain areas near the water's edge around the city. These high-level storm sewers sit on top of the combined sewer and accept stormwater from the street before diverting it to a nearby waterway, with the combined sewer below it sending wastewater and a reduced amount of stormwater to a treatment plant. Such high-level storm sewers are able to capture 50 percent of rainfall before it enters combined sewers. Among the benefits of high-level storm sewers are mitigation of CSOs and the potential to reduce street flooding. To this end, DEP will continue to pursue approximately 15 high-level storm sewer projects that will be completed by 2023, and will continue to seek additional opportunities near the water's edge for additional high-level storm projects that are deemed to be most cost-effective and can be implemented in conjunction with NYCDOT street improvements and other community infrastructure projects.

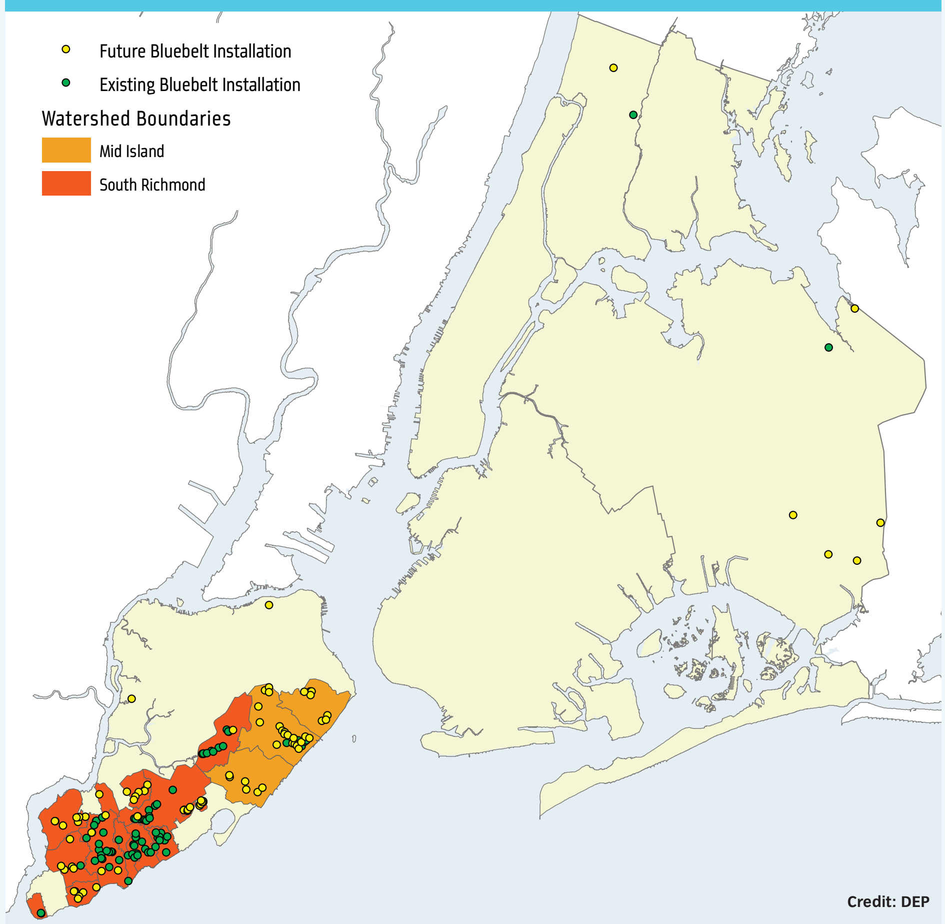
Initiative 10
Continue to implement and accelerate investments in Bluebelts across the city

Some areas of the city lack a fully built-out storm sewer system, and street flooding can occur even during minimal rain events. The City will, in addition to implementing new sewer build-outs and upgrades, continue to implement and accelerate its innovative Bluebelt drainage program. It will do so in several of these areas where opportunities exist to preserve and enhance natural areas, including streams, ponds, and other wetlands that remove pollutants before stormwater enters waterways. Through the next decade, DEP will complete substantially the South Richmond Bluebelt in Staten Island and additional Bluebelts in Twin Ponds, Queens. DEP also will begin to construct the Mid-Island Bluebelt on the East Shore of Staten Island. DEP will also accelerate planning and design of some Bluebelt systems including in Van Cortlandt Park in the Bronx and at Last Chance Pond in Staten Island, subject to available funding and environmental review.

Bluebelt installation under normal conditions

Credit: DEP

Citywide Bluebelt Map



Credit: DEP

Initiative 11
Build out stormwater sewers in areas of Queens with limited drainage systems

Large areas of South Queens, including portions of Broad Channel, Edgemere, Bayswater, Far Rockaway, Rockaway Beach and Arverne, as well as surrounding neighborhoods in Southeast Queens, such as Rosedale and Jamaica, do not have fully built-out storm sewer systems and currently experience street flooding, which may be exacerbated if rainfall increases with climate change. DEP, therefore, will continue to build out the storm sewer systems in these locations along with sanitary sewer upgrades and high-level storm sewers, undertaking approximately 30 projects through 2023. DEP will seek additional sewer build-out, improvement, or upgrade opportunities in conjunction with NYCDOT street improvements and other community infrastructure projects, including in areas with street flooding.

Initiative 12
Periodically review rainfall trends and implications for stormwater infrastructure

Future changes in rainfall intensity may warrant reconsideration of sewer design to decrease street flooding. DEP recently completed an assessment of historical rainfall data which revealed no changes in hourly and sub-hourly rainfall intensity. However, in order to recognize any emerging trends in precipitation intensity, DEP will work with the Mayor's Office of Long-Term Planning and Sustainability and the New York City Panel on Climate Change to create a process to reassess precipitation data periodically and incorporate any advances in climate modeling. Based on material emerging trends indicated by the foregoing, DEP will assess implications for the sizing of stormwater detention systems, sewer site connections, and green infrastructure, as appropriate. These assessments will occur approximately every eight years, with the next reassessment in 2021.

Strategy: Promote redundancy and flexibility to ensure constant supply of high-quality water

The City owns and operates an extensive water supply network that may increasingly be affected by climate change. However, redundancy and flexibility, which are already built into the system, allow the City to draw upon the largest quantity of water from the highest-quality sources in varying weather conditions. Building on this redundancy and flexibility, the City will protect critical infrastructure and watershed lands and improve upon the physical connections between different parts of the system to enable the use of the most appropriate source of water at any given moment in time.

Initiative 13
Repair the leak in the Delaware Aqueduct

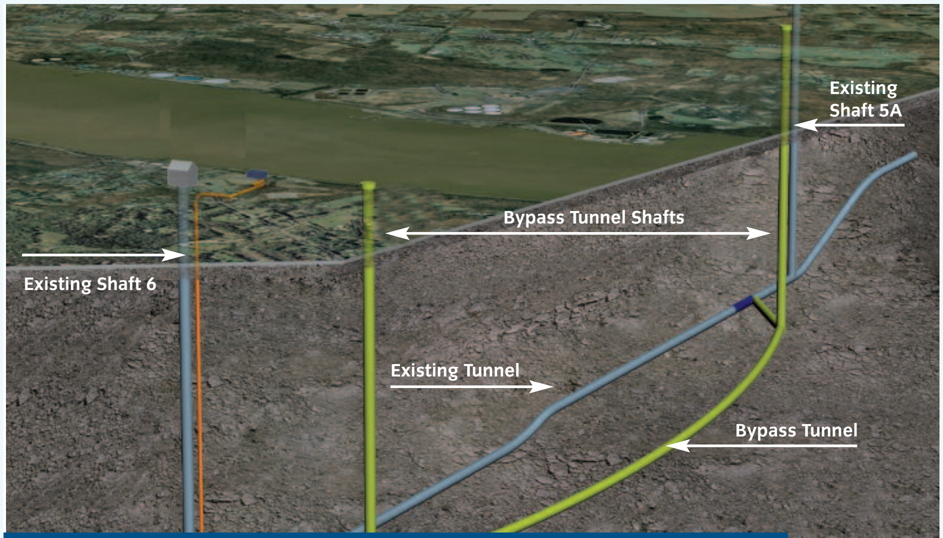
Every drop of clean water counts, particularly in times of drought and other extreme weather events that affect supply. The City will implement planned repairs to the Delaware Aqueduct, which conveys, on average, 50 percent of the city's water from Upstate sources. This aqueduct has been leaking between 15 and 35 million gallons of water a day for many years. In 2013, DEP will begin construction of a three-mile bypass tunnel around the section which has the largest leak. While the bypass is connected and the aqueduct is out of service, DEP will repair other sections of the tunnel. These repairs will enhance the reliability of the city's water supply and maintain flexibility during normal operations, as well as during periods when the water system is depleted, or when water quality in other parts of the system is affected by heavy rain or heat waves. Since the Delaware Aqueduct will need to be shut down in order to connect the new bypass tunnel, this will result in a temporary decrease in water supply. Accordingly, in preparation for the shutdown, DEP will increase the capacity and use of the Catskill and Croton systems; reactivate a groundwater system in Southeast Queens; and adopt both a new Water Demand Management Plan that will conserve water citywide, and water shortage rules to impose use restrictions during droughts and infrastructure repairs. The tunnel shutdown, repairs, and reactivation are expected to be completed in 2022.

Initiative 14
Improve interconnection between the Catskill and Delaware aqueducts and maximize capacity to deliver water from the Catskill/Delaware system

The impacts of climate change on the city's three water supply systems—the Catskill, Delaware, and Croton systems—are likely to vary. For example, while the Catskill system is prone to elevated turbidity, the Delaware system is less so. This variability is one of the strengths of the city's water supply system. However, tapping into that strength requires the right infrastructure. The City, therefore, will complete several planned infrastructure projects, including a new connection between the Catskill and Delaware water supply systems. The City also will consider a project to pressurize the Catskill Aqueduct between Kensico Reservoir and DEP's Ultraviolet Disinfection Facility, in order to give DEP the ability to maximize use of water from Kensico Reservoir and maximize flow to Hillview Reservoir. DEP will begin construction of the interconnection between the Catskill and Delaware system in 2013 and, subject to pending analysis, would commence construction of the pressurized Catskill Aqueduct after the repair of the Delaware Aqueduct is completed in 2022.

Initiative 15
Continue the Watershed Protection Program to maintain drinking water quality

The City will maintain its commitment to protect its reservoirs and the watersheds that surround them while considering the challenges of climate change. DEP will continue to implement its Long-Term Watershed Protection Program to protect water quality in the streams and other water bodies that feed its reservoirs, and in the reservoirs themselves. The City will continue to acquire land strategically in the watershed and manage that land. DEP also will continue its stream, farm, and forestry programs. These and other watershed protection efforts help maintain water quality, promote environmentally compatible economic development, and enable the City to avoid building a water filtration facility for the Catskill/Delaware systems. DEP's support of these programs in the watershed also helps to reduce the high levels of nutrients associated with stormwater, which can otherwise cause increased algae levels in reservoirs. In 2013, DEP expects that the filtration waiver applicable to the Delaware and Catskill systems will be revised and will incorporate updates to its Long-Term Watershed Protection Program, as outlined above.



Rendering of the bypass tunnel around the leaking section of the Delaware Aqueduct

Credit: DEP