NYC WASTEWATER RESILIENCY PLAN

CLIMATE RISK ASSESSMENT AND ADAPTATION STUDY

NYC Environmental Protection

Michael R. Bloomberg
Mayor
Carter H. Strickland, Jr.
Commissioner

October 2013

Carter H. Strickland, Jr.
Commissioner

Dear Friends:

The New York City Department of Environmental Protection (DEP) is proactively planning for climate change, from reducing greenhouse gas emissions to preparing for the impacts of extreme weather to drinking water and wastewater infrastructure. When Hurricane Sandy hit in October 2012, DEP was already in the process of studying the potential impacts of storm surge and sea level rise, to consider measures to protect the low-lying wastewater treatment plants and pumping stations that help drain our streets and keep our waterways and beaches clean for the enjoyment of millions of New Yorkers. After Sandy's surge caused damage to wastewater facilities, resulting in millions of gallons of untreated and partially treated wastewater spilling into the harbor, DEP quickly reacted to repair damage and to develop resiliency measures—such as elevating and flood-proofing equipment—to ensure the highest levels of protection from future storms.

The NYC Wastewater Resiliency Plan presents a comprehensive assessment of facilities at-risk from future storms, potential costs, and suggested measures to protect critical equipment and reduce the risk of damage and loss of services. The report follows the recent release of Mayor Bloomberg's *A Stronger, More Resilient New York*, which committed the City to harden its wastewater treatment plants and pumping stations. With 14 wastewater treatment plants and 96 pumping stations, prioritizing the most at-risk facilities included an extensive and in-depth assessment of the height of critical assets in relation to projected flood heights.

In determining the benefits of resiliency measures and the level of acceptable costs, DEP considered not only the value of wastewater assets, but also the population and critical facilities in the service areas and potential impacts on beaches. Resiliency measures were then selected based upon costs and level of risk reduction. The result is a portfolio of strategies that will be "shovel ready" for funding opportunities and implementation as part of planned capital projects.

Investing in our wastewater infrastructure today will ensure the continuity of critical services well into the future. By implementing these strategies along with initiatives to improve energy reliability, build green infrastructure, improve and expand drainage infrastructure, and promote redundancy and flexibility of our water supply, DEP will continue to be a leader in proactive planning for climate change, to ensure the resiliency of New York City's water resources.

Sincerely,

Carter H. Strickland, Jr.
Commissioner

Cover photograph: Newtown Creek Wastewater Treatment Plant, Brooklyn, New York

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TABLE OF CONTENTS

Executive Summary 1

Chapter 1: Citywide Framework 23

Chapter 2: Wastewater Treatment Plants 31

33 Introduction
35 26th Ward
41 Bowery Bay
47 Coney Island
53 Hunts Point
59 Jamaica
65 Newtown Creek
71 North River
77 Oakwood Beach
83 Owls Head
89 Port Richmond
95 Red Hook
101 Rockaway
107 Tallman Island
113 Wards Island

Chapter 3: Pumping Stations 119

121 Introduction
125 2nd Avenue
127 6th Road
129 15th Avenue
131 19th Street
133 24th Avenue
135 37th Avenue
137 40th Road
139 49th Street
141 122nd Street
143 Avenue M
145 Avenue U
147 Bayswater Avenue
149 Borden Avenue
151 Broad Channel
153 Bush Terminal
155 Canal Street
157 Cannon Avenue
159 Clearview
161 Commerce Avenue

Pumping Stations

163 Conner Street
165 Co-op City North
167 Douglaston Bay
169 Eltingville
171 Ely Avenue
173 Flushing Bridge
175 Gildersleeve Avenue
177 Hannah Street
179 Hollers Avenue
181 Howard Beach
183 Hunts Point Market
185 Kane Street
187 Linden Place
189 Marble Hill
191 Mason Avenue
193 Mayflower Avenue
195 Melvin Avenue
197 Nautilus Court
199 Nevins Street
201 New York Times
203 Old Douglaston
205 Orchard Beach
207 Paerdegat
209 Richmond Hill Road
211 Rikers Island North
213 Roosevelt Island Main
215 Roosevelt Island North
217 Roosevelt Island South
219 Rosedale
221 Sapphire Street
223 Seagirt Avenue
225 South Beach
227 Throgs Neck
229 Van Brunt Street
231 Victory Boulevard
233 Warnerville
235 Zerega Avenue

Chapter 4: Precipitation, Watershed, and Tide Gate Analysis 237

239 Introduction
241 Phase I: Precipitation Analysis
247 Phase II: Watershed Analysis
251 Phase III: Tide Gate Analysis
253 Conclusion
254 References

NEWTOWN CREEK WASTEWATER TREATMENT PLANT VISITOR CENTER, BROOKLYN, NEW YORK

EXECUTIVE SUMMARY

The New York City Department of Environmental Protection (DEP) owns and operates one of the largest wastewater collection and treatment systems in the world, with 14 wastewater treatment plants and 96 pumping stations that convey stormwater and wastewater. The City's wastewater treatment plants (WWTP) utilize advanced biological and chemical processes to treat on average 1.3 billion gallons of wastewater per day, using state-of-the-art technology that removes between 85 and 95 percent of pollutants before discharging the treated water into the city's waterways. During wet weather, these treatment plants can disinfect two times their dry weather capacity. This immense system protects the environment and the health of more than eight million New Yorkers, and DEP is committed to ensuring its continued performance and reliability.

Many of the City's wastewater treatment plants and pumping stations are low-lying and necessarily located close to the waterfront in order to discharge treated wastewater and for efficient sludge handling. This waterfront dependency creates challenges that were plainly evident when a number of facilities experienced extensive damage during Hurricane Sandy. Flooding risk is likely to increase over time, as climate change brings more extreme storm surge events and continued sea level rise in the next several decades.

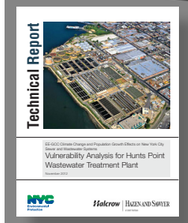
All 14 wastewater treatment plants and 60 percent of pumping stations are at risk of flood damage.

As such, DEP has taken a proactive stance in assessing its infrastructure risks and setting forth a framework to implement protective measures. Since 2008, DEP has been investigating the impacts of climate change on its infrastructure, not only for wastewater facilities, but also for drinking water supply and stormwater management.

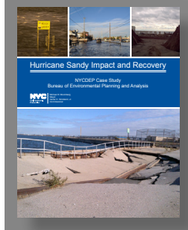
Building upon previous studies, this climate risk assessment and adaptation study sets forth cost-effective strategies for reducing flooding damage to wastewater infrastructure and safeguarding public health and the environment. This comprehensive study examined buildings and infrastructure at DEP's 96 pumping stations and 14 wastewater treatment plants, identifying and prioritizing infrastructure that is most at risk of flood damage. Through the study, DEP developed a set of recommended design standards and cost-effective protective measures tailored to each facility to improve resiliency in the face of future flood events.

April 2007
Mayor Bloomberg released PlaNYC, the City's long-term sustainability plan to accommodate a growing population, enhance the quality of life for all New Yorkers, and address climate change. The 2007 report entitled *A Greener, Greater New York* laid out PlaNYC's 127 goals, including reducing the city's greenhouse gas emissions by more than 30 percent by 2030.

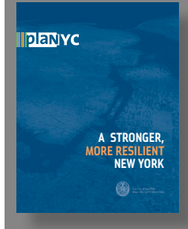
May 2008
DEP began implementing climate change resiliency measures after developing and issuing its Climate Change Assessment and Action Plan. This plan established the framework for subsequent studies to understand the linkages between climate change and specific service areas such as drinking water supply and delivery, stormwater management, and wastewater collection and treatment.



February 2011
DEP began a detailed Climate Risk Assessment and Adaptation Study for representative wastewater treatment plants, pumping stations, and drainage areas to evaluate the impacts of projected changes in temperature, precipitation, storm surge, and sea level.



October 2012
The potential impact of storm surge and sea level rise were demonstrated when Hurricane Sandy swept over New York City on October 29th, 2012. The surge caused extensive flooding and resulted in over $95 million in damage at 10 wastewater treatment plants and 42 pumping stations.



June 2013
Mayor Bloomberg released *A Stronger, More Resilient New York*, outlining more than 250 recommendations to protect neighborhoods and infrastructure from future climate events. The results of DEP's Climate Risk Assessment and Adaptation Study were incorporated into the report's Water and Wastewater chapter.

The study produced a number of key results: All 14 wastewater treatment plants and 60 percent of pumping stations (58 out of 96) are at risk of flood damage. The study estimates that equipment valued at more than $1 billion is at risk and requires additional protection. It is unlikely that this high damage cost would be incurred during a single storm surge event, as flood heights tend to vary across New York City depending on storm characteristics; however, some at-risk equipment may incur repetitive damage from multiple storm surge events over time. Considering the entire range of surge heights up to and including the 100-year flood with 30 inches of sea level rise, the cumulative damages over the next 50 years may exceed $2 billion if no protective measures are put in place.

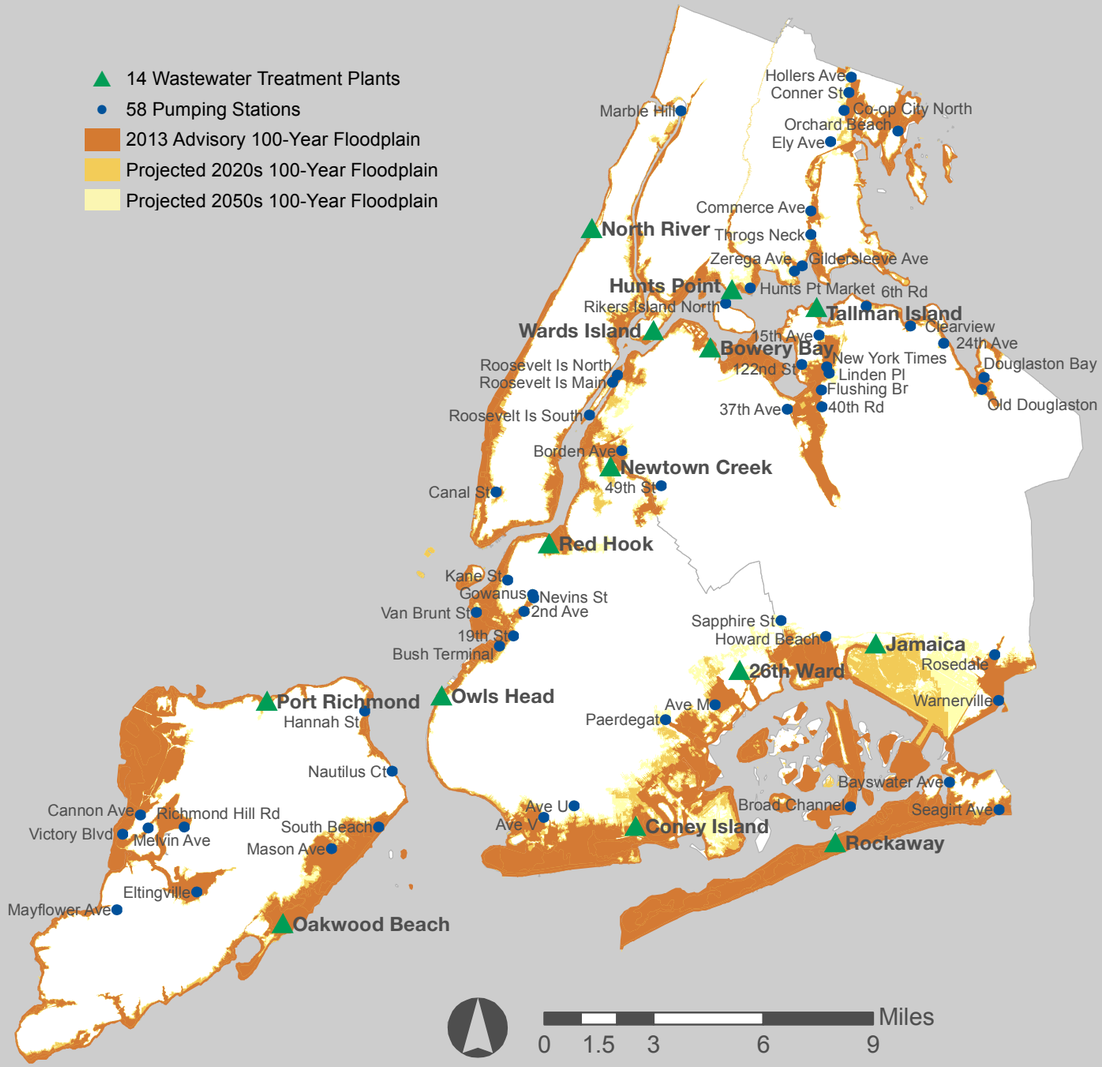
The recommended protective measures, totaling $315 million in improvements, are costly but critical. Increased resiliency not only reduces damage to DEP's assets, but also enables rapid recovery of full service to the community following a flood event, reduces risk of sewer backup into homes, and reduces the likelihood of the release of untreated sewage into the environment. DEP will prioritize these measures as part of planned capital projects and with an eye toward other proposals for engineered barriers or wetlands as part of the broader coastal protection initiatives described in *A Stronger, More Resilient New York*.

Wastewater infrastructure valued at over $1 billion is at risk if no protective measures are implemented. Over 50 years, cumulative damages could exceed $2 billion.

KEY FINDINGS

What is at risk?

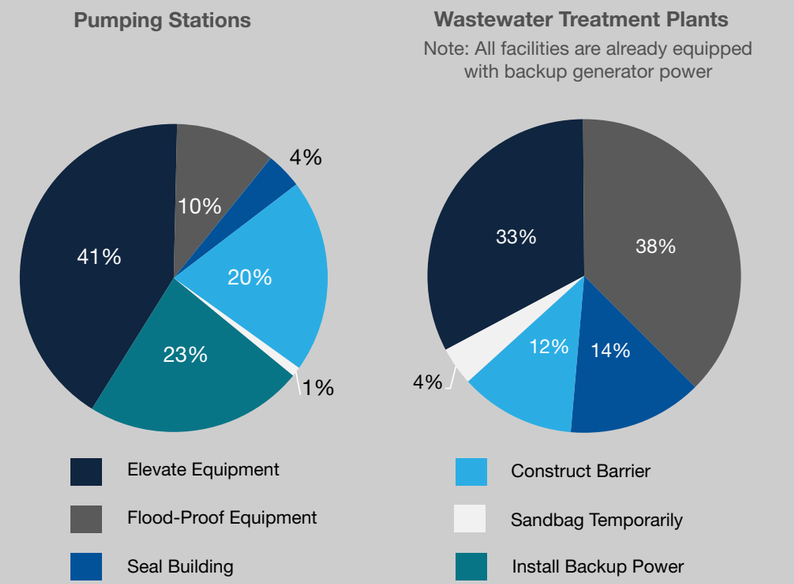
Wastewater Facilities At-Risk of Storm Surge Inundation



Source: FEMA; CUNY Institute for Sustainable Cities

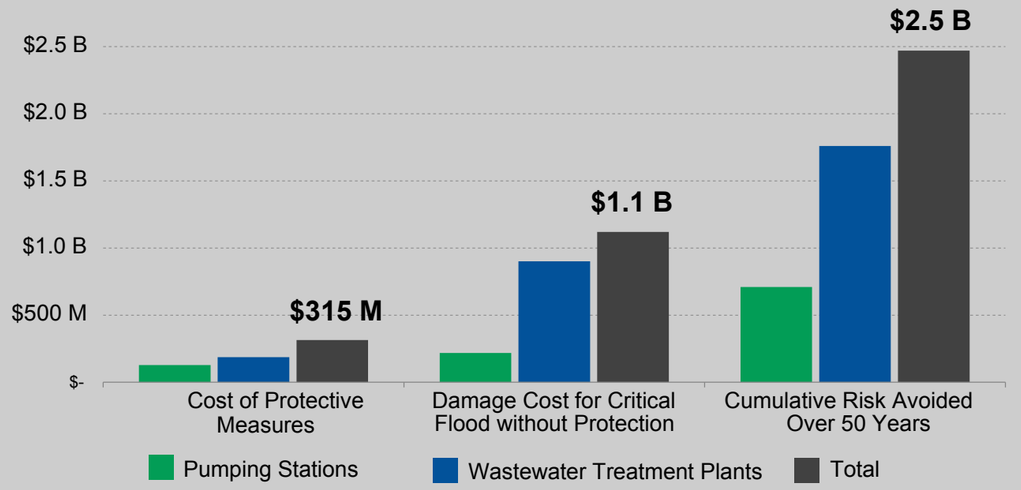
How should it be mitigated?

Adaptation Strategies



What is the cost?

Summary of Estimated Costs for Wastewater Infrastructure



HIGH WATER MARK AT HUNTS POINT WASTEWATER TREATMENT PLANT

Lessons Learned from Hurricane Sandy

Hurricane Sandy was a devastating coastal flood event that left many New Yorkers without homes, electricity, and their livelihoods. The damage to DEP's wastewater treatment plants and pumping stations alone has been estimated to exceed $95 million. The inundation experienced at these facilities during the storm was unprecedented, forcing many of DEP's staff to work around the clock in difficult conditions through the surge and in the days that followed to maintain or restore service.

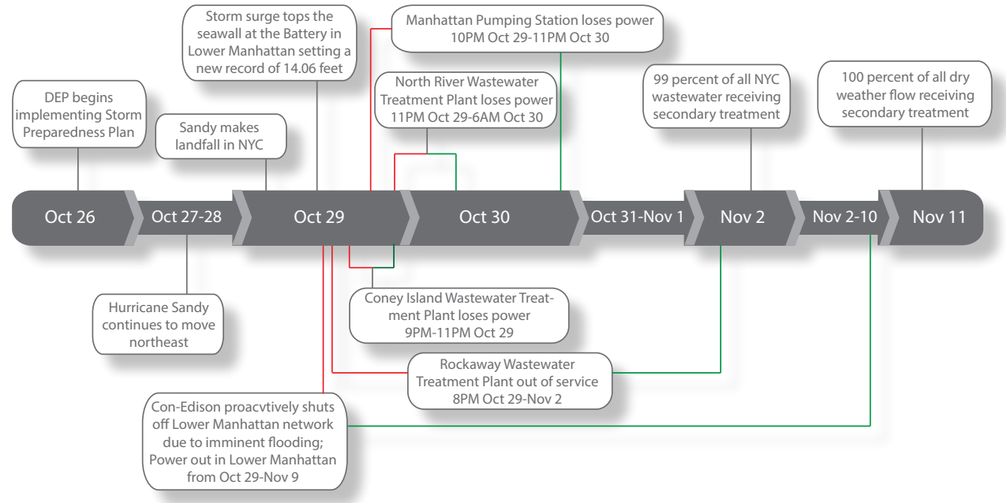
The surge also provided DEP with a unique and unprecedented example of risks at its wastewater facilities. To improve protection and response in the future, staff rigorously documented flood depths, providing valuable information regarding the impacts of flooding on site.

Of particular note, most of the damage experienced during Sandy was to electrical equipment that supplies power throughout the plants. Failure of this electrical equipment endangered many treatment processes. Fortunately, DEP implemented its Storm Preparedness Plan in advance so most facilities were able to retain some degree of power and operation using emergency generators. Only three facilities were non-operational as a result of the storm: Coney Island (two hours), North River (seven hours), and Rockaway (three days, although basic disinfection processes continued during this time). Many of the other plants experienced varying levels of flood damage to equipment and were forced to operate on their emergency generators for up to two weeks due to utility power outages.

Damage caused to wastewater infrastructure led to environmental impacts on surrounding waters. Partly due to power outages and plant inundation, and partly due to a large influx of floodwater into the sewer system, DEP reported that approximately 562 million gallons of untreated and diluted sewage that was mixed with stormwater and seawater was released into local waterways. The majority of this combined sewage overflow originated from the areas served by the Tallman Island, North River, Newtown Creek, Coney Island, and Rockaway plants. Advanced (secondary) treatment was also reduced at the Port Richmond, Oakwood Beach, Rockaway, Coney Island, and 26th Ward Wastewater Treatment Plants; however these plants were able to continue basic (primary) treatment to meet their permit requirements for pollutant removal.

Overall, given the severity of the storm, recovery was fairly quick. Just four days after the storm, DEP was treating 99 percent of all New York City wastewater; within two weeks, DEP had restored full treatment at all plants. DEP also enacted a number of emergency preparedness and response plans prior to the storm to protect its facilities, without which damage costs would have been much higher.

Timeline of Hurricane Sandy Impacts and Recovery



Out of the 96 pumping stations, 42 were affected by Sandy, with approximately half failing due to damage from floodwaters, the other half due to loss of power supply. Electrical equipment and power supply were found to be the systems at risk. Many of the pumping stations had to employ backup emergency generators during the surge. In addition, in some cases the main sewage pump motors were flooded which prevented the transfer of wastewater and stormwater.

DEP immediately put into action many of the lessons learned from Hurricane Sandy. At two facilities already in the midst of upgrades — the Manhattan Pumping Station and the Gowanus Pumping Station — a number of resiliency measures are being incorporated to address the risks identified during the storm. DEP is committing the time and money to include resiliency upgrades into these planned improvement projects, since combining upgrades is often less costly than performing them separately.

Hurricane Sandy provided an unprecedented example of flood risks at wastewater facilities.

Area Near the Rockaway Wastewater Treatment Plant

Pre-Hurricane Sandy (May 2008)
Source: NOAA

Post-Hurricane Sandy (November 2011)
Source: NOAA

The Rockaways experienced significant damage due to wave action during Hurricane Sandy. Waves swept away significant portions of beaches and inundated and battered homes and the nearby Rockaway Wastewater Treatment Plant. This facility and the surrounding community were amongst the hardest hit during Sandy's surge.

ELECTRICAL FEED AT OAKWOOD BEACH WASTEWATER TREATMENT PLANT

Climate Framework

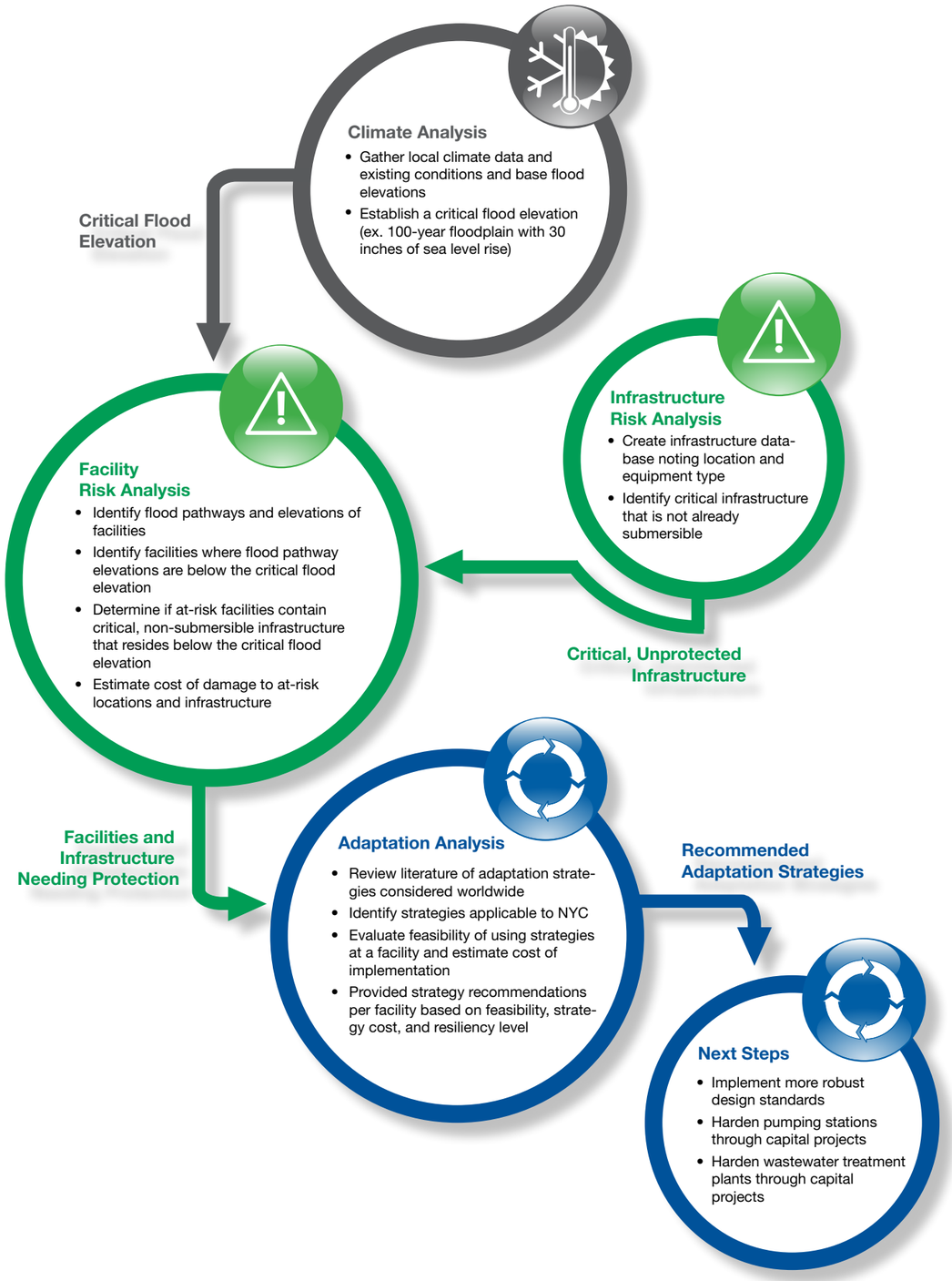
The *NYC Wastewater Resiliency Plan* used a unique framework to assess flood risk and identify appropriate protective measures. This framework can be applied as a prototype to protect a wide range of vital City infrastructure beyond wastewater facilities. As shown in the adjacent flowchart, the framework is comprised of three major modules:

CLIMATE ANALYSIS: What is NYC's climate likely to be in the future, especially in terms of storm surge and sea level rise? What conditions should NYC prepare for?
While climate science cannot predict when a surge will occur, current climate studies project that large surge events are likely to become more frequent in the future and will be exacerbated by sea level rise. The FEMA 100-year flood event was selected as the maximum surge assessed in this study. An additional 30 inches of flooding were also added to account for future sea level rise by the 2050s, the high end of the projections from the New York City Panel on Climate Change.

RISK ANALYSIS: Which infrastructure will be affected in flood events?
Potential risks at each facility were identified through site visits, analysis of facility blueprints, and interviews with facility personnel. Information about conditions during Hurricane Sandy also helped pinpoint specific risks and operational challenges. The elevations of flood pathways and infrastructure were then compared to the flood elevation defined in the Climate Analysis to determine which infrastructure is potentially at risk. Cost estimates for the replacement of at-risk equipment under emergency conditions, cleaning of facilities, and temporary power and pumping were developed, and then used as a metric to inform the prioritization of risks.

ADAPTATION ANALYSIS: What can be done to protect at-risk infrastructure from surges and how much will this cost?
DEP performed an extensive literature review of strategies being considered around the globe to protect against climate change and narrowed the list down to six measures that would work best for NYC's wastewater infrastructure. These protective measures were then evaluated for use at each wastewater facility. Strategy recommendations were made based on feasibility, effectiveness, and cost.

Climate Risk Assessment and Adaptation Framework



ELEVATED CONTROL PANELS AT 26TH WARD WASTEWATER TREATMENT PLANT

Adopt Resilient Design Standards

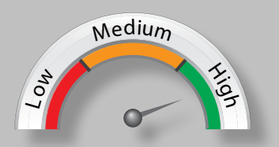
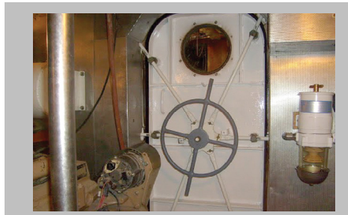
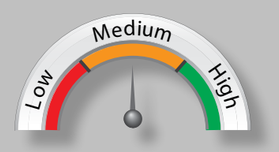
To increase the resiliency of wastewater treatment facilities against elevated flood levels, DEP is rapidly enacting a range of initiatives to implement the recommendations developed in the Climate Risk Assessment and Adaptation Study. One of these initiatives is to adopt new wastewater facility design standards that incorporate more robust measures than were formerly required.

Previous wastewater facility designs typically provided protection against the highest historically-recorded water height of nearby water bodies. However, with the new surge records set by Sandy and projected future sea level rise, the new design standards will account for the critical flood elevation used in the study: the FEMA 100-year flood elevation plus 30 inches of sea level rise.

To address the need for more robust protection, the design standard will incorporate appropriate protective strategies that were identified in the study as being highly effective for the site conditions of New York City's wastewater infrastructure. The portfolio of possible adaptation strategies includes six primary options, as follows: elevating equipment above the critical flood elevation, making pumps submersible and encasing electrical equipment in watertight casings, constructing a static barrier around a location, sealing structures with watertight windows and doors, sandbagging temporarily, and where feasible, providing backup power generation to pumping stations (treatment plants are already so equipped). Although these strategies may not necessarily keep the facility fully operational during a large storm event, the primary goal is to protect equipment from flood damage and reduce the time needed to return to normal operations following a flood event.

The new design standard will account for the critical flood elevation of the FEMA 100-year flood elevation plus 30 inches of sea level rise.

Each strategy has associated advantages and disadvantages relating to strategy effectiveness, cost, and complexity. For example, the higher the resiliency of the measure, the more thoroughly the strategy protects the facility during a flood event and the more risk the strategy can help avoid. However, strategies with higher resiliency are often more costly to implement. While the six strategies were all analyzed in the study and recommendations made for each wastewater facility, through the design standard, planners and designers will have the option to choose which strategy is implemented at a facility based on funding availability and more detailed site-specific analyses.

Adaptation Strategy		Resiliency/Effectiveness	Cost
	Elevate Equipment on pads or platforms, to a higher floor, to the roof, or to a new elevated building.		$$$$
	Flood-Proof Equipment by replacing pumps with submersible pumps and installing watertight boxes around electrical equipment		$$$
	Install Static Barrier across critical flood pathways or around critical areas.		$$$
	**Seal Building** with water-tight doors and windows, elevating vents and secondary entrances for access during a flood event.		$$
	Sandbag Temporarily around doorways, vents, and windows before a surge event.		$
	Install Backup Power via generators nearby or a plug for a portable generator.	Does not protect equipment, but ensures rapid service recovery	$$$

The adaptation strategies identified in this study were narrowed down from a comprehensive literature review of climate resiliency measures being implemented or considered in various locations around the world. These strategies will be incorporated into wastewater facility design moving forward to ensure more resilient plants and pumping stations.

CANNON STREET PUMPING STATION

Harden Pumping Stations

As part of capital projects and subject to available funding, DEP will design and implement resiliency projects at the 58 pumping stations that are vulnerable to storm surge damage from a 100-year flood with 30 inches of sea level rise.

These pumping stations are situated across the five boroughs and vary greatly in their configurations. Some are located entirely underground, some have above ground structures, some are under streets and sidewalks, and others are in parks. Despite their diverse characteristics, the 58 pumping stations tend to have similar risks. The most common flood pathways were doorways, hatches, and pipe penetrations leading to areas containing electrical equipment and pump motors, which Hurricane Sandy showed were especially vulnerable. It is critical that these facilities be protected since at-risk pumping station infrastructure is valued at approximately $220 million.

Recommendations for resiliency improvements were made in close consultation with DEP's operating bureaus and predominately involve making pumps submersible and elevating electrical equipment on platforms or to higher floors, new buildings, and nearby roofs. Depending on space constraints, backup power generators or plugs to connect to portable generators were also frequently recommended to ensure rapid recovery in restoring service. The recommended strategies, which would cost a total of $128 million to implement, were specifically selected to protect equipment from flood damage and increase the likelihood of continued pumping during or immediately following a flood event.

Implementing $128 million in capital improvements at pumping stations would reduce equipment failures and potential damage by more than $700 million over the next 50 years.

While the implementation cost is steep, investing in resiliency measures at particularly low-lying pumping stations will protect them not just in a large flood, but also from less severe storms when flooding may occur.

Pumping Station Configurations

Avenue M: Under the sidewalk

37th Avenue: Under a park

40th Road: Small Building

Arlene Street: Above ground, no building

Bayswater Avenue: On a pier

Bush Terminal: Large building with outdoor equipment

New York's pumping stations vary greatly in size, configuration, and site characteristics. While their risks tend to be consistent, implementation of adaptive measures may vary depending on site specific constraints.

Pumping Stations At-Risk of Storm Surge Inundation

Source: FEMA; CUNY Institute for Sustainable Cities

The total value of risk avoided over 50 years if protective measures are implemented for all 58 pumping stations is $709 million, multiple times the total value of infrastructure that is at risk ($220 million). Although it is not likely that all at-risk equipment and facilities would be affected at once in a single storm event, the value of at-risk equipment is twice the total cost of implementing the recommended strategies ($128 million), lending strong economic support for implementation. Considering pumping stations also provide a critical service of transporting sewage and stormwater from homes, businesses, hospitals, and other facilities, implementing the recommended strategies makes sense both from an operational basis and from an economic basis.

Prioritizing pumping stations for capital improvements is an important aspect of planning since the required economic funding needs are greater than the available resources. In order to aid prioritization, a number of criteria were applied including operational, environmental, social and financial metrics. These metrics included historical flooding frequency at each pumping station, proximity to beaches and sensitive water bodies, population served, number of critical facilities served (e.g. hospitals, nursing homes, fire and police stations, etc.), and whether the particular pumping station is scheduled for improvements in DEP's 10-year capital plan. Based on the multiple criteria, the top 5 priority pumping stations are currently the Van Brunt, Howard Beach, Throgs Neck, Nautilus Creek, and 40th Road pumping stations.

DEP will upgrade pumping stations based on level of risk at the facility, level of service to the community, and whether the facility has other planned capital improvements.

Pumping Station Estimated Cost

Pumping Stations	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]
122nd Street	$0.28	$1.85	$0.62
15th Avenue	$2.66	$3.51	$1.00
19th Street	$0.30	$3.66	$1.43
24th Avenue	$1.48	$5.03	$15.75
2nd Avenue	$1.91	$1.32	$6.78
37th Avenue	$0.06	$3.51	$3.85
40th Road	$0.51	$1.77	$8.32
49th Street	$2.87	$2.12	$10.91
6th Road	$2.87	$1.37	$6.77
Avenue M	$1.07	$3.84	$19.75
Avenue U	$2.60	$3.70	$19.04
Bayswater Avenue	$0.17	$1.14	$5.29
Borden Avenue	$1.94	$3.24	$15.22
Broad Channel	$2.40	$2.34	$12.03
Bush Terminal	$0.59	$3.47	$17.84
Canal Street	$2.42	$2.71	$13.33
Cannon Avenue	$1.43	$4.39	$20.46
Clearview	$4.71	$7.82	$16.80
Commerce Avenue	$0.63	$1.04	$5.34
Conner Street	$5.46	$6.57	$32.13
Co-op City North	$0.35	$3.70	$3.26
Douglaston Bay	$7.39	$1.80	$9.26
Eltingville	$0.59	$9.51	$5.44
Ely Avenue	$0.47	$2.02	$3.58
Flushing Bridge	$1.26	$1.74	$8.51
Gildersleeve Avenue	$0.89	$1.14	$3.97
Hannah Street	$1.37	$12.80	$63.24
Hollers Avenue	$2.48	$2.82	$14.53
Howard Beach	$8.16	$17.44	$20.65
Hunts Point Market	$0.73	$1.86	$5.65
Kane Street	$4.80	$6.23	$11.93
Linden Place	$1.15	$4.03	$4.41
Marble Hill	$0.62	$3.38	$15.67
Mason Avenue	$0.55	$3.37	$15.60
Mayflower Avenue	$0.04	$6.50	$28.43
Melvin Avenue	$2.54	$1.78	$9.14
Nautilus Court	$2.42	$3.28	$16.85
Nevins Street	$1.09	$1.31	$6.75
New York Times	$5.56	$1.99	$10.23
Old Douglaston	$0.74	$4.07	$20.95
Orchard Beach	$0.66	$1.15	$3.05
Paerdegat	$16.96	$15.41	$19.21
Richmond Hill Road	$0.01	$5.49	$1.20
Rikers Island North	$2.87	$3.14	$6.35
Roosevelt Island Main	$0.27	$3.02	$0.70
Roosevelt Island North	$2.54	$1.66	$8.56
Roosevelt Island South	$0.66	$1.66	$0.51
Rosedale	$9.94	$5.22	$26.84
Sapphire Street	$0.80	$3.70	$19.04
Seagirt Avenue	$2.30	$4.23	$21.75
South Beach	$0.29	$2.36	$10.93
Throgs Neck	$5.92	$10.67	$53.00
Van Brunt Street	$2.74	$0.93	$4.79
Victory Boulevard	$0.88	$1.85	$9.52
Warnerville	$0.88	$1.14	$5.87
Zerega Avenue	$0.66	$1.28	$6.60
Total	**$128 M**	**$218 M**	**$709 M**

Notes: Avenue V and Gowanus Pumping Stations are considered at-risk, but are already undergoing extensive protective upgrades and are not considered in this cost estimate.
1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Harden Wastewater Treatment Plants

The city's wastewater treatment plants are large facilities spanning multiple elevations and flood zones, as seen at the Bowery Bay Wastewater Treatment Plant to the right. The plants also contain thousands of pieces of equipment, including pumps, motors, electrical power equipment, mechanical equipment, instrumentation, and controls. The facilities are also highly complex, with multiple buildings, tanks, and outdoor areas interconnected by tunnels, pipe work, and electrical conduits.

A site-specific analysis of each plant was required to ensure the nuances and layouts were adequately assessed. Each plant was visited to determine flood pathways and at-risk equipment. Common pathways documented were doorways, windows, vents, basement access ways, tunnels, and buried electrical conduits. These electrical conduits crisscross the plants and represent a significant risk as waterproofing sealant on conduits is difficult to maintain and monitor over time.

In total, infrastructure valued at $901 million is at risk at the City's wastewater treatment plants. While all 14 wastewater treatment plants are at risk from the 100-year flood with 30 inches of sea level rise, not all will be affected to the same degree. For example, the Jamaica

Infrastructure valued over $900 million is at risk in a large flood event, making these facilities prime targets for resiliency upgrades.

Wastewater Treatment Plant is located on relatively higher ground. Only one large piece of electrical equipment is at risk. This risk was already known to staff, who regularly sandbag around the infrastructure.

In contrast, the Rockaway Wastewater Treatment Plant was devastated during Hurricane Sandy and would be under more than 6 feet of water in a 100-year flood with 30 inches of sea level rise. This plant is also very close to the ocean, and could experience severe structural damage due to pounding waves. Low-lying plants such as the Rockaway Wastewater Treatment Plant can expect resiliency measures to provide protection in small and large flood events, making the case for adaptation strong even at higher costs.

FEMA Flood Zones at Bowery Bay Wastewater Treatment Plant

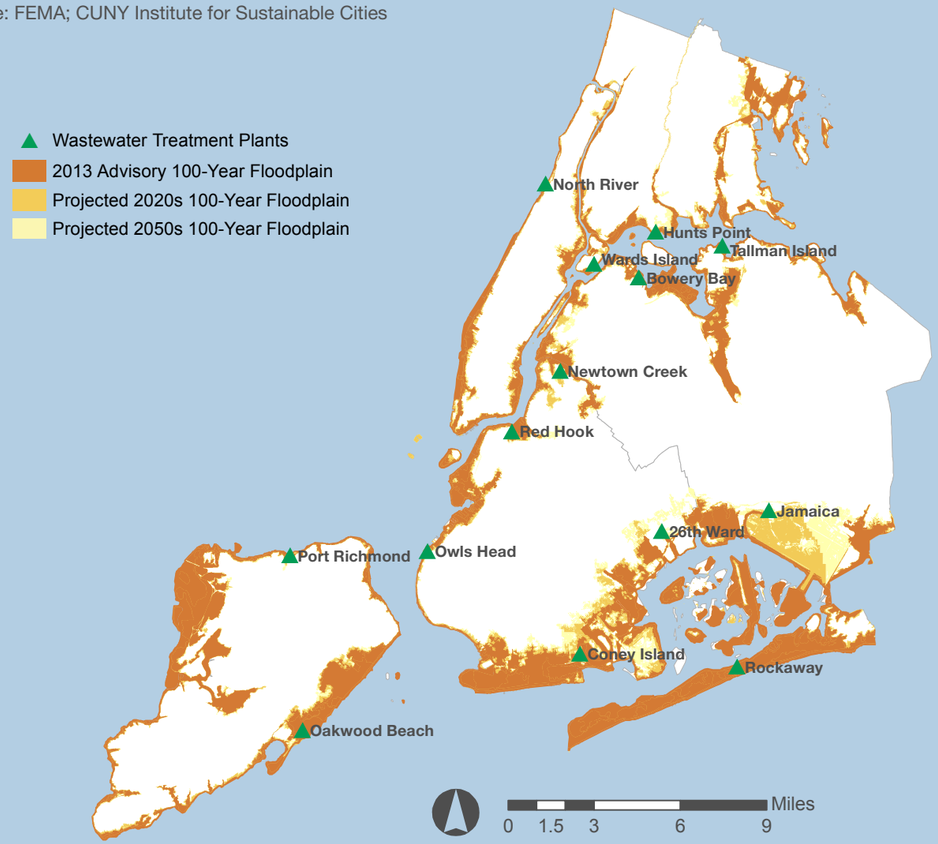
An aerial image of Bowery Bay Wastewater Treatment Plant is shown with the 2013 Advisory FEMA flood map and sea level rise projections overlaid. During the study, these maps provided flood elevation information which was then compared to the elevations of doorways, windows, and other flood pathways at the plant to see what areas and equipment would be vulnerable to flood damage.

Potential Flood Pathways

Doorways and windows are easy to identify as flood pathways. However, understanding the often complex system of underground tunnels, pipes, and electrical conduits at wastewater treatment plants is much more difficult and requires the use of facility blueprints.

Wastewater Treatment Plants At-Risk of Storm Surge Inundation

Source: FEMA; CUNY Institute for Sustainable Cities



As with pumping stations, the total potential damage to the wastewater treatment plants is extremely high and warrants protection. The study associated and tailored strategies to each facility based on preliminary site feasibility assessments and a comprehensive cost-risk analysis. This quantitative assessment accounts for the cost to implement each strategy and the amount of risk each strategy could mitigate. For equipment that is critical to meeting a minimum required level of service by state law, strategies with high resiliency were selected to promote continuous service. For other equipment, recommended strategies provide a balance of resiliency and a good return on investment.

The study also identified a number of additional resiliency measures that are under consideration for implementation at wastewater treatment plants. These include:

- Upgrading and retrofitting the plant generation systems to incorporate new technologies that allow for digester gas reuse and use as a backup power source during a flood event.
- Establishing safe houses for staff during the storm with backup power and supplies.
- Having electrical and mechanical contractors ready for immediate repairs following a flood event.

Quick references such as storm surge impact charts were also developed from this study, and will be distributed to plant operators to better inform emergency efforts before a surge event.

Wastewater Treatment Plant Estimated Cost

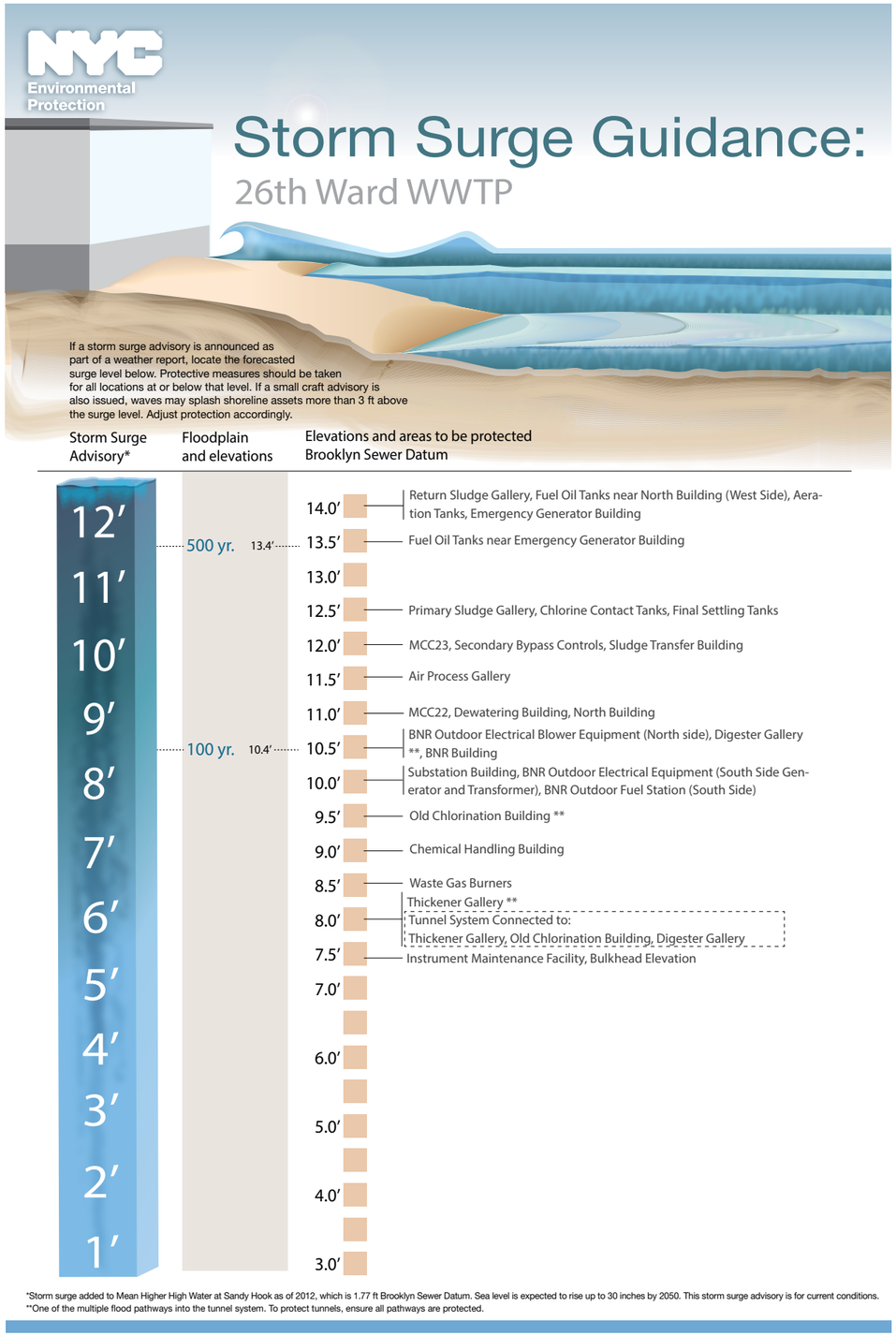
Wastewater Treatment Plant	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]
Wastewater Treatment Plants with Greatest Potential for Affecting Beaches			
26th Ward	$8.18	$82.42	$79.45
Coney Island	$15.48	$84.95	$349.81
Hunts Point	$24.28	$201.36	$246.44
Jamaica	$0.21	$1.70	$0.46
Oakwood Beach	$5.33	$20.97	$44.28
Rockaway	$15.12	$49.28	$198.10
Subtotal	**$68.61**	**$440.67**	**$918.55**
All Other Wastewater Treatment Plants			
Bowery Bay	$40.26	$112.60	$69.03
Newtown Creek	$8.85	$28.79	$9.13
North River	$17.15	$94.10	$445.79
Owls Head	$11.01	$48.41	$158.81
Port Richmond	$10.39	$54.85	$60.36
Red Hook	$18.56	$67.38	$24.95
Tallman Island	$11.02	$45.18	$32.80
Wards Island	$1.48	$8.73	$40.46
Subtotal	**$118.74**	**$460.04**	**$841.32**
Wastewater Treatment Plants Citywide	**$187 M**	**$901 M**	**$1,760 M**

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

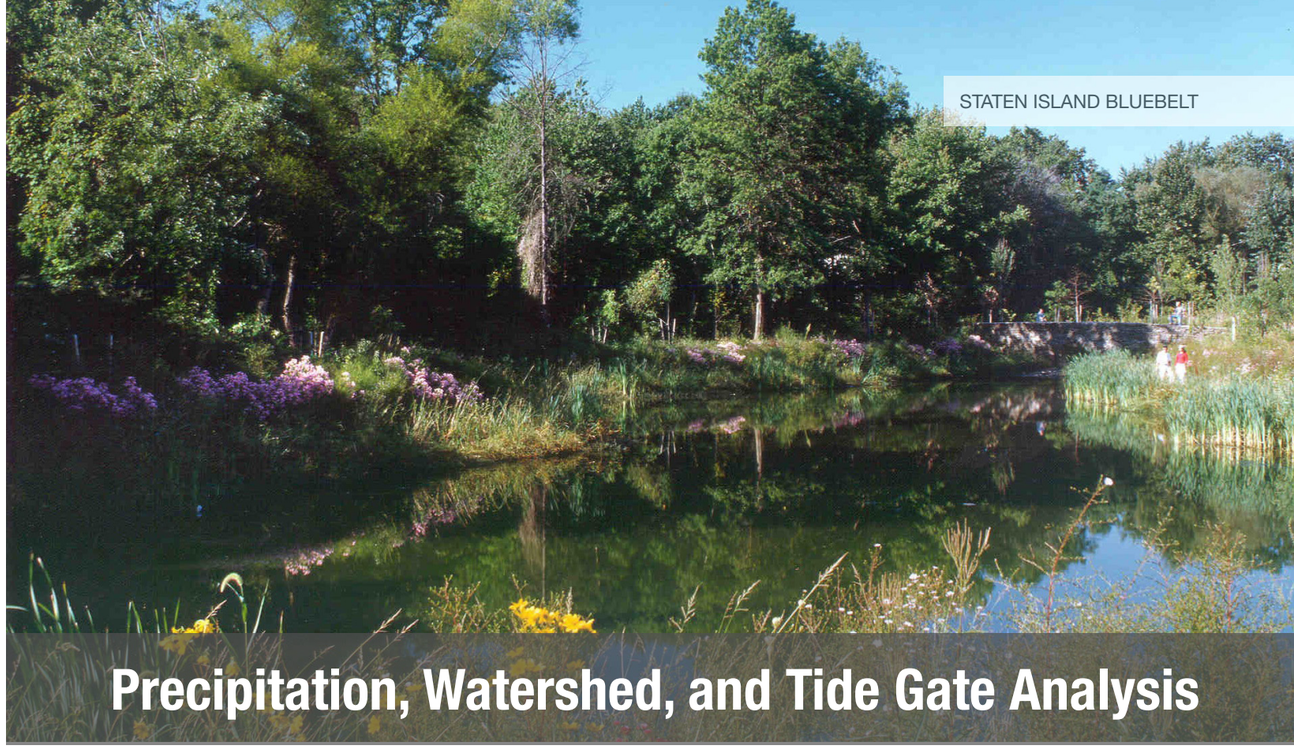
DEP plans to start protecting wastewater treatment facilities by implementing the six adaptation measures (presented in the Adopt New Design Standards section) as part of repairs and other planned capital improvements. As facilities are upgraded, the recommendations made through this study will be reassessed with detailed site analyses, and may be modified within the context of other capital improvements being made.

Timing with other capital improvements is especially important for resiliency upgrades, as the cost of implementing protective measures with other upgrades and at the end of equipment life spans often significantly reduces capital cost and may provide additional opportunities for improvement. Since water quality in New York City's waterways is vital to environmental and public health, DEP has also selected wastewater treatment plants that can affect bathing beaches as high priority for implementing protective measures. These plants include 26th Ward, Coney Island, Hunts Point, Jamaica, Oakwood Beach, and Rockaway.

In all, investing $187 million in a strategic mix of protective measures could improve resiliency at New York City's wastewater treatment plants and reduce risk by almost 85 percent. The damage costs avoided over 50 years from flood events, up to and including projected 100-year storms with 30 inches of sea level rise, is an estimated $1.76 billion. These estimates provide strong support for implementing protective measures as they will likely save the City more money as compared to the cost of repairs and disaster relief over time.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.



Precipitation, Watershed, and Tide Gate Analysis

DEP manages drainage system infrastructure with many elements that will last longer than 100 years, and must make sensible long-term plans that account for anticipated changes beyond its control. Among these important changes are rising sea level, increased population, elevated surface temperatures, and the possibility of more intense precipitation patterns. These factors could have an impact on wastewater treatment processes, the frequency of combined sewer overflow (CSO) events, and flooding on local streets. This study focused on the anticipated changes in rainfall and sea level from projected climate change, and assessed the alternatives available to mitigate these impacts.

This study included three phases:

- Phase 1: *Precipitation Analysis*
  Rainfall statistics are critical for design standards for city drainage systems; the goal of Phase 1 was to assess whether there have been changes to the rainfall intensity, duration, and frequency statistics, or IDF curves, that are used for sewer design. The study examined a longer, more complete rainfall dataset than has been used in the past to produce the revised IDF curves and to revisit the 'typical rainfall year' that is modeled for DEP's CSO Long-Term Control Plan (LTCP).
- Phase 2: *Watershed Analysis*
  In this phase of the analysis, a representative drainage area was assessed using hydraulic and hydrologic simulation models developed for the LTCP. These models were used to assess the potential impact of changes in sea level and precipitation on the performance of the drainage system, with particular attention on changes to CSO frequency and street flooding. Finally, the models were used to estimate the possible benefits of implementing combinations of green and grey infrastructure alternatives.
- Phase 3: *Tide Gate Analysis*
  The final phase of the study assessed the effectiveness, costs, and benefits of installing tide gates at stormwater outfalls to prevent storm surge inundation in adjacent communities.

Precipitation Analysis

Most of the city is served by a combined sewer system, and drainage pipes are large enough to carry both stormwater and sanitary flow for the majority of precipitation events. During dry weather, the pipes have ample capacity. This study sought to understand if there have been statistically relevant changes to wet weather patterns in New York City, and included an update of regional precipitation statistics to include an additional 50 years of data beyond the previous record.

The study determined that, although there have been some notable extreme events in recent years, the complete record shows no statistically significant trend towards more intense rainfall events over the longer historical record. IDF curves, one of the most common and useful tools for sewer design, were reassessed using historical rainfall data which revealed that the intensities for a storm with a 5-year return period are not significantly different between the current and updated IDF curves for durations (or travel time) up to 100 minutes. In other words, for durations relevant to sewer design, the expanded, more recent data record revealed no discernible trend toward more intense rainfall.

The relevance of this finding for DEP's current sewer design standards is that current drainage planning tools (IDF curves) remain suitable for design. However, to recognize any emerging trends in precipitation intensity due to future climate change, 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 any material emerging trends, DEP will assess implications for the sizing of stormwater detention systems, sewer site connections, and green infrastructure, as appropriate.

Historical rainfall data analysis did, however, result in a change in the 'typical year' to represent average annual conditions for LTCP modeling. Data from JFK Airport in 2008 is now used to represent the 'typical' rainfall year and will be used for modeling the efficacy of projects to reduce CSOs. Furthermore, to account for more extreme years that may become the norm in the future with climate change, the historical time series used for LTCP modeling has been expanded to ten years--including 2005 and 2006, which most closely fit the projections for future precipitation. The incorporation of additional years will be used to test the robustness of various CSO mitigation approaches under a range of average and extreme conditions.

Watershed Analysis

Watershed analysis is an integral component of DEP's planning for water quality projects to reduce the effects of CSOs, and is based on a simulation of the actual urban environment that considers how the system responds to precipitation events and fluctuations in tides. The Flushing Bay watershed was chosen as a sample case study because it is representative of the city as a whole in a number of critical ways, and therefore feasible adaptation strategies developed for this watershed may be applicable citywide.

The analysis showed that CSO discharges and local flooding would likely increase under future climate conditions in response to potential increases in precipitation volume and intensity. Overall annual rainfall volume is the most important driver of increased CSO volume and potential effects on water quality. A detailed analysis of various solutions to address increased local flooding and CSO events showed that a combination of green infrastructure and grey infrastructure has the greatest benefit, but that adaptation strategies must be evaluated and implemented on a site-by-site basis in order to confirm feasibility, and compared on a cost-benefit basis with other proposed projects.

Already, DEP is implementing an ambitious Green Infrastructure Plan to build green infrastructure citywide to reduce CSO events. Continuing to implement the PlaNYC goal for green infrastructure is an important element of a strategy to adapt to climate change. Used in combination with cost-effective grey infrastructure practices, such as high-level storm sewers, these strategies will help to ensure that the city's wastewater system continues to provide a high level of service to the public and the environment, now and in the future.

Tide Gate Analysis

Tide gates prevent salt water from entering the combined sewer system and disrupting operations at wastewater treatment plants. Discharge points for stormwater pipes, however, are only occasionally fitted with tide gates. This portion of the study sought to determine where additional tide gates might improve the functioning of the system during a storm surge event. A preliminary, static analysis was performed to determine the viability and impacts of tide gate installations at 211 DEP-owned stormwater outfalls in New York City.

The screening analysis looked at the local topography of the community upstream of each associated outfall and compared it to the elevations of typical tidal events to see whether the installation of a tide gate would provide flood protection. The results varied and are highly dependent on the engineering of the sewers in each area. It demonstrated that tide gates must be analyzed on a case-by-case basis at each outfall to examine the hydraulics of the local drainage system, the surrounding topography of the community, and the typical tidal elevation along the associated shoreline. In some cases, tide gates would yield benefits, but it would not be cost-effective or provide effective flood mitigation to install tide gates at every outfall in the city, adding costs for maintenance and replacements, and in some cases, potentially exacerbating flooding conditions.

Moving Forward

The *NYC Wastewater Resiliency Plan* was a tremendous effort, with vital data sharing and intensive discussion between operators, risk analysts, climate specialists, and policy makers. The study greatly improved understanding of wastewater infrastructure risks and resulted in identification of a portfolio of robust adaptation strategies that will be incorporated in DEP design standards and capital planning. DEP has also established resources and institutional programs to help staff members understand the risks of climate change and continue to improve resiliency.

This study, therefore, does not mark the end of climate resiliency efforts at DEP. As New York City's climate continues to change, DEP is ready and committed to continue risk evaluations and pursue resiliency upgrades, not only in wastewater, but also for stormwater management, ecosystems management, and drinking water supply, as described in the report from Mayor's Special Initiative for Rebuilding and Resiliency. With a combination of hardened infrastructure and better emergency response, DEP is well positioned to better protect the City's water infrastructure and waterways on multiple fronts, and is committed to continue serving the public to create a stronger and more resilient New York City.

Additional Information

In addition to this document, DEP has developed a number of detailed public reports regarding the citywide risk framework and climate analyses used in this study, as well as facility-specific documents which serve as a valuable resource regarding lessons learned from Sandy and site-specific recommended adaptation strategies. Please see subsequent chapters for further details.

RESIDUALS HANDLING FACILITY, WARDS ISLAND WASTEWATER TREATMENT PLANT, MANHATTAN, NY

CHAPTER 1: CITYWIDE FRAMEWORK

WARDS ISLAND WASTEWATER TREATMENT PLANT, MANHATTAN, NY

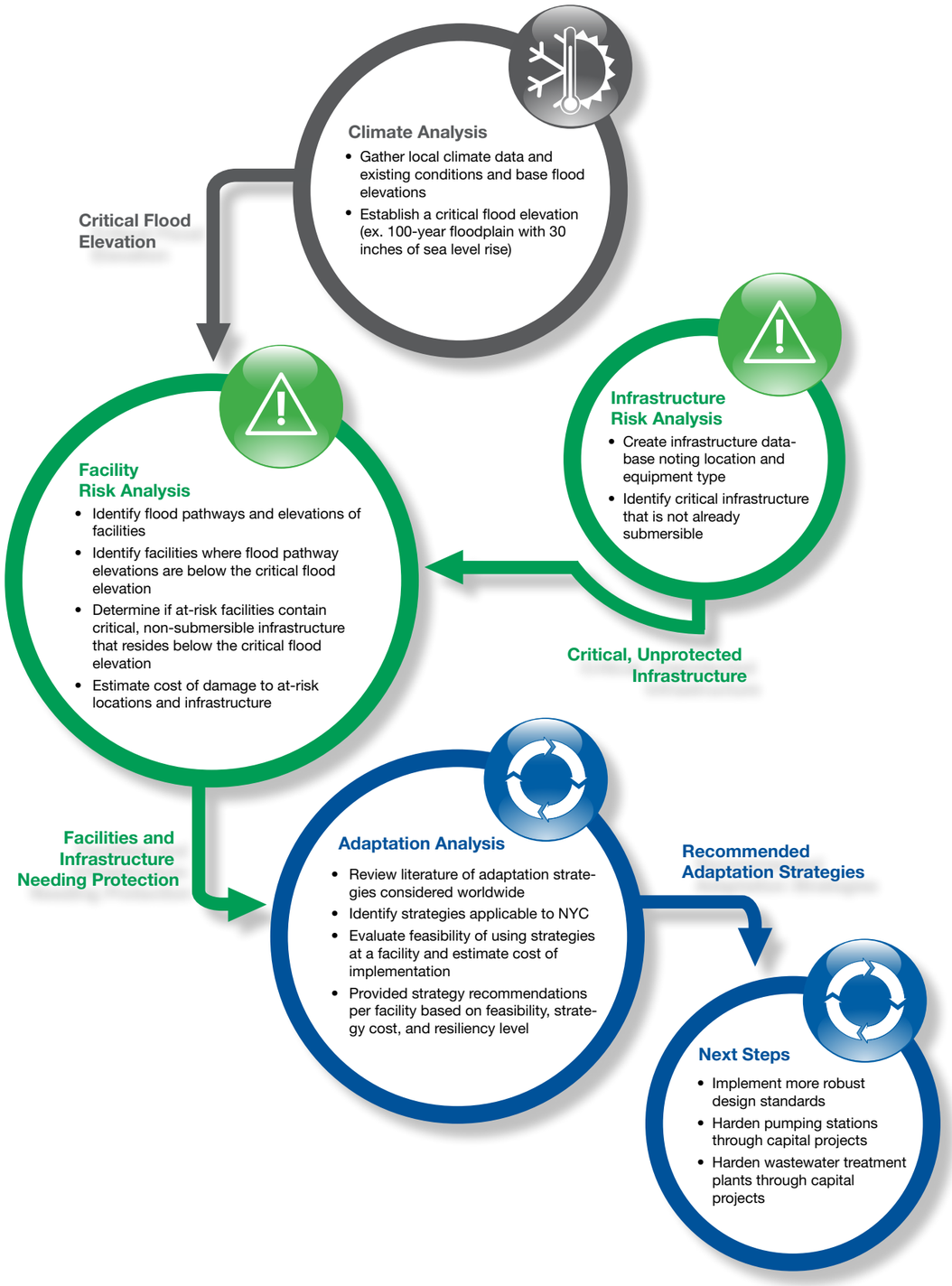
Citywide Framework

The Climate Risk Assessment and Adaptation Study was developed as a planning level framework to assess the flood risk posed to wastewater infrastructure and to provide adaptation recommendations based on site feasibility and cost-benefit evaluation. This approach evaluates the cost of adaptation strategies against the value of risk avoided after strategy implementation.

The study yielded insight into the risk of DEP's wastewater infrastructure to flood damage, documented lessons learned from Hurricane Sandy, and provides a valuable framework that may be used as a prototype to protect a wide range of vital city infrastructure in New York and around the world.

The Citywide Resiliency Framework is summarized as a flowchart in Figure 1, and comprises three main analyses: 1) Climate Analysis, 2) Risk Analysis, and 3) Adaptation Analysis. These analyses build upon each other and are described in further detail in subsequent sections.

Figure 1: Climate Risk Assessment and Adaptation Framework



Climate Analysis

While climate science cannot predict when a storm surge will occur, current climate studies project that future storm surge events are likely to be exacerbated by sea level rise. The climate analysis in this study established the future storm surge conditions for which DEP should plan and prepare.

The March 2013 FEMA 100-year advisory base flood elevation (ABFE) plus an additional 30 inches for sea level rise was selected as the "critical flood elevation" against which DEP infrastructure would be assessed. This flood elevation was obtained for each wastewater facility location from online FEMA ABFE maps which provide flood levels accounting for specific local conditions, such as topography.

The 2013 ABFE maps were developed by FEMA to guide rebuilding efforts after Hurricane Sandy and were the most current flood elevations available at the time of the analysis. The ABFEs were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. The critical flood elevations in the updated maps are in most cases very similar to the ABFE maps, and are more conservative than the PWM elevations, and therefore more protective. Using the updated maps would not significantly affect the results of this analysis.

The additional 30 inches added to the ABFEs approximates future sea level rise in the 2050s, as projected by the New York City Panel on Climate Change. As shown in Table 1, 30 inches represents a high estimate of sea level rise[2]. The year 2050 was chosen to evaluate future conditions in the study in order to be consistent with DEP capital planning programs. Using a higher estimate for the analysis provides for more conservative design standards that will better protect wastewater infrastructure from future storm surge conditions.

Table 1: NPCC 2013 Climate Projections

Chronic Hazards	Baseline (1971-2000)	2020s		2050s	
		Middle Range (25th - 75th percentile)	High End (90th percentile)	Middle Range (25th - 75th percentile)	High End (90th percentile)
Average Temperature	54 ºF	+2.0 to 2.8 ºF	+3.2 ºF	+4.1 to 5.7 ºF	6.6 ºF
Precipitation	50.1 in.	+1 to 8%	+10%	+4 to 11%	+13
Sea Level Rise[1]	0	+4 to 8 in.	+11 in.	+11 to 24 in.	+31 in.

Source: NPCC; for more details, see *Climate Risk Information 2013.*

[1]Baseline period for sea level rise projections is 2000-2004.

[2]The New York City Panel on Climate Change issued its final report in 2013, with slight changes to the high end estimate for sea level rise. The change of 1 inch to the projections would not alter the recommendations of this study.

Risk Analysis

The Risk Analysis sought to determine which facilities and infrastructure would be at risk from the critical flood elevation (100-year ABFE plus 30 inches of sea level rise), and how much damage DEP could expect to incur.

A detailed analysis of potential flood-related risks at each facility was conducted by walking through the facilities, documenting flood pathways for different buildings and plant areas, and interviewing operational staff to determine which infrastructure had been frequently subject to flooding during the facilities' active history. Of particular value was evaluating what flooded during Hurricane Sandy, which helped paint a picture of how floodwater moves throughout the facilities and the operational challenges that flooding creates. The most common flood pathways identified on site included doorways, outfall pipes, bulkheads, windows, vents, conduits, and tunnel systems. The site visit was accompanied by an analysis of facility blueprints to determine the height of a surge that would inundate the various flood pathways identified once a threshold elevation was overtopped (the sill of a door for example, or, in the case of pumping stations, the ground elevation). If the threshold elevation fell below the critical flood elevation, the location was determined to be at risk of flood damage.

An extensive assessment was performed on critical infrastructure within at-risk locations to determine the value of damage DEP could expect to incur in a large surge event. Pumps, motors, electrical equipment and controls, and other equipment necessary to meet basic (primary) treatment levels were of particular interest due to the receiving waterbody impacts.

DEP has an infrastructure database that catalogs the thousands of pieces of wastewater equipment at each treatment plant and pumping station. This database was reviewed and supplemented with information from inspections and drawing review pertaining to location, equipment resiliency, and equipment elevation with respect to the critical flood elevation. Replacement and repair costs were also developed for at-risk infrastructure. Total damage cost estimates for each plant location and pumping station considered the cost of replacement for infrastructure, and the cost to clean up the site and provide temporary power and pumping services, if necessary.

ASSESSING WASTEWATER INFRASTRUCTURE USING TRIPLE BOTTOM LINE ANALYSIS

Flood damage not only comes in the form of needing to replace equipment and clean a site, but also includes damages from extended loss of service. New York City's pumping stations convey millions of gallons of sewage from homes, businesses, hospitals, and other important buildings to treatment facilities, ensuring sewage does not back up into basements, which could pose a health risk. Similarly, wastewater treatment plants provide an invaluable service by treating sewage to protect water quality in New York's waterways. Without the treatment plants running, sewage would degrade the environment and contaminate beaches.

Thus, flood damage not only presents an economic burden, but also has significant social and environmental costs. Considered together, all three of these costs provide a more holistic assessment of damage from flood surge and can guide adaptation decision-making more appropriately for a service-driven agency such as DEP. Because it considers financial, social, and environmental consequences, this relatively new method of assessment is called Triple Bottom Line Analysis.

Quantifying the value of social and environmental damages is much more challenging than developing the cost estimates for replacing damaged equipment. For example, how does one determine the cost of damage to water ecosystems from sewage, the loss of wildlife and plant matter, and the loss of recreational uses of these ecosystems? How can we quantify the cost of health impairments in New Yorkers exposed to sewage: the medication, the sick leave from work, and the stress that results?

Answering these questions with monetary value is complex. As such, during the Risk Analysis, the environmental and social costs of flood damage at each wastewater facility were analyzed from a qualitative perspective using various metrics. DEP anticipates using these metrics within the broader set of criteria to inform implementation schedules and prioritization of capital upgrades for wastewater infrastructure.

More specifically, since water quality in New York City's waterways is highly important to the environment and public health, during the study DEP looked at each wastewater treatment plant and determined what level of impact it might have on nearby bathing beaches. Those treatment plants that can heavily affect bathing beaches were deemed higher priority for adaptation measures.

Pumping stations were prioritized based on operational, environmental, social, and financial metrics. These metrics included historical flooding frequency, proximity to beaches and sensitive waterbodies, tributary area population, facility size, number of critical facilities (hospitals, schools, etc.) potentially affected by failure of the wastewater infrastructure, and whether the facility is scheduled for improvements in DEP's 10-year capital plan.

Adaptation Analysis

For the Adaptation Analysis, a number of adaptation strategies were selected through a broad literature review of strategies in use or being considered in municipalities around the world to harden infrastructure. The strategies that were determined to be most applicable to New York City wastewater facilities included sealing a building with watertight windows and doors, elevating equipment, making pumps submersible, encasing electrical equipment in watertight casings, constructing a static barrier across doors and other access ways, temporary sandbagging, and providing backup power generation to pumping stations where feasible (wastewater treatment plants are already equipped with backup power). The purpose of these strategies is to prevent damage during a flood event and to minimize the recovery time needed to reestablish normal operations. It was assumed that any strategy would need to be operated and maintained for 50 years.

Each strategy has advantages and disadvantages associated with cost, logistics of implementation, effectiveness, and failure potential. The failure potential is the probability that the strategy will fail during a flood event, as estimated from manufacturer details, site observations, and engineering judgment. The resiliency level and failure potential are directly related — the higher the resiliency level, the better the strategy for protecting infrastructure during a flood event and the lower the failure potential. Table 2 summarizes the resiliency level, failure potential, and explanation of the residual risk for the adaptation strategies considered in this study.

The failure potential was a key quantitative metric used to select a recommended strategy for each at-risk plant location and pumping station. The strategy recommendations were also based on feasibility, the importance of the infrastructure in a location, and a cost-risk analysis. Feasibility was established during the site visits, when it was easy to see whether certain strategies could be implemented given site specific configurations and conditions.

For locations containing important infrastructure needed for the plant to meet basic (primary) treatment requirements, the feasible strategy with the lowest failure potential was recommended. As a result, flood-proofing and elevating equipment were often recommended for these locations. For instances where all critical infrastructure could not be elevated or flood-proofed due to site or infrastructure constraints, a second strategy was recommended to block flood pathways into the at-risk location. As a result, in many cases the cost of protecting these primary locations was high since multiple strategies were recommended to increase redundancy; however, since the infrastructure being protected serves such a pivotal role in protecting the environment and public health, the non-monetary benefits (social and environmental) outweigh the monetary costs.

Strategy selection for locations which contained pumps, motors, and electrical equipment that are not essential to meeting basic permit requirements were required to be cost-effective. Strategy selection for these locations was therefore based on feasibility and return on investment. To determine which strategy was most cost-effective, the cost of implementing and maintaining any strategy was compared to the anticipated benefit of implementing that strategy in terms of the resulting damage that would be avoided. The anticipated value of damage avoided accounts for the resiliency level of the strategy and includes the value of at-risk infrastructure in the location as estimated in the Risk Analysis. Future storms and surges are associated with a probability of occurrence based on historical storms and the likelihood that any storm will occur during any given year. Naturally, the bigger the surge, the less likely it is to occur in any given year; thus, the 100-year flood has a 1 percent chance of occurring in any given year and a 2-year flood event has a 50 percent chance of occurring in any given year.

The anticipated value of damage avoided also depends on the elevation of the location and how frequently surges are likely to reach that elevation. Certain low-lying locations are more likely to be frequently flooded over 50 years, so anticipated damage may be multiple times the value of at-risk infrastructure (as it may need to be replaced several times). Likewise implementing an adaptation strategy at these locations can protect the equipment through multiple floods, so the anticipated damage avoided may be very high over 50 years. Given that the benefits are higher than the cost of implementation, the strategy would be recommended due to its good return on investment.

In contrast, locations at high elevations may only be affected by very large storms such as the 100-year flood, which tend to occur infrequently. If strategies are implemented at these locations, they may protect against a surge that may or may not occur in the next 50 years. Therefore, the expected risk avoided at such locations will be much lower. If the risk avoided is lower than the cost to implement the strategy, the adaptation measure will not have a good expected return on investment, and would not be recommended.

An understanding of expected damage avoided provides insight into why some locations do not warrant protection at this time. These locations were often at higher elevations that would not be flooded frequently, and often contained fewer pieces of equipment, that were typically not critical to meeting primary treatment requirements. Therefore, the cost to protect a building by sealing doors or constructing a barrier could not be justified economically for these locations.

Table 2: Adaptation Strategies

Strategy	Resiliency Level	Failure Potential	Explanation of Residual Risk
No Action	Level 0	100%	No protection
BUILDING LEVEL STRATEGIES			
Emergency Response (Sandbagging)	Level 1, 2	11% - 25%	Human element, may overtop
Seal Building or Control Room	Level 3	6% - 10%	May leak in from conduits; difficult to detect all leaks
Construct Barrier	Level 4	1% - 5%	Alternative flood pathways other than over the wall
ASSET LEVEL STRATEGIES			
Floodproof Equipment	Level 4	1% - 5%	May exceed rated pressure
Elevate Equipment	Level 5	< 1%	If elevated above critical flood height, only risk from larger storms and greater climate change
Provide Temporary Power Generation for Pumping Station	NA	NA	This measure does not protect the Pumping Station, but helps it to regain service following a surge

Programmatic Solutions

To ensure continued progress towards more resilient wastewater infrastructure, and to ensure that the resiliency concepts developed during this study are translated into feasible projects to harden facilities, DEP has established a number of programmatic steps which will be executed in the next few years.

- Maintain a portfolio of “shovel ready” projects that can be further developed when funding opportunities arise or when potentially at-risk assets are due for maintenance or replacement;
- Incorporate climate change and extreme weather considerations in risk assessment exercises designed to allocate funding and prioritize capital projects;
- Revise engineering design standards to accommodate anticipated increases in sea level and storm intensity;
- Include critical flood elevations in asset management databases; place storm surge guidance in visible locations within the wastewater treatment plants; and refine emergency response plans to improve disaster preparedness and recovery based on risk assessment and feedback from operating staff.

With the proper institutional mechanisms in place, DEP will be at the forefront of climate-resilient infrastructure planning, and will be able to make informed decisions about wastewater infrastructure upgrades and emergency response.

WARDS ISLAND WASTEWATER TREATMENT PLANT, MANHATTAN, NY

CHAPTER 2: WASTEWATER TREATMENT PLANTS

Introduction

The New York City Department of Environmental Protection (DEP) own and operates 14 wastewater treatment plants. These facilities are highly complex, with a number of different treatment processes that collectively remove between 85 and 95 percent of pollutants in the 1.3 billion gallons of wastewater generated in New York City each day. Treatment plants keep waterways and bathing beaches clean and are fundamental to protecting the environment and public health. As such, DEP is committed to ensuring their continued performance and reliability.

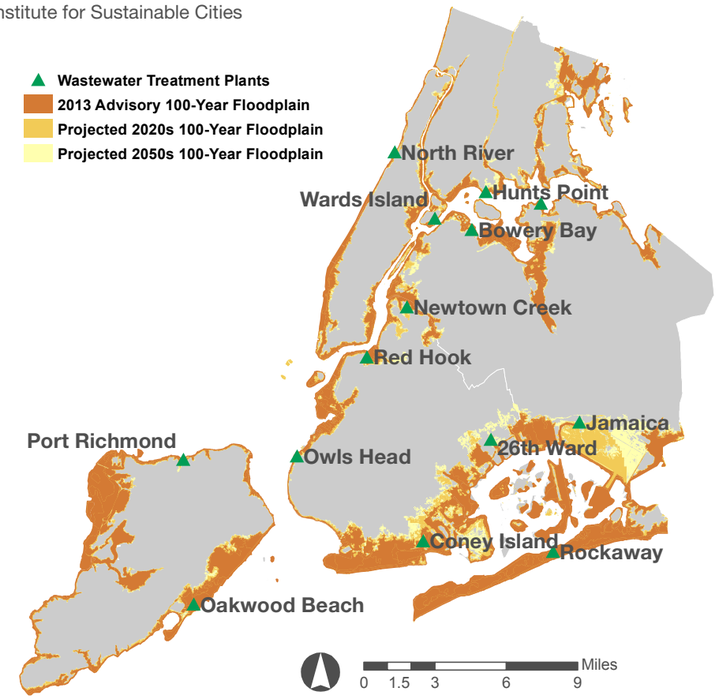
One of DEP's priorities in the coming years will be hardening its wastewater infrastructure to increase resiliency against flood damage. Many of the City's wastewater treatment plants are located within close proximity to the waterfront and are at risk from flooding, as was evident during Hurricane Sandy. Given that this risk is likely to increase over time with sea level rise, DEP performed the 2013 Climate Risk Assessment and Adaptation Study to identify treatment plant risks and protective measures which will reduce flood damage and the time needed to restore normal operating conditions following a flood event.

The study revealed that all 14 wastewater treatment plants are at risk of flood damage during the critical flood event (the 100-year flood plus 30 inches of sea level rise), totaling over $900 million of at-risk infrastructure. The recommended protective measures, totaling $187 million in improvements, are also costly but will significantly reduce risk to the equipment, environment, and public health.

DEP plans to implement the protective measures systematically through capital projects in the coming years, with added consideration given to those plants whose failures will most likely affect bathing beaches. This chapter provides additional information regarding individual wastewater treatment plants, their risks, and which measures DEP may implement in the future to protect them.

Wastewater Treatment Plants

Source: FEMA; CUNY Institute for Sustainable Cities



Wastewater Treatment Plant Estimated Costs

Wastewater Treatment Plant	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]
Wastewater Treatment Plants with Greatest Potential for Affecting Beaches			
26th Ward	$8.18	$82.42	$79.45
Coney Island	$15.48	$84.95	$349.81
Hunts Point	$24.28	$201.36	$246.44
Jamaica	$0.21	$1.70	$0.46
Oakwood Beach	$5.33	$20.97	$44.28
Rockaway	$15.12	$49.28	$198.10
Subtotal	**$68.61**	**$440.67**	**$918.55**
All Other Wastewater Treatment Plants			
Bowery Bay	$40.26	$112.60	$69.03
Newtown Creek	$8.85	$28.79	$9.13
North River	$17.15	$94.10	$445.79
Owls Head	$11.01	$48.41	$158.81
Port Richmond	$10.39	$54.85	$60.36
Red Hook	$18.56	$67.38	$24.95
Tallman Island	$11.02	$45.18	$32.80
Wards Island	$1.48	$8.73	$40.46
Subtotal	**$118.74**	**$460.04**	**$841.32**
Wastewater Treatment Plants Citywide	**$187 M**	**$901 M**	**$1,760 M**

26th Ward Wastewater Treatment Plant

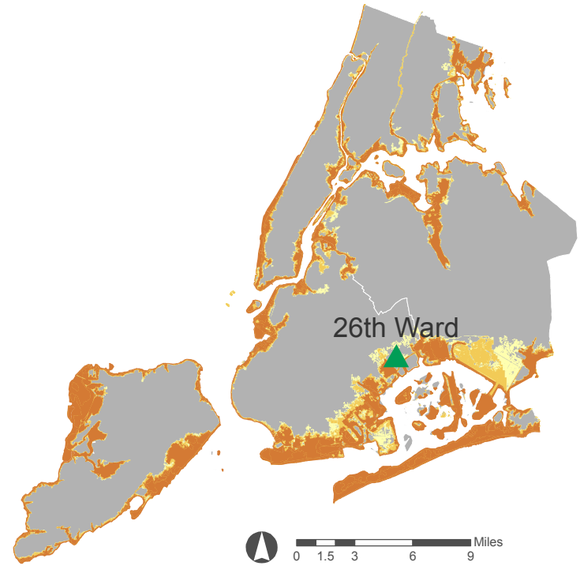
PLANT DESCRIPTION

The 26th Ward Wastewater Treatment Plant is located on a 57.3 acre site at the intersection of Flatlands and Van Siclen Avenues in southeastern Brooklyn, Community District 5. The plant abuts Flatlands Avenue on the north, Van Siclen Avenue to the west and Shore Parkway to the south; Hendrix Creek separates the site from the land to the east. General plant characteristics for 26th Ward can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +13.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.4 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	Yes
Design Dry Weather Flow (MGD)	85
Maximum Wet Weather Flow (MGD)	170
Number of Residents Served	283,428
Discharge Waterbody	Jamaica Bay
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+13.5 ft NAVD88 (+12.9 ft Brooklyn Sewer Datum)
Hurricane Sandy Flood Elevation	+12.6 ft NAVD88 (+12.0 ft Brooklyn Sewer Datum)
Hurricane Sandy Flood Damage	Major
High Likelihood to Impact Beaches	Yes

FEMA Flood Zones near 26th Ward Wastewater Treatment Plant



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Electrical conduits in the basement of the Main Building provided a pathway for floodwaters during Hurricane Sandy.

A basement access way leading to the Primary Sludge Gallery would be a flood pathway during the critical flood event.

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at 26th Ward. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Basement access ways with windows, low-lying doorways, and electrical conduits represent the most common flood pathways found on site. In addition, since the plant has a relatively flat terrain, several areas may be flooded by up to 5 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment that are needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 1,239 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

In particular, the Digester and Thickener Galleries contain numerous large sludge pumps below ground that would be at risk via a number of doorways and the tunnel system which connects the galleries to the at-risk Chlorination Building. During Hurricane Sandy, these galleries experienced several feet of flooding, and warrant additional protection.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power, would be approximately $82.4 million.

ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at 26th Ward. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements, and may be modified to account for new and changing site conditions and infrastructure.

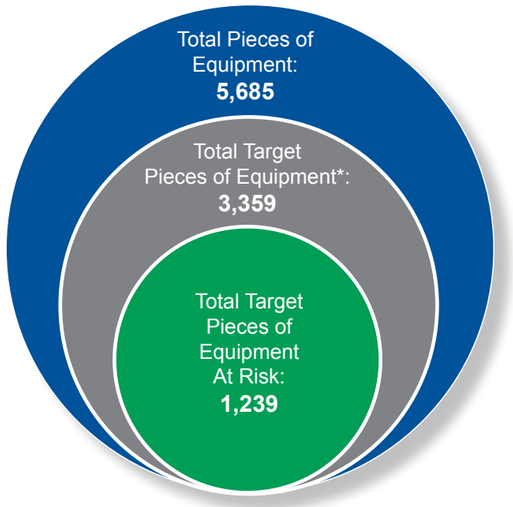
Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over the 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

For many of the locations at 26th Ward containing at-risk, large pumping operations below ground, protecting flood pathways into the basements and tunnel system with barriers, sandbags, or watertight doors was recommended.

Furthermore, in locations such as the Primary and Return Sludge Galleries which contain critical pumps needed for basic treatment, additional protection is recommended. Since these pumps are large and the necessary overhead space is limited at these locations, elevating these pumps would not be realistic. Instead, it is recommended that the pumps be replaced with submersible pumps, preferably at the end of their life cycle to reduce costs.

In total, the cost to implement all recommended strategies at 26th Ward is $8.2 million. While this cost is high, the potential damage cost that a large surge may impose totals $82.4 million. Furthermore, since 26th Ward is at a relatively low elevation, smaller flood events could affect this site. As the recommended strategies would also protect infrastructure during these smaller events, the total value of risk avoided over a 50-year time span is estimated at $79.5 million, which is almost ten times the cost of implementation.

This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering that they would also minimize service disruptions in Brooklyn during flood events, reduce sewage bypasses, and protect public health.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Table B: 26th Ward Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Air Process Gallery	Sandbag	$132,000	$724,000	$369,000	Moderate-Low
BNR Building	No Action Required	$0	$139,000	$0	No Protection
Chemical Handling	No Action Required	$0	$49,000	$0	No Protection
Chlorination Building (Old)	Flood-proof Equipment and Construct Barrier	$1,201,000	$1,093,000	$3,132,000	High
Chlorine Contact Tanks	Elevate Equipment	$14,000	$270,000	$90,000	Very High
Dewatering Building	Sandbag	$697,000	$43,567,000	$31,399,000	Moderate-Low
Digester Gallery	Sandbag	$105,000	$753,000	$654,000	Moderate-Low
Final Settling Tanks	No Action Required	$0	$2,294,000	$0	No Protection
Fire Pump Station	No Action Required	$0	$335,000	$0	No Protection
Instrument Maintenance	No Action Required	$0	$604,000	$0	No Protection
Main Building	Flood-proof Equipment and Seal Building	$1,879,000	$11,815,000	$9,268,000	Moderate
Primary Sludge Gallery	Flood-proof Equipment and Construct Barrier	$3,500,000	$5,083,000	$1,660,000	High
Return Sludge Gallery	Flood-proof Equipment and Seal Building	$287,000	$3,426,000	$1,064,000	Moderate
Sludge Transfer	Sandbag	$158,000	$6,092,000	$2,274,000	Moderate-Low
Substation Building	No Action Required	$0	$46,000	$0	No Protection
Thickener Gallery	Construct Barrier	$212,000	$6,044,000	$29,544,000	High
Waste Gas Burners	No Action Required	$0	$86,000	$0	No Protection
Total for All 17 At-Risk Locations		**$ 8.2 M**	**$ 82.4 M**	**$ 79.5 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

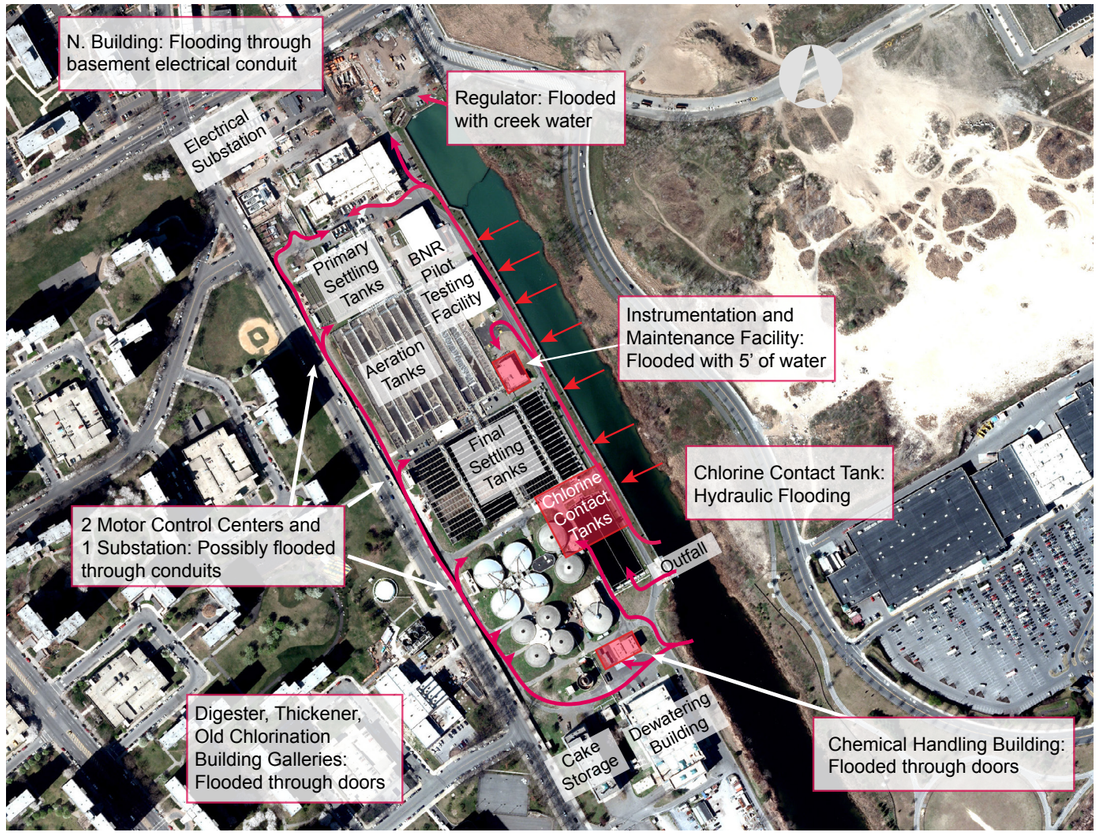
HURRICANE SANDY IMPACTS

26th Ward experienced major flooding as a result of Hurricane Sandy. During the peak of the storm, floodwaters from Hendrix Creek overtopped the plant walls and backed up into the plant through the outfall discharge pipe. The backflow of water through the plant's outfall caused water to build up in the adjacent Chlorine Contact Tanks, eventually causing them to overflow.

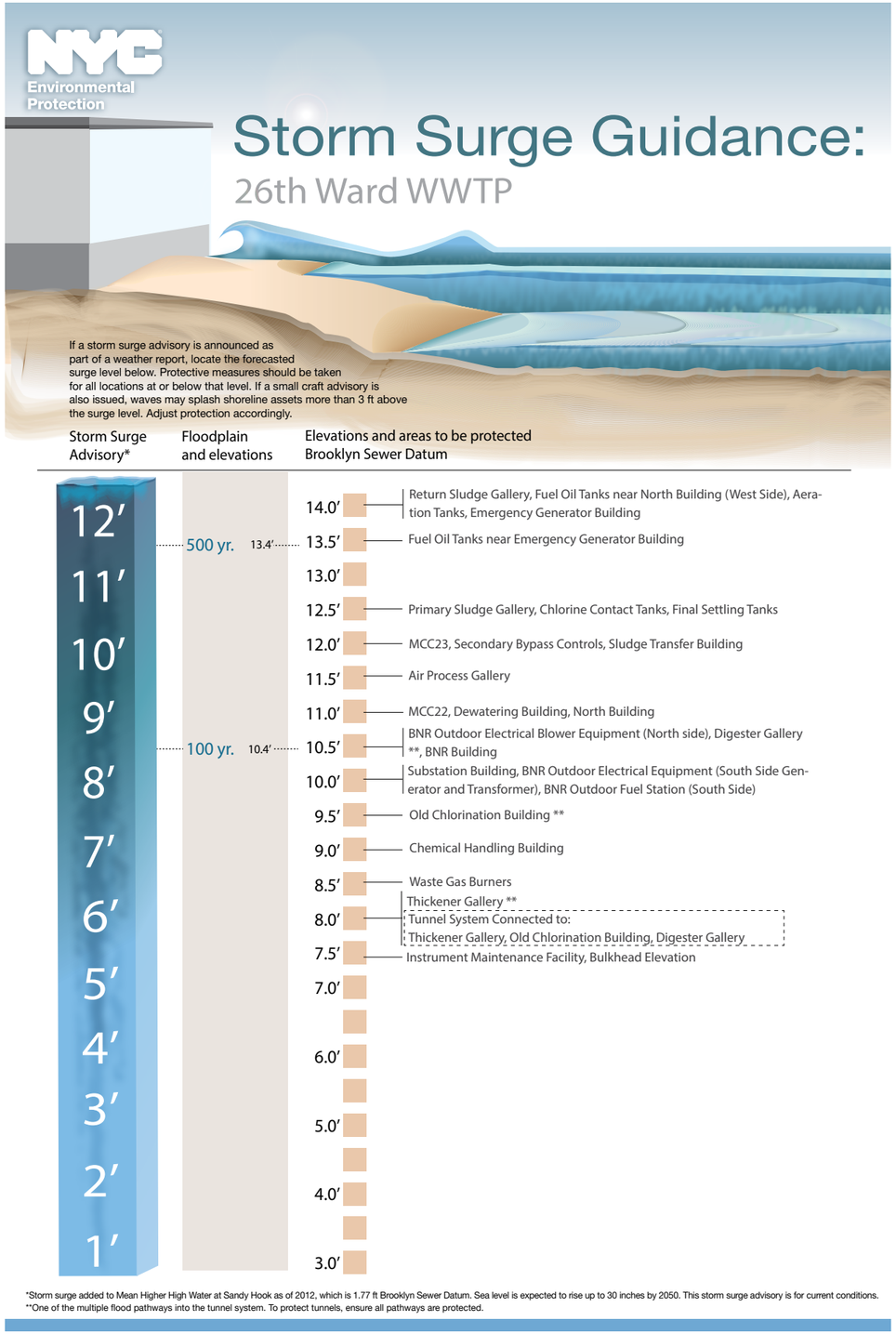
Storm surge also overtopped the plant sea wall and traveled via the West and East Road, flooding a number of plant locations and limiting plant access during the storm. Flooding occurred in the Digester and Thickener Galleries, Old Chlorination Building, Return Activated Sludge Gallery, Chemical Handling Building, electrical stations along West Road, and in the parking lot just north of the Dewatering Building. In addition, the motor control center in the Instrumentation and Maintenance Facility was flooded. The plant dock was also damaged.

Fortunately, overland floodwater did not reach any of the exterior doors of the Main Building, where raw sewage is initially pumped into the plant for treatment. However, the basement experienced flooding through an electrical channel. In all, none of the main sewage pumps were damaged, and the plant was able to continue pumping and performing basic wastewater treatment during the storm.

Plant staff worked actively before, during, and after the storm to protect the plant and bring it back to normal operation. Electrical power was proactively shut off throughout the plant during the storm surge, except in the North Building, to prevent short circuiting as the water level continued to rise. After the storm, all flooded areas were dewatered and flooded motors and electrical equipment were cleaned, dried, and repaired or replaced depending on their condition.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Bowery Bay Wastewater Treatment Plant

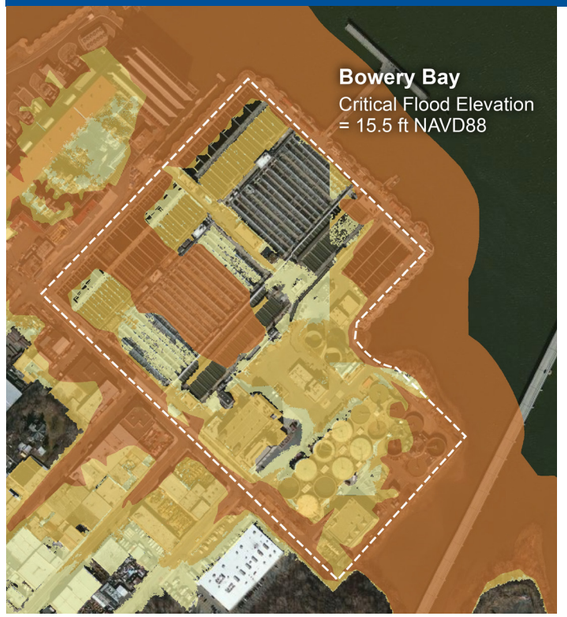
PLANT DESCRIPTION

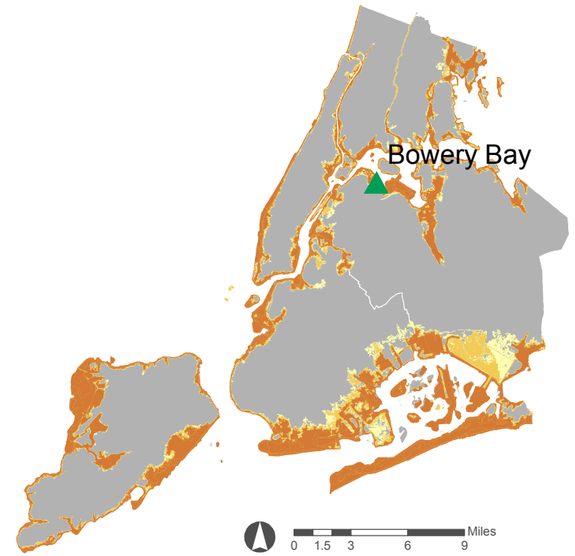
The Bowery Bay Wastewater Treatment Plant is located on a 34.6 acre site along Berrian Boulevard in the northwestern section of Queens, Community District 1. The plant abuts the Rikers Island Channel to the north and east, Berrian Boulevard to the south and Steinway Street to the west. General plant characteristics for Bowery Bay can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +15.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +8.5 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated sludge
Dewatering Facilities	Yes
Design Dry Weather Flow (MGD)	150
Maximum Wet Weather Flow (MGD)	300
Number of Residents Served	848,328
Discharge Waterbody	Upper East River
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+15.5 ft NAVD88 (+13.9 ft Queens Datum)
Hurricane Sandy Flood Elevation	+11.6 ft NAVD88 (+10.0 ft Queens Datum)
Hurricane Sandy Flood Damage	Minor
High Likelihood to Impact Beaches	No

FEMA Flood Zones near Bowery Bay Wastewater Treatment Plant



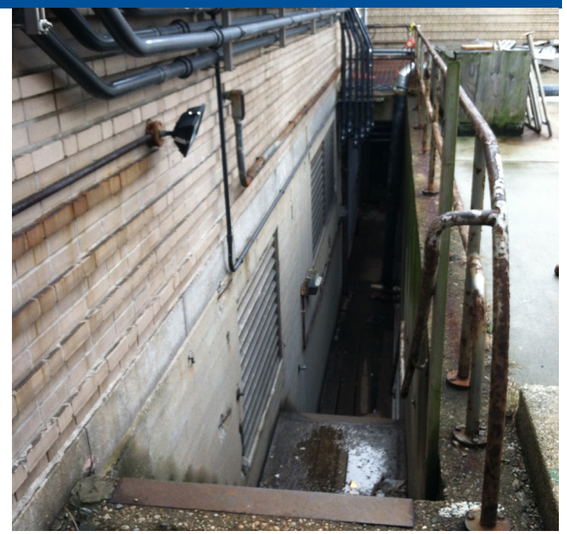


2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Typical hatch at grade level leading to tunnel system



Stairway at grade leading to the Main Building

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Bowery Bay. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation.

Since the plant has a relatively flat terrain, several areas may be flooded by up to 5 feet of water during the critical flood event. In addition, there is an extensive underground tunnel system that connects several locations and can convey water throughout the plant if not properly protected.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 1,215 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $112.6 million.

ADAPTATION STRATEGIES

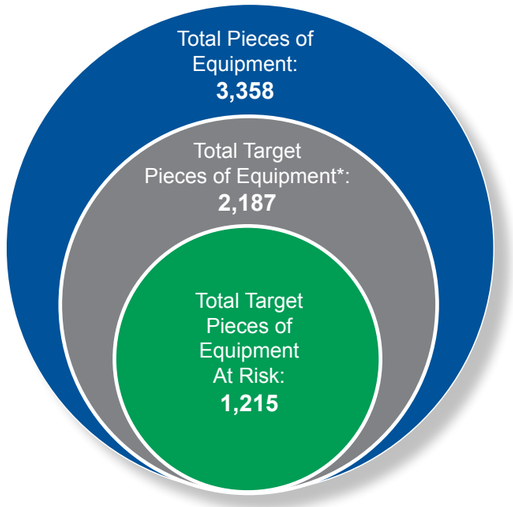
A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Bowery Bay. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Since many of the areas at Bowery Bay contain critical infrastructure, often elevating and flood-proofing were chosen as strategies since they provide a high degree of protection. In locations where not all infrastructure could be elevated or flood-proofed, additional strategies were chosen that protect openings into the plant areas. In addition, since Bowery Bay is susceptible to flood damage from an interconnected tunnel system, sealing doors and hatches leading to the tunnel is recommended. Providing more robust coverings and seals would greatly reduce this risk and prevent floodwaters from entering the tunnel system, traveling throughout the plant, and damaging target pieces of equipment in basements.

In total, the cost to implement all recommended strategies at Bowery Bay is $40.3 million. While this cost is high, the potential damage cost that a large surge may impose totals $112.6 million. Furthermore, since Bowery Bay is at a relatively low elevation, smaller flood events could affect this site. As the recommended strategies would also protect infrastructure during these smaller events, the total value of risk avoided over a 50-year time span is estimated at $69 million, which is nearly twice the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering that they would also minimize service disruptions in Queens during flood events, reduce sewage bypasses, and protect public health.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Table B: Bowery Bay Adaptation Strategy Recommendations

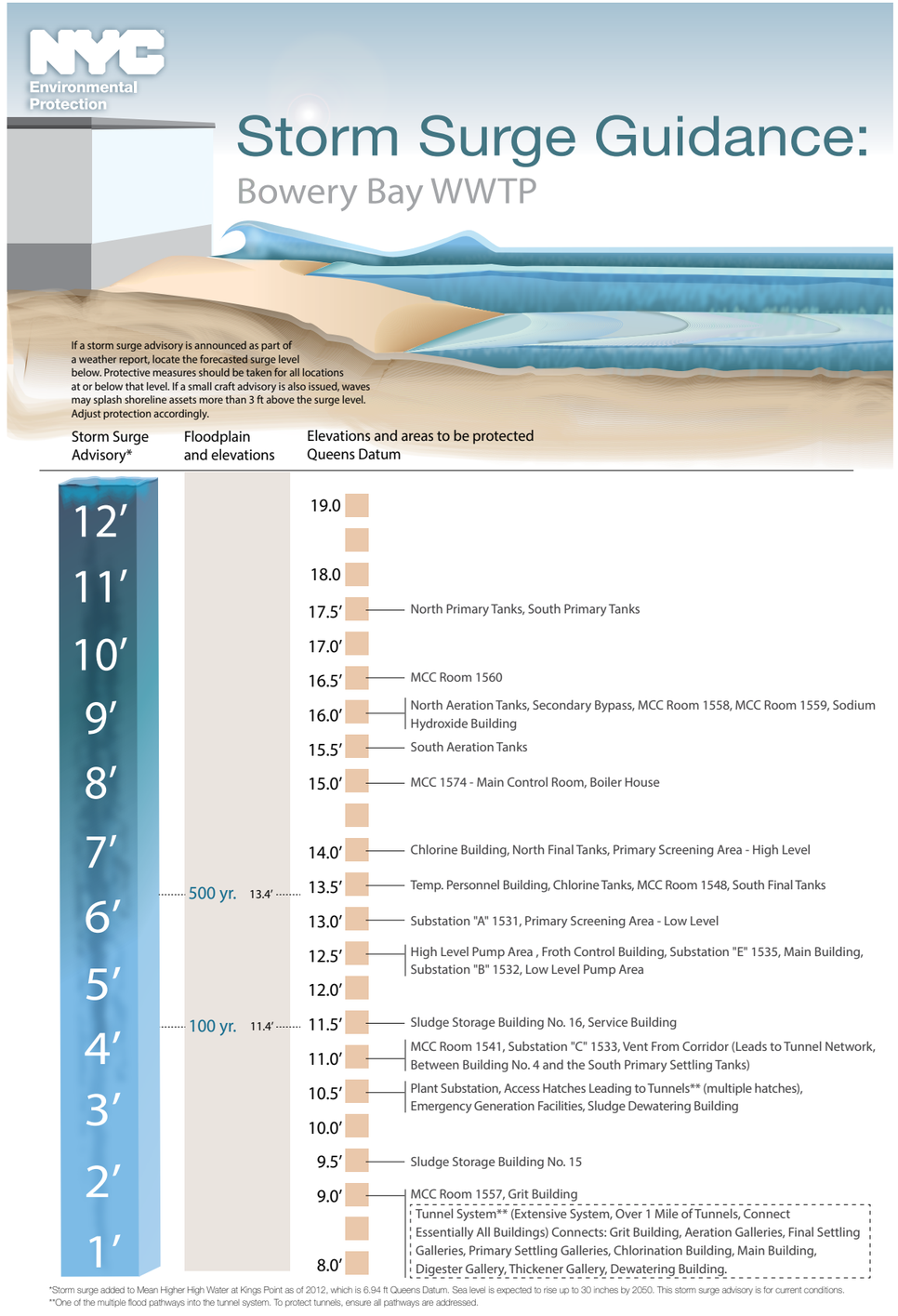
Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Chlorine Tanks	Elevate Equipment	$236,000	$446,000	$124,000	Very High
Emergency Generation Facilities	Elevate Equipment and Construct Barrier	$964,000	$5,940,000	$5,644,000	Very High
Grit Building	Seal Building	$557,000	$3,318,000	$6,683,000	Moderate
Main Building	Construct Barrier	$1,427,000	$37,313,000	$12,761,000	High
MCC Room 1541	Sandbag	$132,000	$902,000	$575,000	Moderate-Low
MCC Room 1548	Sandbag	$132,000	$902,000	$216,000	Moderate-Low
Plant Substation	Elevate Equipment and Construct Barrier	$1,150,000	$7,494,000	$7,149,000	Very High
Primary Screening Area - Lower Level	Flood-proof Equipment and Sandbag	$314,000	$405,000	$121,000	Moderate
Service Building	Elevate Equipment and Sandbag	$791,000	$742,000	$372,000	Moderate
Sludge Dewatering Building	Flood-proof and Elevate and Construct Barrier	$3,419,000	$15,315,000	$12,641,000	High
Sludge Storage Building No. 15	No Action Required	$0	$861,000	$0	No Protection
South Final Tanks	No Action Required	$0	$3,966,000	$0	No Protection
Substation "A" 1531	Elevate Equipment and Seal Building	$563,000	$3,131,000	$947,000	High
Substation "B" 1532	Elevate Equipment and Seal Building	$563,000	$3,131,000	$1,221,000	High
Substation "C" 1533	Elevate Equipment and Seal Building	$563,000	$3,131,000	$2,122,000	High
Substation "E" 1535	Elevate Equipment and Seal Building	$535,000	$3,131,000	$1,219,000	High
Tunnels And Corridors	Flood-proof and Elevate and Seal Building	$28,918,000	$21,263,000	$17,230,000	High
Digester Gallery	No Action Required	$0	$768,000	$0	No Protection
Fire Pump House	No Action Required	$0	$446,000	$0	No Protection
Total for All 19 At-Risk Locations		**$ 40.3 M**	**$ 112.6 M**	**$ 69.0 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

HURRICANE SANDY IMPACTS

Bowery Bay experienced minor flooding as a result of Hurricane Sandy, as depicted in the figure below. During the peak of the storm, water overtopped the plant bulkhead and northern access road which parallels the Rikers Island Channel. However, the water from the storm surge stopped just short of entering into any of the plant's process or electrical buildings. The storm surge caused minor damage to several temporary contractor office trailers, several storage sheds, and the barge dock. Plant staff took precautions ahead of the storm, which included sandbagging buildings and other routine emergency preparation procedures outlined in the plant's Wet Weather Operations Plan. The plant maintained electrical power and continued normal wet weather operation throughout the storm.

Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Coney Island Wastewater Treatment Plant

PLANT DESCRIPTION

The Coney Island Wastewater Treatment Plant is located on a 30 acre site along Knapp Street in south central Brooklyn, Community District 15. The plant abuts Avenue Y to the north, Coyle Street to the west, Voorhies Avenue to the south and Rockaway Inlet/Shell Bank Creek to the east. General plant characteristics for Coney Island can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +15.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.4 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

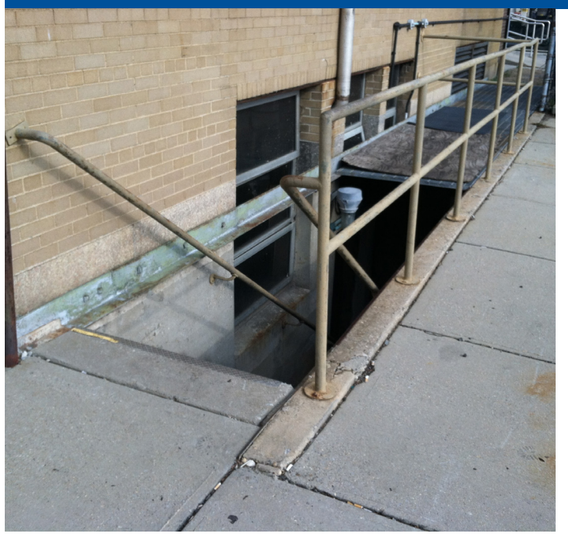
Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	No
Design Dry Weather Flow (MGD)	110
Maximum Wet Weather Flow (MGD)	220
Number of Residents Served	596,326
Discharge Waterbody	Jamaica Bay
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+15.5 ft NAVD88 (+14.02 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Elevation	+10.1 ft NAVD88 (+8.62 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Damage	Major
High Likelihood to Impact Beaches	Yes

FEMA Flood Zones near Coney Island Wastewater Treatment Plant

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways



Access stairway to the basement and gas booster room of the Pump and Power Building

Sinkholes developed near the Sludge Storage Area after Hurricane Sandy. Groundwater may present a flood risk during the next critical flood event

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Coney Island. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since the plant has a relatively flat terrain, most plant buildings would be flooded by three or more feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 1,204 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Of particular note, the Main Electrical Substation, which provides power to a significant portion of the plant; the main sewage pumps in the Pump and Blower Building which bring sewage into the plant; and the tunnel system which connects numerous buildings on site, are all at risk. Fortunately, most of the tanks would be protected from direct inundation, but may spill over as water backs up into the plant from the outfall during a large flood.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $84.9 million.

ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Coney Island. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

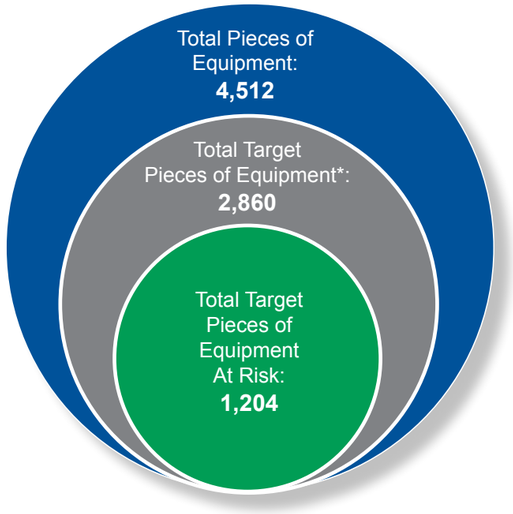
When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Given that Coney Island is susceptible to flood damage from an interconnected tunnel system (Tunnel A), constructing static barriers around grates and providing stop logs on doorways leading to the tunnel is recommended to minimize spreading of floodwater.

Locations containing equipment critical for primary treatment operations, particularly the main pumps, screens, and disinfection equipment, also warrant protective measures. Since most of the equipment is relatively large and below ground, elevating equipment from this underground area is challenging. Flood-proofing the equipment is recommended instead, and in locations where not all infrastructure can be flood-proofed, additional strategies which block flood pathways can provide added levels of protection.

Finally, key outdoor electrical components that are below the critical flood elevation should either be elevated or have a barrier constructed around them. If flood waters penetrate these areas, power should be turned off.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Primary treatment process equipment can be operated with emergency generators as was done during Hurricane Sandy.

In total, the cost to implement all recommended strategies at Coney Island is $15.5 million. While this cost is high, the potential damage cost that a large surge may impose totals $84.9 million. Furthermore, since Coney Island is at a relatively low elevation, smaller flood events could affect this site. As the recommended strategies would also protect infrastructure during these smaller events, the total value of risk avoided over a 50-year time span is estimated at $349.8 million, which is 23 times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering that they would also minimize service disruptions in Brooklyn during flood events, reduce sewage bypasses, and protect public health.

Table B: Coney Island Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Administration Building	No Action Required	$0	$1,109,000	$0	No Protection
Digesters	Seal Building	$622,000	$8,138,000	$37,692,000	Moderate
Distributed Equpment	No Action Required	$0	$265,000	$0	No Protection
Grit Building	Flood-proof Equipment and Construct Barrier	$2,685,000	$5,133,000	$25,341,000	High
Hypo Building	Flood-proof Equipment and Seal Building	$1,027,000	$1,524,000	$6,766,000	Moderate
IRE Building/Storage Garage	No Action Required	$0	$81,000	$0	No Protection
Main Electrical Substation	Construct Barrier	$617,000	$10,771,000	$52,648,000	High
Odor Control Building	Seal Building	$594,000	$2,892,000	$12,519,000	Moderate
Old Power House	No Action Required	$0	$306,000	$0	No Protection
Plant Maintenance Building	No Action Required	$0	$318,000	$0	No Protection
Primary Screening Building	Flood-proof Equipment and Construct Barrier	$3,702,000	$4,579,000	$9,319,000	High
Pump and Power Building	Flood-proof Equipment and Construct Barrier	$4,675,000	$18,853,000	$86,788,000	High
Sludge Storage Building	Construct Barrier	$212,000	$1,112,000	$5,434,000	High
Thickener Building	Construct Barrier	$482,000	$22,783,000	$111,378,000	High
Tunnel A	Flood-proof Equipment and Construct Barrier	$409,000	$251,000	$1,221,000	High
Distributed Power	Elevate Equipment	$460,000	$6,833,000	$706,100	Low
Total for All 16 At-Risk Locations		**$ 15.5 M**	**$ 84.9 M**	**$ 349.8 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

HURRICANE SANDY IMPACTS

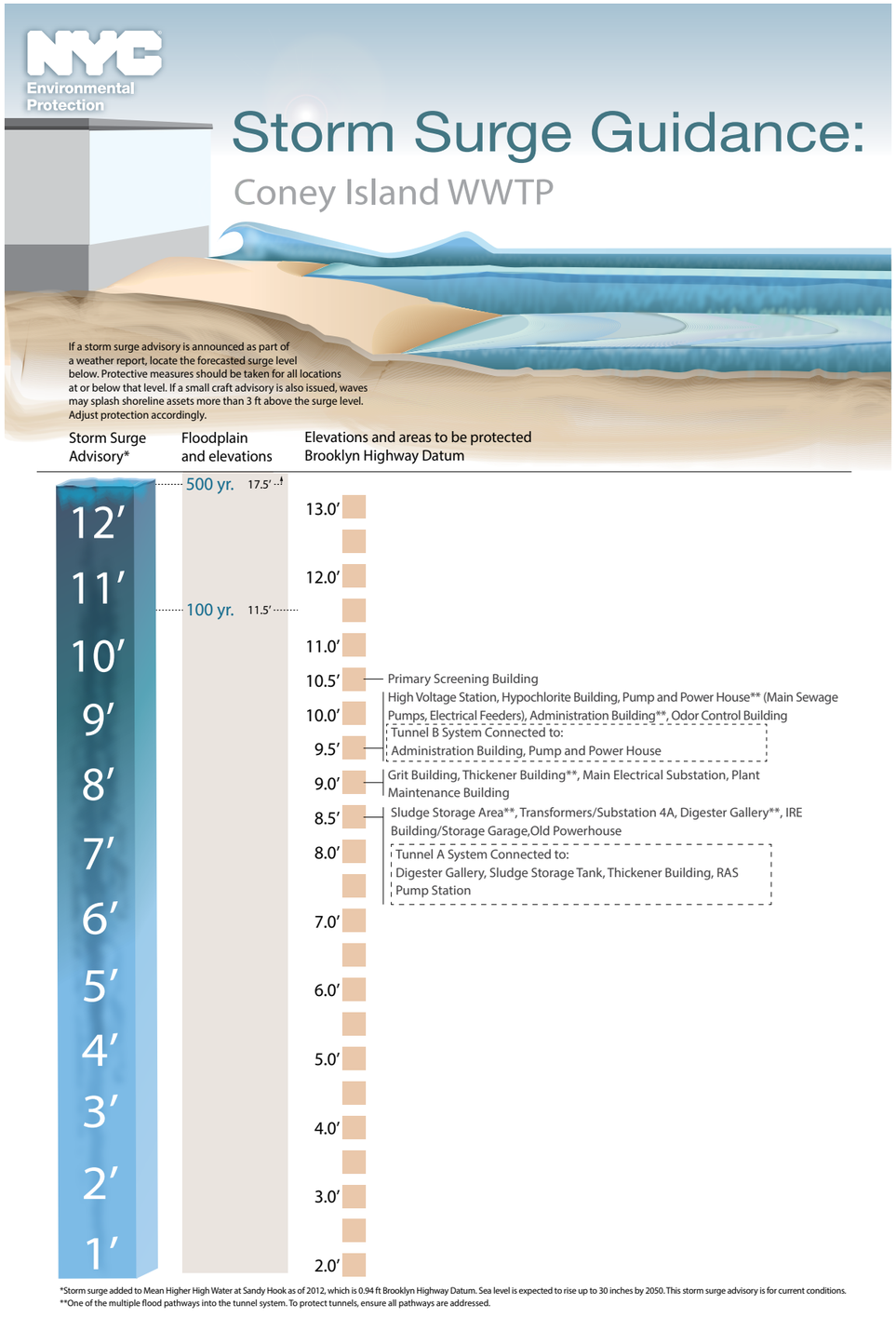
Coney Island experienced major flooding as a result of Hurricane Sandy. During the peak of the storm, water from the adjacent Rockaway Inlet/Shell Bank Creek overtopped the banks behind the Sludge and Digester building complex, flooded Knapp Street and flowed through the main wastewater treatment plant parking lot and into low-lying buildings. There was extensive damage to the Storage Garage, located at grade level, which contained spare parts and other equipment. Over 1 foot of water filled the lower levels of the Sludge Storage/ Digester Gallery, the Pump and Power House Building, and the Primary Screening Building, compromising mechanical and electrical equipment. Water spilled out of the Chlorine Contact Tanks and a tunnel which spans Knapp Street, connecting the Sludge Storage/Digester Gallery on the east side with the Thickener Building on the west side, also filled with water.

Three of the five main electrical feeds from Con Edison were lost during the storm event and the remaining two lines were shut down the next day for four hours. In addition, since the elevation of the plant discharge outfall was overwhelmed by the storm surge, treated wastewater backed up within the plant.

The storm event resulted in several sinkholes causing the ground around the buildings to settle. A ground penetrating radar survey performed after Hurricane Sandy revealed numerous areas in the parking lot adjacent to the Storage Garage that require geotechnical restoration.

The plant staff took precautions ahead of the storm, which included sandbagging low-lying buildings, relocating some of the portable equipment, filling chemical tanks, ensuring emergency power equipment was operational, closing certain inflow pipes to reduce inflow of combined sewage to the plant, and other procedures outlined in their Wet Weather Operations Plan. Despite the damage, the plant maintained normal wet weather operation through the storm event.

Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Hunts Point Wastewater Treatment Plant

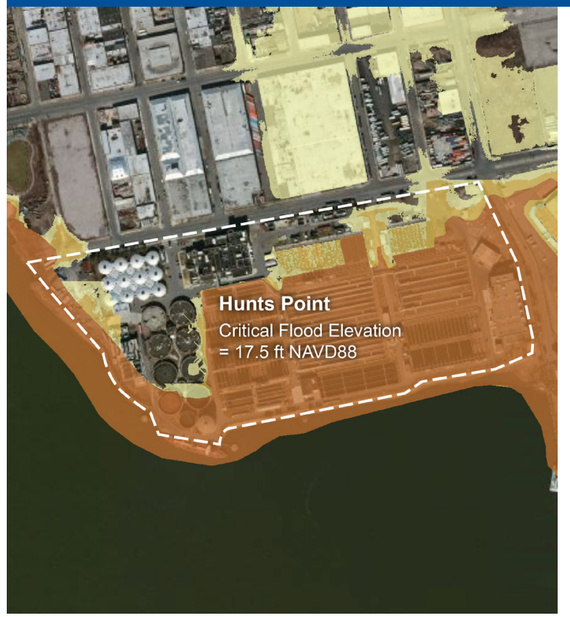
PLANT DESCRIPTION

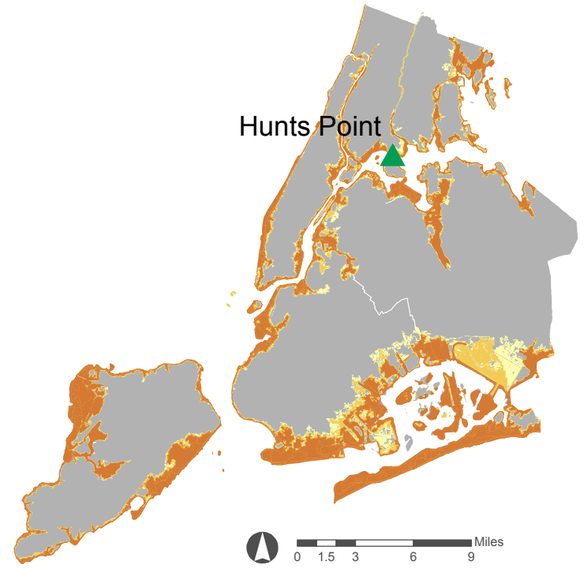
The Hunts Point Wastewater Treatment Plant is located in the Hunts Point section of the Bronx, on the shore of the upper East River. The plant abuts Ryawa Avenue on the north, Halleck Street to the east, and the East River separates the site from the land to the west and south. General plant characteristics for Hunts Point can be found in Table A.The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +17.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +8.2 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	Yes
Design Dry Weather Flow (MGD)	200
Maximum Wet Weather Flow (MGD)	400
Number of Residents Served	684,569
Discharge Waterbody	Upper East River
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+17.5 ft NAVD88 (+16.0 ft Bronx Sewer Datum)
Hurricane Sandy Flood Elevation	+10.2 ft NAVD88 (+8.7 ft Bronx Sewer Datum)
Hurricane Sandy Flood Damage	Minor
High Likelihood to Impact Beaches	Yes

FEMA Flood Zones near Hunts Point Wastewater Treatment Plant





2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

The overhead grate above the Aeration Gallery is a potential flood pathway to the sludge pumps.

Access doors to the Sludge Storage Tanks next to the East River

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Hunts Point. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since parts of the plant are situated at a relatively low elevation, a number of areas would be flooded by up to 7 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 3,782 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

The Aeration Galleries and the Electrical Substations contain some of the most expensive pieces of equipment that are at risk at the plant. The Aeration Gallery houses a series of large sludge pumps below ground, and the Electrical Sustations contain equipment used to transmit power throughout the plant. This equipment, therefore, is not only expensive to replace, but is fundamental to the plant's funcitonality.

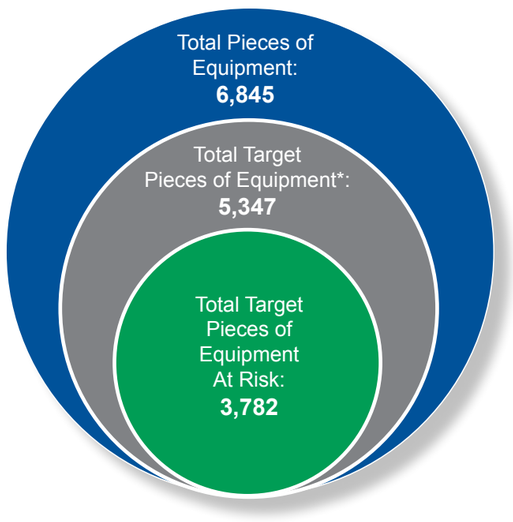
Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $201.4 million.

ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Hunts Point. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements. When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide.

In total, the cost to implement all recommended strategies is $24.3 million. While this cost is high, the potential damage cost that a large surge may impose totals $201.4 million. Furthermore, since Hunts Point is at a relatively low elevation, smaller flood events could affect this site. As the recommended strategies would also protect infrastructure during these smaller events, the total value of risk avoided over a 50-year time span is estimated at $246.4 million, which is ten times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering that they would also minimize service disruptions during flood events, reduce sewage bypasses, and protect public health.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Table B: Hunts Point Adaptation Strategy Recommendations

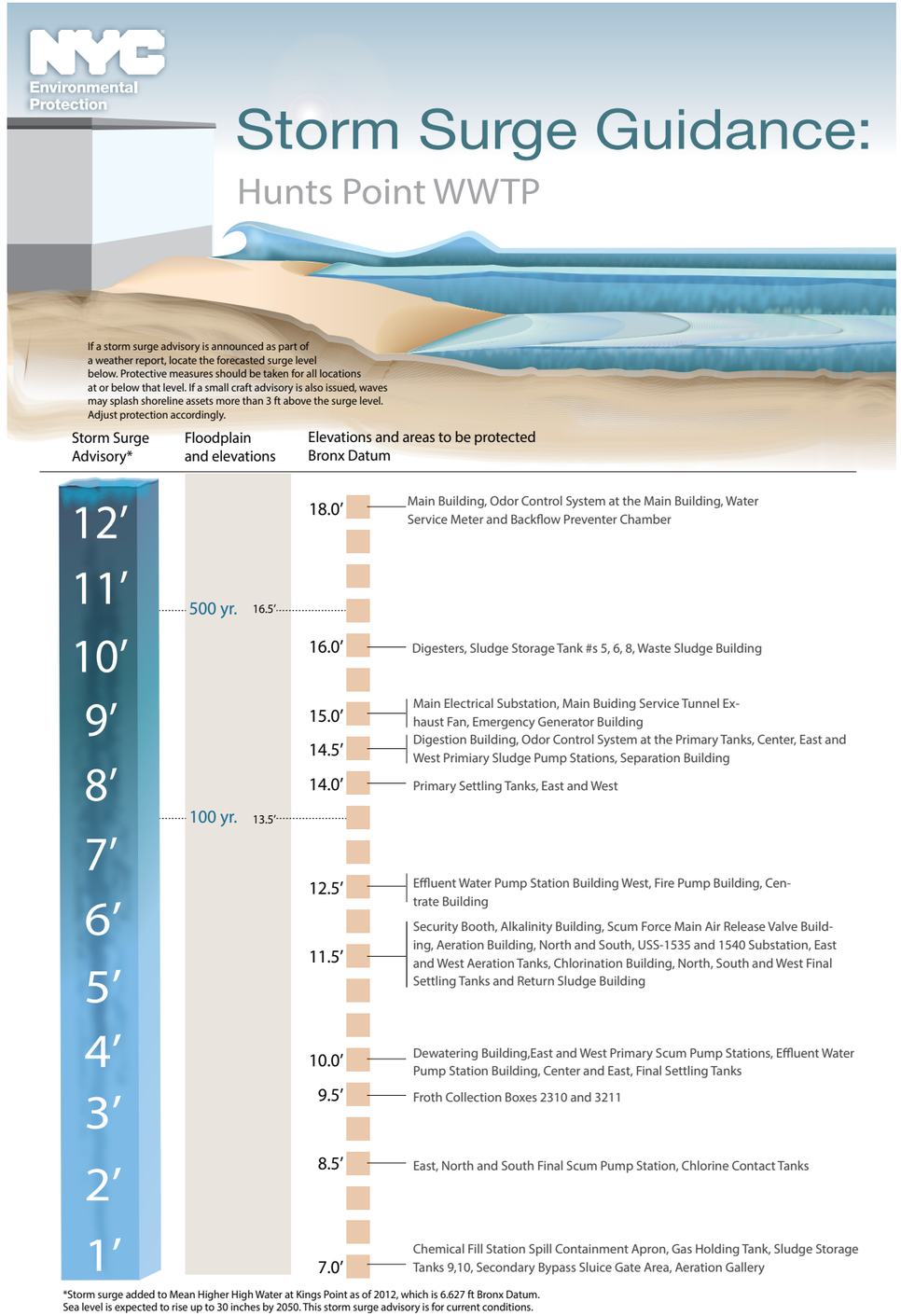
Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Aeration Building – North	Seal Building	$318,000	$1,477,000	$2,186,000	Moderate
Aeration Building – South	Seal Building	$318,000	$1,273,000	$1,887,000	Moderate
Aeration Gallery	Flood-proof Equipment and Construct Barrier	$745,000	$9,168,000	$44,980,000	High
Aeration Tank - East	Elevate Equipment	$2,036,000	$8,627,000	$13,212,000	Moderate-Low
Aeration Tank - West	Elevate Equipment	$4,363,000	$18,251,000	$28,295,000	Moderate
Alkalinity Building	Seal Control Room	$299,000	$5,398,000	$7,323,000	Moderate
Centrate Building	Sandbag	$103,000	$1,820,000	$1,255,000	Moderate-Low
Chlorination Building	Elevate Equipment	$1,636,000	$2,359,000	$4,045,000	Very High
Chlorine Contact Tank	Elevate Equipment	$142,000	$525,000	$2,700,000	Very High
Dewatering Building	Seal Building	$597,000	$42,718,000	$75,305,000	Moderate
Digestion Building	Sandbag	$103,000	$6,674,000	$2,434,000	Moderate-Low
Effluent Water Pump Station Building - Center	Elevate Equipment and Seal Building	$594,000	$1,413,000	$4,508,000	Moderate
Effluent Water Pump Station Building - East	Elevate Equipment and Construct Barrier	$1,258,000	$1,152,000	$3,953,000	High
Effluent Water PS Building – West	Elevate Equipment and Construct Barrier	$1,229,000	$1,093,000	$1,010,000	High
Final Scum Pump Station - East	Elevate Equipment and Construct Barrier	$248,000	$1,613,000	$7,906,000	High
Final Scum Pump Station - North	Elevate Equipment and Seal Building	$400,000	$1,376,000	$6,414,000	Moderate
Final Scum Pump Station - South	Seal Control Room	$269,000	$1,548,000	$7,164,000	Moderate
Final Settling Tank - East	No Action Required	$0	$1,718,000	$0	No Protection
Final Settling Tank - North	No Action Required	$0	$2,178,000	$0	No Protection
Final Settling Tank - South	No Action Required	$0	$2,264,000	$0	No Protection
Final Settling Tank - West	No Action Required	$0	$13,629,000	$0	No Protection
Fire Pump Building	No Action Required	$0	$53,000	$0	No Protection
Froth Collection Boxes 3210 and 3211	No Action Required	$0	$789,000	$0	No Protection
Gas Holding Tank	No Action Required	$0	$135,000	$0	No Protection
Main Electrical Substation	Flood-proof Equipment and Construct Barrier	$1,252,000	$54,982,000	$14,633,000	High
Primary Scum PS - East	Elevate Equipment	$1,234,000	$1,342,000	$2,883,000	Very High
Primary Scum PS - West	Elevate Equipment	$1,145,000	$1,338,000	$2,874,000	Very High
Primary Settling Tank - East	Elevate Equipment	$1,452,000	$2,481,000	$1,171,000	Moderate
Primary Settling Tank - West	Elevate Equipment	$2,835,000	$4,287,000	$2,169,000	High
Primary Sludge PS – Center	Sandbag	$102,000	$368,000	$135,000	Moderate-Low
Primary Sludge PS – East	No Action Required	$0	$58,000	$0	No Protection
Primary Sludge PS – West	No Action Required	$0	$58,000	$0	No Protection
Return Sludge Building	No Action Required	$0	$1,395,000	$0	No Protection
Separation Building	No Action Required	$0	$290,000	$0	No Protection
Sludge Storage Tanks #9, 10	No Action Required	$0	$2,103,000	$0	No Protection
USS-1535 Substation	Seal Building	$799,000	$2,692,000	$3,986,000	Moderate
USS-1540 Substation	Seal Building	$799,000	$2,714,000	$4,015,000	Moderate
Total for All 37 Locations At-Risk		**$ 24.3 M**	**$ 201.4 M**	**$ 246.4 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

HURRICANE SANDY IMPACTS

Hunts Point experienced minor flooding as a result of Hurricane Sandy. During the peak of the storm, floodwaters entered the plant from the East River. Storm surge overtopped the plant wall located along the southern shoreline and flooded the roadways. The West Effluent Water Building flooded and many electrical components, including motors, were damaged. Equipment in the storage buildings behind the South Final Settling Tanks was also damaged. The plant maintained normal wet weather treatment operation during and after the storm.

Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Jamaica Wastewater Treatment Plant

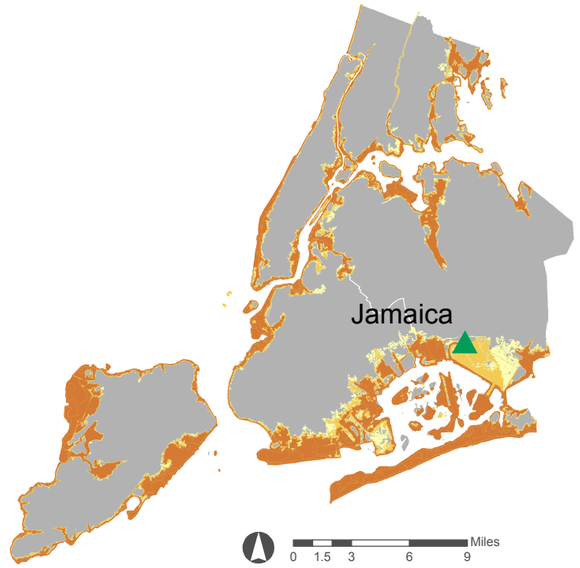
PLANT DESCRIPTION

The Jamaica Wastewater Treatment Plant is located on a 26 acre site adjacent to the western end of John F. Kennedy Airport in southwestern Queens, Community District 10. The plant is situated between the Nassau Expressway to the north, 130th Street to the west, 155th Avenue to the south and 134th Street to the east. General plant characteristics for Jamaica can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +13.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.4 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	Yes (Not currently in use)
Design Dry Weather Flow (MGD)	100
Maximum Wet Weather Flow (MGD)	200
Number of Residents Served	728,123
Discharge Waterbody	Jamaica Bay
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+13.5 ft NAVD88 (+11.9 ft Queens Highway Datum)
Hurricane Sandy Flood Elevation	Not Flooded
Hurricane Sandy Flood Damage	Minor
High Likelihood to Impact Beaches	Yes

FEMA Flood Zones near Jamaica Wastewater Treatment Plant



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

The Unit Substation adjacent to the Return Sludge Pump Station #3 would be flooded at grade level during the critical flood event.

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Jamaica. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation.

Since the plant is located on relatively high terrain, there is only one area that would be at risk during the critical flood event - the outdoor Unit Substation (USS 1533). Water in the 100-year flood event with 30 inches of sea level rise would be able to travel along one of the plant roads to this substation and enter through the fence.

An assessment of the infrastructure in this area revealed the substation contains large electrical equipment which supplies energy to a number of important sludge pumps. All other equipment throughout the plant, even those located in basements or the tunnel system, are not at risk because the flood pathways leading to these areas are not within reach of the critical flood.

Table B lists the Unit Substation as the only area of the plant containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace the Unit Substation, plus clean the plant and provide temporary power would be approximately $1.7 million.

ADAPTATION STRATEGIES

The critical flood event would only result in half a foot of flooding near the Unit Substation; therefore, sandbagging around the Substation is recommended. This strategy is regularly employed at the Substation, already as staff know this area has the greatest potential for flooding. This option can be implemented as needed prior to large flood events. It is also affordable and provides an adequate level of protection for the Substation.

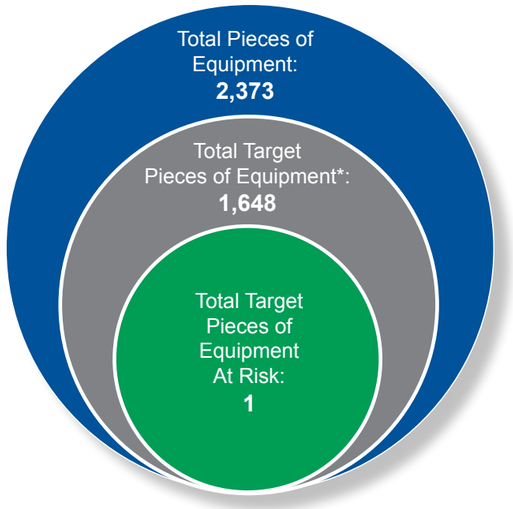
Table B presents a cost comparison for the Unit Substation at Jamaica. In this table, the cost of supplying sandbags over the course of 50 years is compared to the total damage which would be incurred in a single large flood event, and the total damage which could be avoided over the course of 50 years given the frequency of flood events which could effect the Substation.

While sandbagging does not provide the highest possible level of resiliency, given the low risk, and the low cost associated with sandbagging, this option is suitable for the Substation.

Sandbagging will certainly reduce the plant's risk by preventing floodwaters from entering and damaging the target equipment. However, as time progresses, plant staff should continue to monitor this area and may consider building a more permanent barrier around the Substation if the need arises.

In total, the cost to implement the recommended strategy at Jamaica is $0.2 million. While the cost to protect the one location is high, the potential damage cost that a large surge may impose totals $1.7 million. Because the frequency of large flood events which could affect the Substation is relatively low, the risk avoided over the next 50 years is only $0.5 million, less than the potential damage cost incurred in a single large flood event. However, it is important to note that the risk avoided is still twice the cost of implementation.

This favorable cost comparison provides strong economic support for using sandbags along the substation to minimize service disruptions in Queens during flood events, reduce sewage bypasses, and protect public health.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Table B: Jamaica Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Unit Substation (USS 1533) - Adjacent to Return Sludge Pump Station #3	Sandbagging	$213,000	$1,700,000	$460,000	Moderate-Low
Total for 1 At-Risk Location		**$ 0.2 M**	**$ 1.7 M**	**$ 0.5 M**	

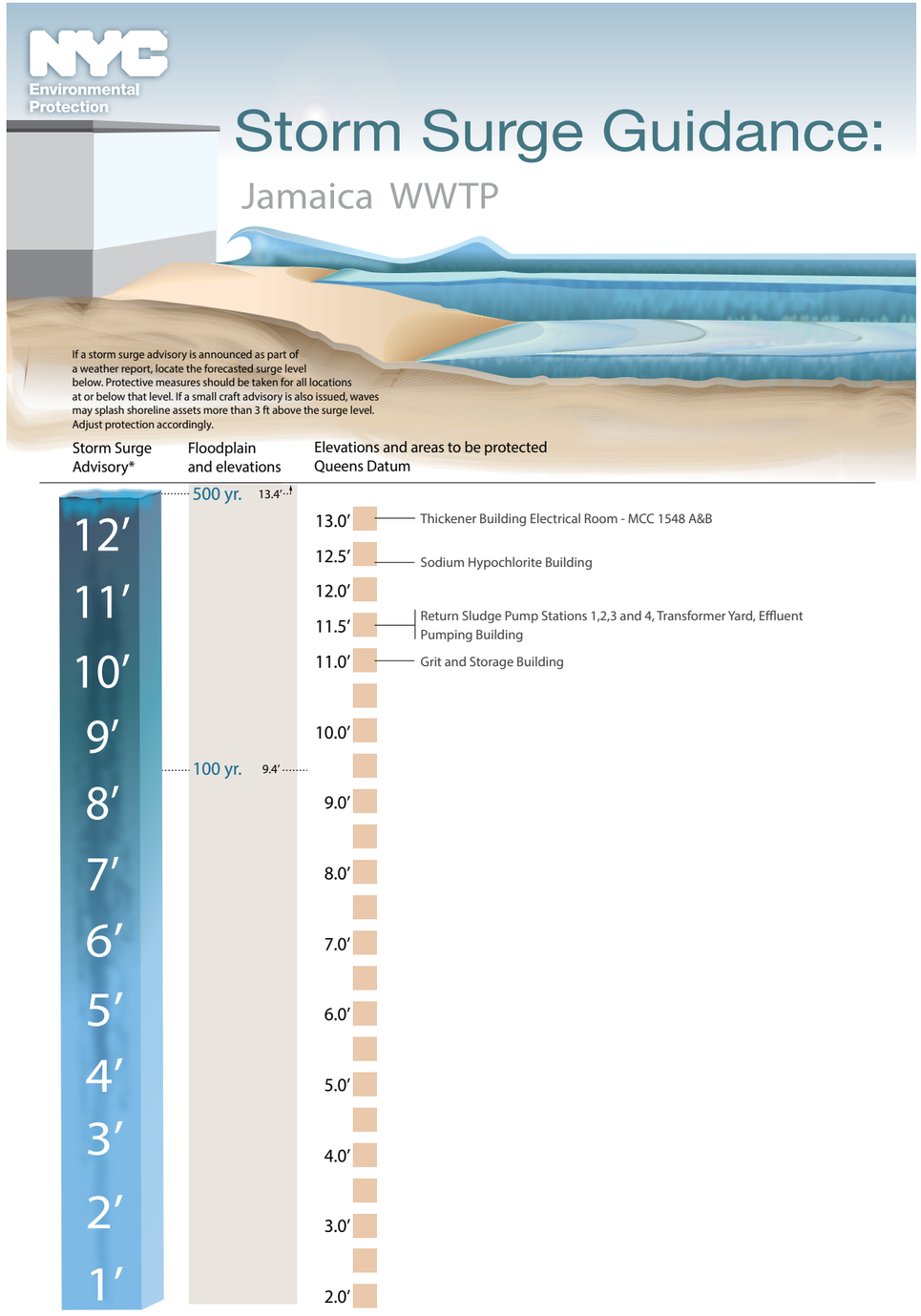
1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

The Unit Substation (USS 1533) is currently protected with sandbags.

HURRICANE SANDY IMPACTS

Jamaica experienced no flood damage as a result of Hurricane Sandy, as floodwaters did not reach the plant. Plant staff took precautions ahead of the storm by sandbagging critical areas of the plant and implementing other procedures outlined in their Wet Weather Operations Plan. The plant received little precipitation and electrical power was continuous during and after the storm event. All primary treatment equipment operated throughout the storm and the plant maintained normal wet weather treatment operations. The only minor damage sustained was from wind, which tore off the siding of a temporary office building on site.

The Jamaica Wastewater Treatment Plant did not sustain any damage due to flooding during Hurricane Sandy.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Newtown Creek Wastewater Treatment Plant

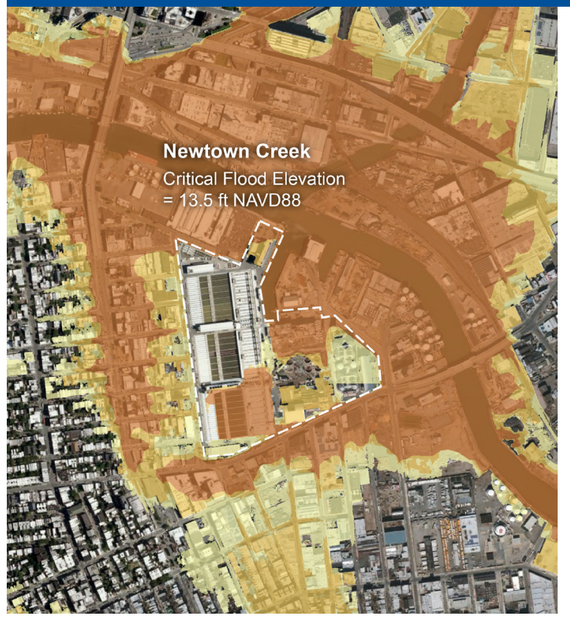
PLANT DESCRIPTION

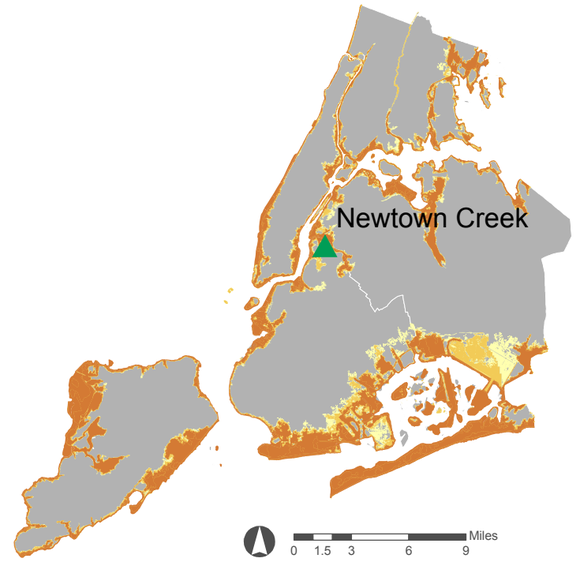
The Newtown Creek Wastewater Treatment Plant is located on a 53 acre site at 301 Greenpoint Avenue in northern Brooklyn, Community District 1. The plant abuts Provost Street on the west, Paidge Avenue on the northwest, Kingsland Avenue on the northeast and north, and Greenpoint Avenue on the south. Newtown Creek and Whale Creek Canal are to the north of the facility. General plant characteristics for Newtown Creek can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of project-ed sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +13.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.3 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	No
Design Dry Weather Flow (MGD)	310
Maximum Wet Weather Flow (MGD)	700
Number of Residents Served	1,068,012
Discharge Waterbody	East River
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+13.5 ft NAVD88 (+12.0 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Elevation	+10.0 ft NAVD88 (+8.5 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Damage	Minor
High Likelihood to Impact Beaches	No

FEMA Flood Zones near Newtown Creek Wastewater Treatment Plant



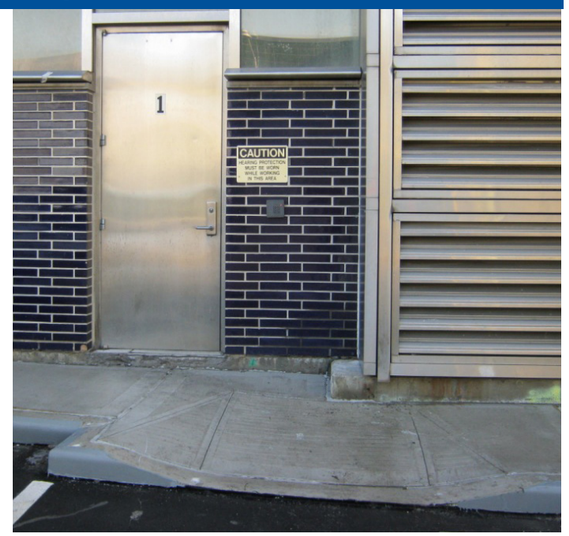


2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Basement access and floor grates on the perimeter of the Main Building



Low-lying louvers along-side the Main Building

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Newtown Creek. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since the plant has a relatively flat terrain, some areas may be flooded by nearly 4 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 381 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $28.8 million.

ADAPTATION STRATEGIES

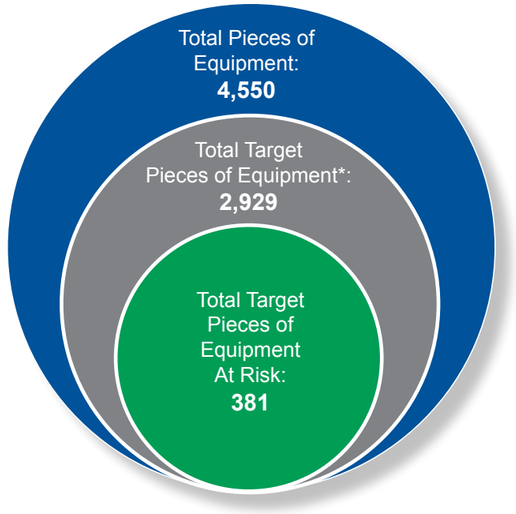
A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Newtown Creek. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency that the adaptation measure may provide to the selected location.

Since many areas at Newtown Creek contain critical infrastructure, often elevating and flood-proofing were chosen as strategies since they provide a high degree of protection. In locations where not all infrastructure could be elevated or flood-proofed, additional strategies were chosen that protect openings into the plant areas. Given that Newtown Creek is susceptible to flood damage from an interconnected tunnel system, sealing doors and access ways leading to the tunnel is recommended. Providing more robust coverings and seals would greatly reduce this risk and prevent floodwaters from entering the tunnel system, traveling throughout the plant, and damaging target pieces of equipment.

The Main Building contains several rooms that are susceptible to flooding under the critical flood event, such as the Main Pump Room, Old Facility Room, and Electrical Substation area. It is recommended to seal the building with water-tight doors and windows and flood-proof target pieces of equipment to provide adequate protection during the critical flood event and smaller storms.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

In total, the cost to implement all recommended strategies at Newtown Creek is $8.9 million. While this cost is high, the potential damage cost that a large surge may impose totals $28.8 million. As the recommended strategies would also protect infrastructure during smaller storm events, the total value of risk avoided over a 50-year time span is estimated at the cost of $9.1 million. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering that they would also minimize service disruptions in Brooklyn during flood events, reduce sewage bypasses, and protect public health.

Table B: Newtown Creek Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Central Residuals Building	No Action Required	$0	$85,000	$0	No Protection
Centrifuge Building	Sandbag	$428,000	$6,916,000	$1,574,000	Moderate-Low
Digestion Building	Sandbag	$885,000	$6,453,000	$1,467,000	Moderate-Low
Disinfection Building	Flood-proof Equipment	$573,000	$565,000	$138,000	High
Grit Handling Building	Elevate Equipment and Construct Barrier	$2,136,000	$2,048,000	$547,000	Very High
Main Building – Electrical Substation	Seal Building	$785,000	$4,897,000	$3,524,000	Moderate
Main Building – Old Facilities	Flood-proof Equipment and Seal Building	$758,000	$607,000	$154,000	High
Main Building – Pump Room	Flood-proof Equipment and Seal Building	$1,174,000	$6,317,000	$1,492,000	Moderate
Solids Handling Facilities Service Building	Elevate Equipment	$27,000	$102,000	$27,000	Very High
Distributed Power and Controls	Elevate Equipment and Construct Barrier	$2,090,000	$803,000	$205,000	High
Total for All 10 At-Risk Locations		**$ 8.9 M**	**$ 28.8 M**	**$ 9.1 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

HURRICANE SANDY IMPACTS

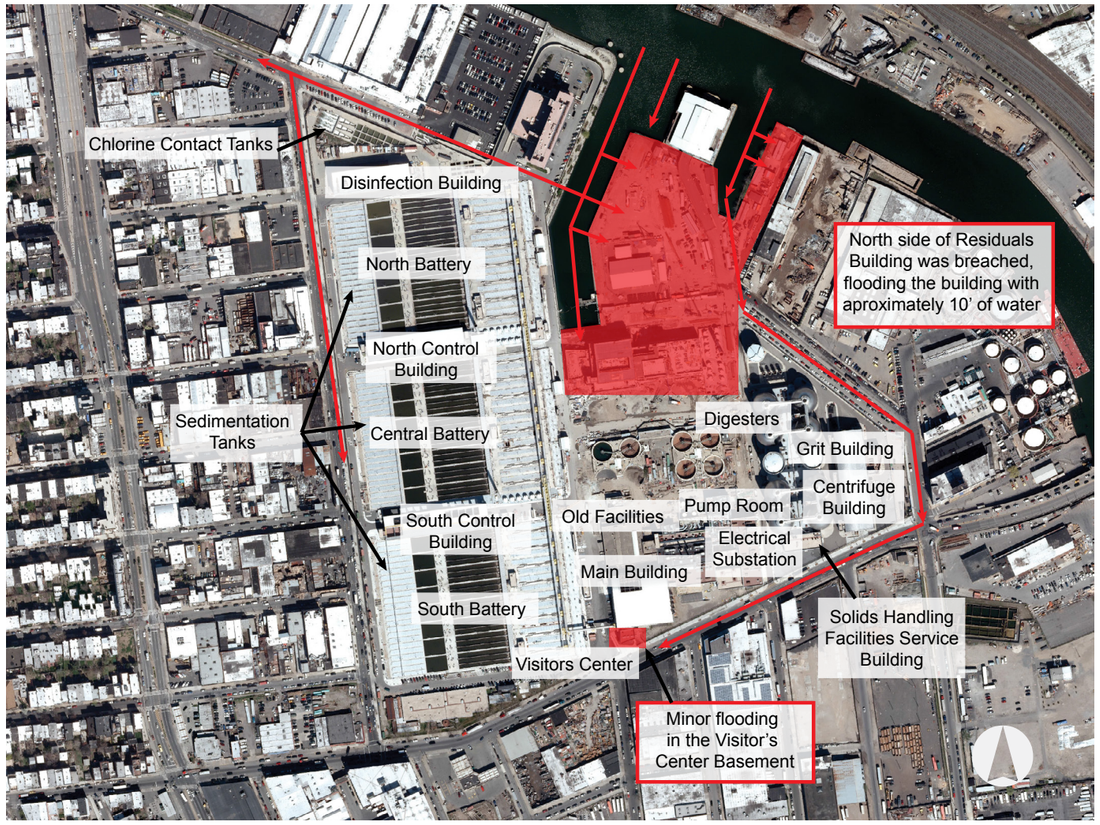
A significant area of Newtown Creek experienced flooding as a result of Hurricane Sandy, however damage was minor. During the peak of the storm, floodwaters entered the site from Whale Creek Canal and Newtown Creek over the bulkheads. Floodwaters inundated Paidge Avenue, Kingsland Avenue, and Greenpoint Avenue, leading up to the plant Visitor's Center. Water reached the doorway of the Visitor's Center but did not breach the entrance. However, there was minor flooding in the basement of the Visitor's Center, as water backed up through the drain system and electrical conduits. These valves were shut during the storm to minimize additional flooding.

Water also flooded internal Road D and reached a low-lying doorway with direct access to the plant's interconnected tunnel system at the north side of the Central Residuals Building, flooding the building with approximately 10 inches of water. The plant effluent structure was flooded with one foot of water, causing flooding in a number of treatment tanks.

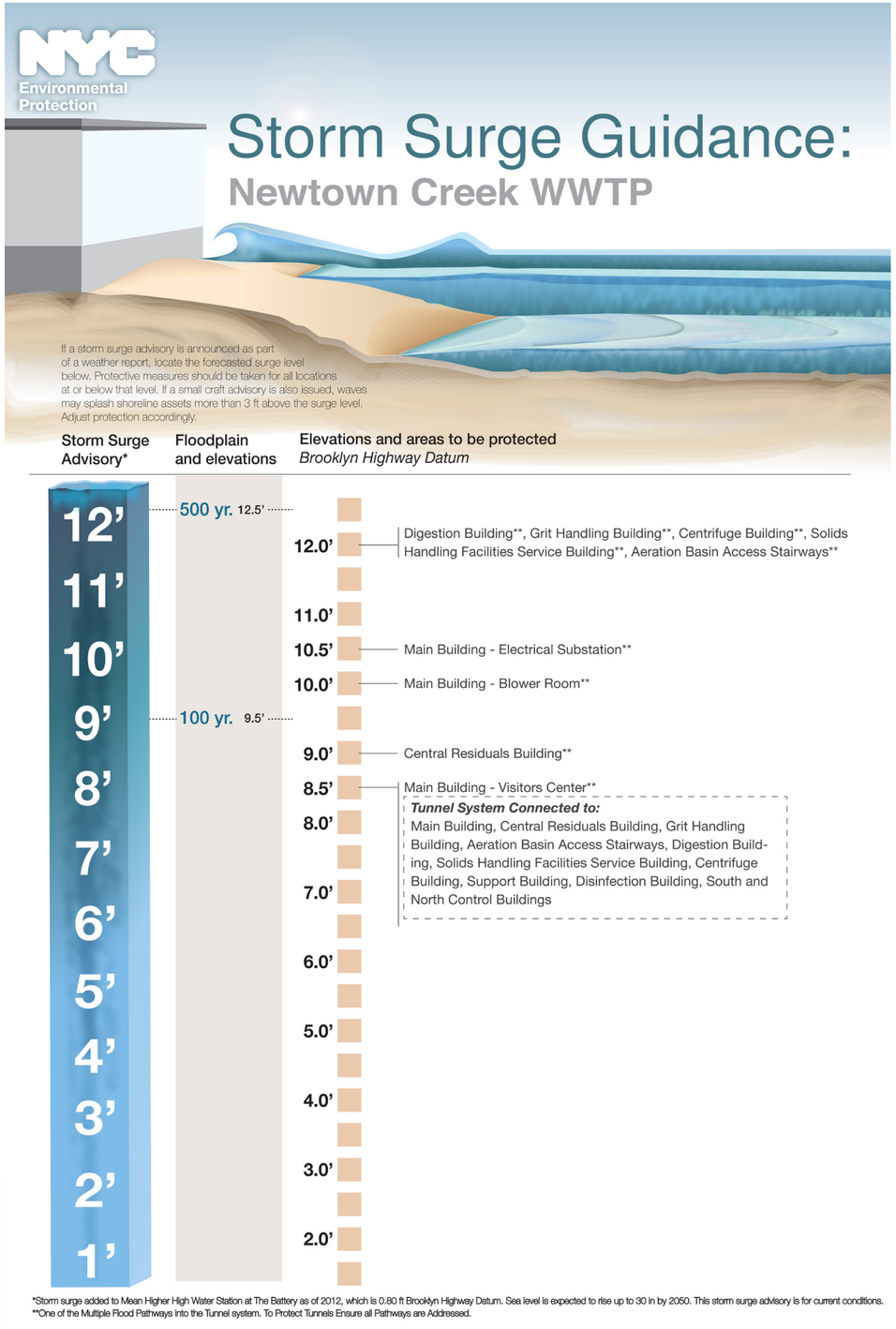
The nature walk surrounding the plant also flooded, however plant staff placed sandbags at critical flood pathways which prevented floodwaters from entering the nearby Support Building. Likewise, flooding of the Central Residuals Building was prevented by sandbagging the doorway at the north side of the building.

Due to local power outages, the plant was powered by emergency generators for three days during and following the storm. When power was restored, the plant continued operation with no evident damage to critical equipment or facilities.

The only significant damage to Newtown Creek's treatment process occurred offsite during the storm. The Manhattan Pump Station, where sewage from some sections of Manhattan is screened and then pumped to Newtown Creek, experienced significant flooding and damage. During Hurricane Sandy, several feet of floodwater surrounded and entered the pumping station and sewage backed up into the dry wells, damaging pump motors.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

North River Wastewater Treatment Plant

PLANT DESCRIPTION

The North River Wastewater Treatment Plant is located on a two-story, 28 acre site at the intersection of Riverside Drive and West 135th Street on the west side of Manhattan, New York. The plant abuts Riverside Drive on the east and the Hudson River on the west, and lies between 135th and 145th Streets. General plant characteristics for North River can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +12.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.3 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Type	Activated Sludge
Dewatering Facilities	No
Dry Weather Flow (MGD)	170
Wet Weather Flow (MGD)	340
No. Residents Served	588,772
Discharge Waterbody	Hudson River
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+12.5 ft NAVD88 (+10.8 ft Manhattan Datum)
Sandy Flood Elevation	+9.7 ft NAVD88 (+8.0 ft Manhattan Datum)
Sandy Flooding	Major
Top Priority for Beach Impacts	No

FEMA Flood Zones near North River Wastewater Treatment Plant

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Arched windows around the perimeter of the ground level (EL 5) are considered pathways for flooding.

Expansion joints are flood pathways as experienced during Hurricane Sandy.

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at North River. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since the plant is located on the first and second floors of a building adjacent to the Hudson River, all critical equipment located on the first floor is low-lying and may be flooded by nearly 6 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 2,251 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $94.1 million.

ADAPTATION STRATEGIES

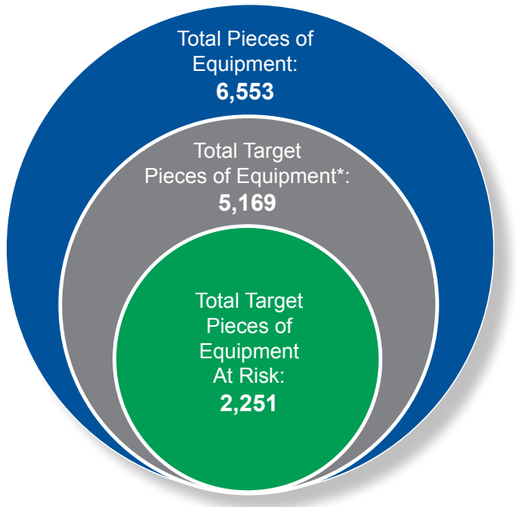
A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at North River. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Since the first floor elevation (EL 5) at North River contains critical infrastructure, flood-proofing is recommended since it provides a high degree of protection. In areas of the first floor where not all infrastructure could be flood-proofed, sealing the openings to the building is recommended. Fortifying the manhole covers, driveway entrance, and arch openings along the perimeter of the building will greatly reduce the plant's risk and prevent floodwaters from entering the first floor, traveling throughout the plant, and damaging target pieces of equipment.

In total, the cost to implement all recommended strategies at North River is $17.2 million. While this cost is high, the potential damage cost that a large surge may impose totals $94.1 million. Furthermore, since North River is at a relatively low elevation, smaller flood events could affect this site. As the recommended strategies would also protect infrastructure during these smaller events, the total value of risk avoided over a 50-year time span is estimated at $445.8 million, which is 26 times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Manhattan during flood events, reduce sewage bypasses, and protect public health.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Table B: North River Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
EL 5	Flood-proof Equipment and Seal Building	$17,155,000	$94,100,000	$445,787, 000	Moderate
Total for 1 At-Risk Location		**$ 17.2 M**	**$ 94.1 M**	**$ 445.8 M**	

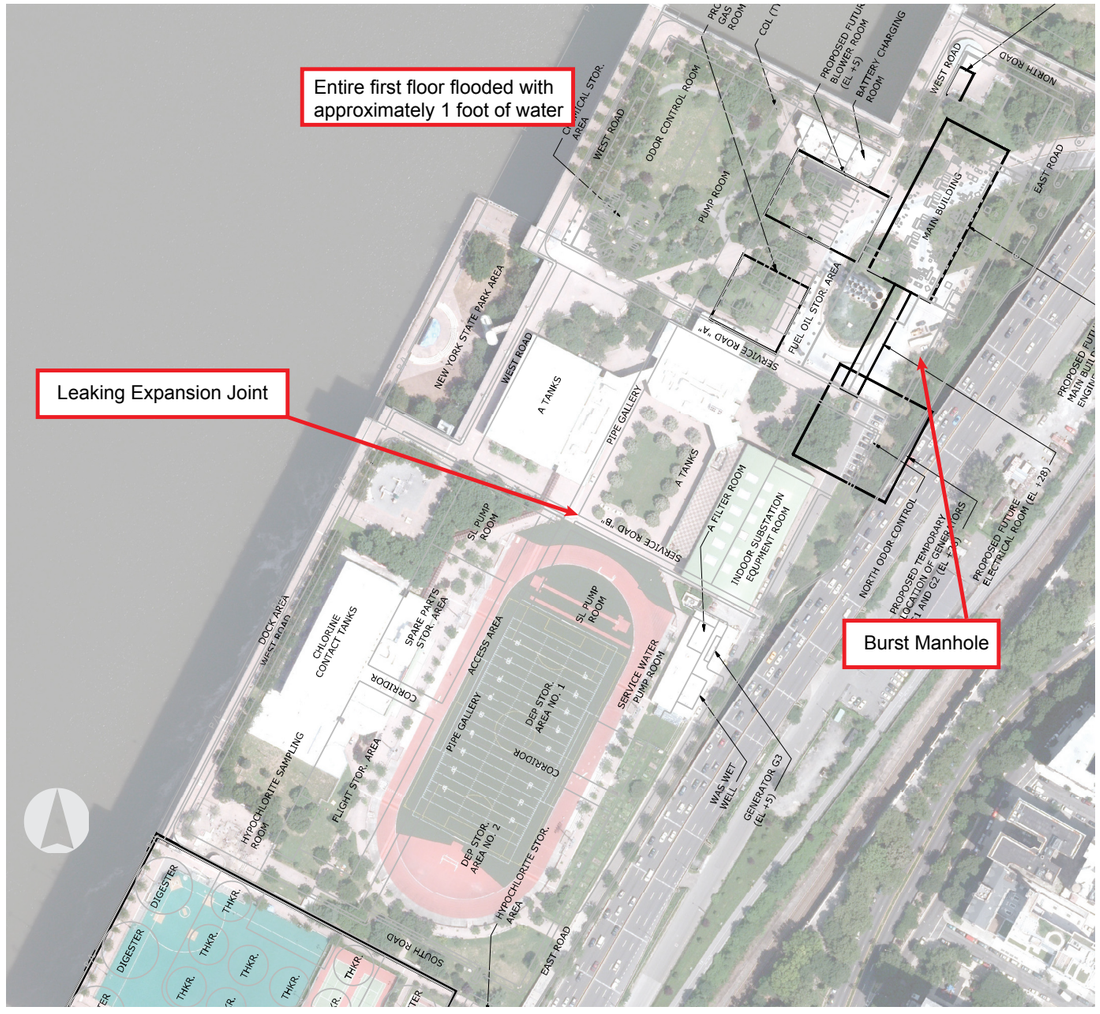
1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

North River Wastewater Treatment Plant

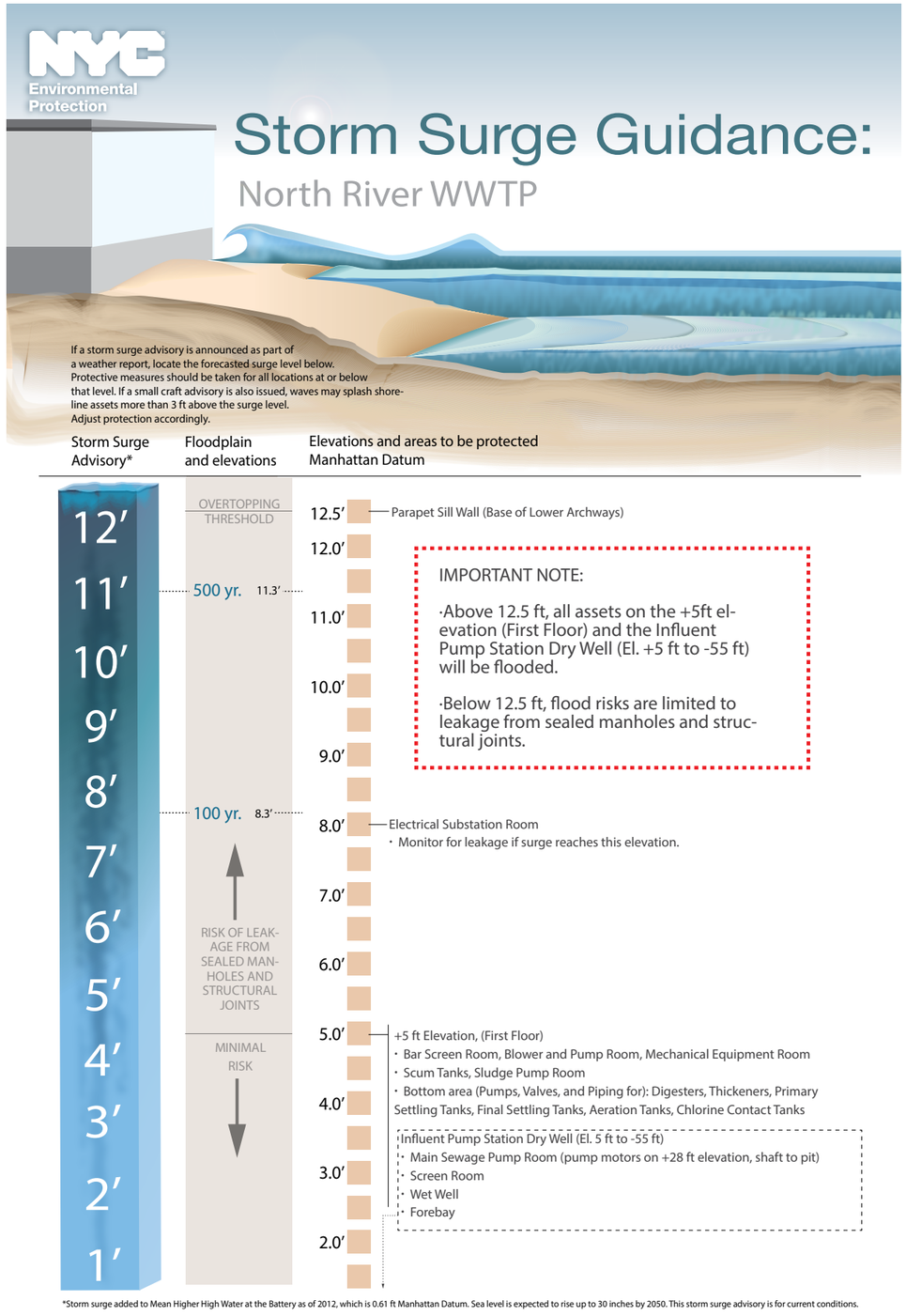
HURRICANE SANDY IMPACTS

North River experienced major flooding as a result of Hurricane Sandy. During the peak of the storm, as depicted in the figure below, floodwater forced its way through a manhole that ruptured on the first floor and through expansion joints near the Thickeners, which flooded the first floor of the plant with one foot of water. Fortunately, the engines that supply power to the main wastewater pumps are located on the second floor, and were not damaged. The Electrical Substation has raised doors, yet it flooded with less than 1 inch of water through cracks and other small pathways in the walls. Plant staff monitored the water level in the Electrical Substation throughout the storm and contacted Con Edison as a precautionary measure in case power to the plant had to be shut down.

The plant did not lose power; however, certain critical components were proactively shut down for up to 7 hours to prevent short circuiting in case the water level continued to rise. Water flooded the low-lying areas of the building first, including the Raw Influent Pump Dry Well through the first floor stairwells. It was at this point that plant staff turned off the electricity in critical plant areas. Once it was safe to restore power to the facility, a single pump was used to empty the dry well, and maintenance was performed on the remaining pumps when the dry well was emptied. After the storm, floodwater on the first floor flowed out of the plant through the ruptured manhole and through the various drains and sump pumps.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Oakwood Beach Wastewater Treatment Plant

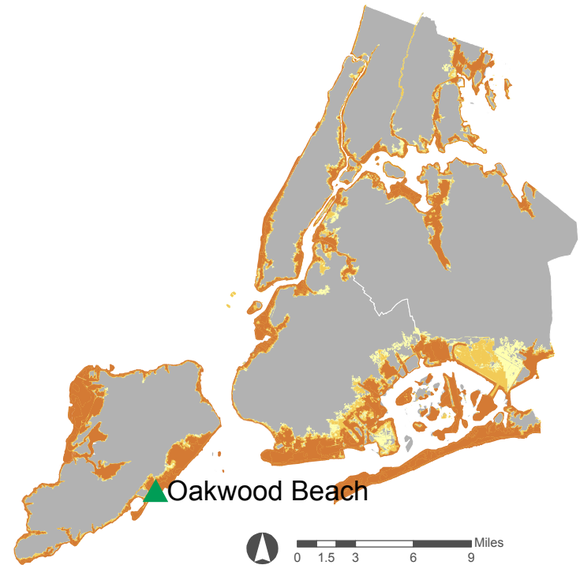
PLANT DESCRIPTION

The Oakwood Beach Wastewater Treatment Plant is located on an approximately 27 acre site at 751 Mill Road in southern Staten Island, Community District 3. The plant abuts the Gateway National Recreational Area to the west, a residential area to the east, and the Lower New York Bay to the south. General plant characteristics for Oakwood Beach can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +16.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +1.8 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	Yes
Design Dry Weather Flow (MGD)	40
Maximum Wet Weather Flow (MGD)	120
Number of Residents Served	244,918
Discharge Waterbody	Lower New York Bay
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+16.5 ft NAVD88 (+14.4 ft Staten Island Highway Datum)
Hurricane Sandy Flood Elevation	+13.1 ft NAVD88 (+11.0 ft Staten Island Highway Datum)
Hurricane Sandy Flood Damage	Major
High Likelihood to Impact Beaches	No

FEMA Flood Zones near Oakwood Beach Wastewater Treatment Plant



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Floor grate outside of the Maintenance Building

A window at the Sludge Storage Building was one of the main areaways for floodwater to enter during Hurricane Sandy.

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Oakwood Beach. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since the plant has a relatively flat terrain, a few areas may be flooded by up to 5 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment that are needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 353 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $21 million.

ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Oakwood Beach. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

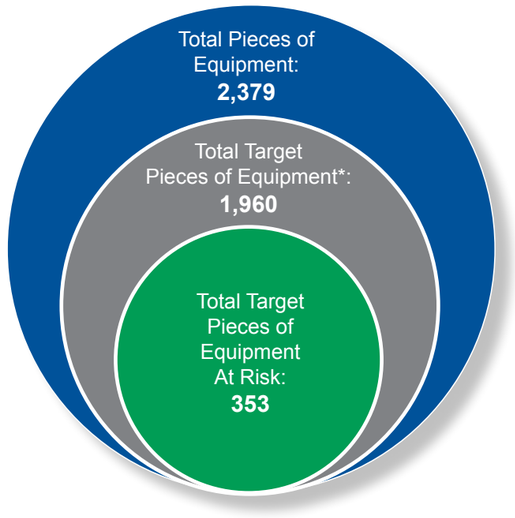
When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Since many of the at-risk areas at Oakwood Beach contain critical infrastructure, often elevating equipment was chosen as the recommended strategy since it provides a high degree of protection. In locations where not all infrastructure could be elevated, additional strategies were chosen such as constructing static barriers to protect openings into the plant areas.

In addition, Oakwood Beach is susceptible to flood damage from an interconnected tunnel system that has key at-risk flood pathways at the Sludge Storage Building. While flood-proofing and elevating equipment within the Sludge Storage Building would offer a high level of protection, constructing a static barrier around the areaways and sealing the doorways and windows to prevent damage at the Main Building and Treatment Building is also recommended.

In total, the cost to implement all recommended strategies at Oakwood Beach is $5.3 million. This cost is relatively low considering that the potential damage cost that a large surge may impose totals $21 million. As the recommended strategies would also protect infrastructure during smaller storm events, the total value of risk avoided over a 50-year time span is estimated at $44.3 million, which is eight times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Staten Island during flood events, reduce sewage bypasses, and protect public health.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Table B: Oakwood Beach Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Chlorine Building	Elevate Equipment and Seal Building	$1,265,000	$1,189,000	$3,701,000	High
Dewatering Building	Sandbag	$966,000	$8,926,000	$2,831,000	Moderate-Low
Diesel Generator	Elevate Equipment	$454,000	$1,193,000	$4,982,000	Very High
Existing Substation	Construct Barrier	$212,000	$3,525,000	$13,984,000	High
Maintenance Building	No Action Required	$0	$824,000	$0	No Protection
Meter Building	Elevate Equipment and Construct Barrier	$328,000	$395,000	$443,000	High
Microstrainer Building	Elevate Equipment and Construct Barrier	$1,101,000	$1,250,000	$6,202,000	High
Sludge Pump Building	No Action Required	$0	$51,000	$0	No Protection
Sludge Storage Building	Flood-proof and Elevate	$522,000	$3,024,000	$11,082,000	Low
Transformer Enclosure	Construct Barrier	$482,000	$594,000	$1,058,000	High
Total for All 10 At-Risk Locations		**$ 5.3 M**	**$ 21.0 M**	**$ 44.3 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

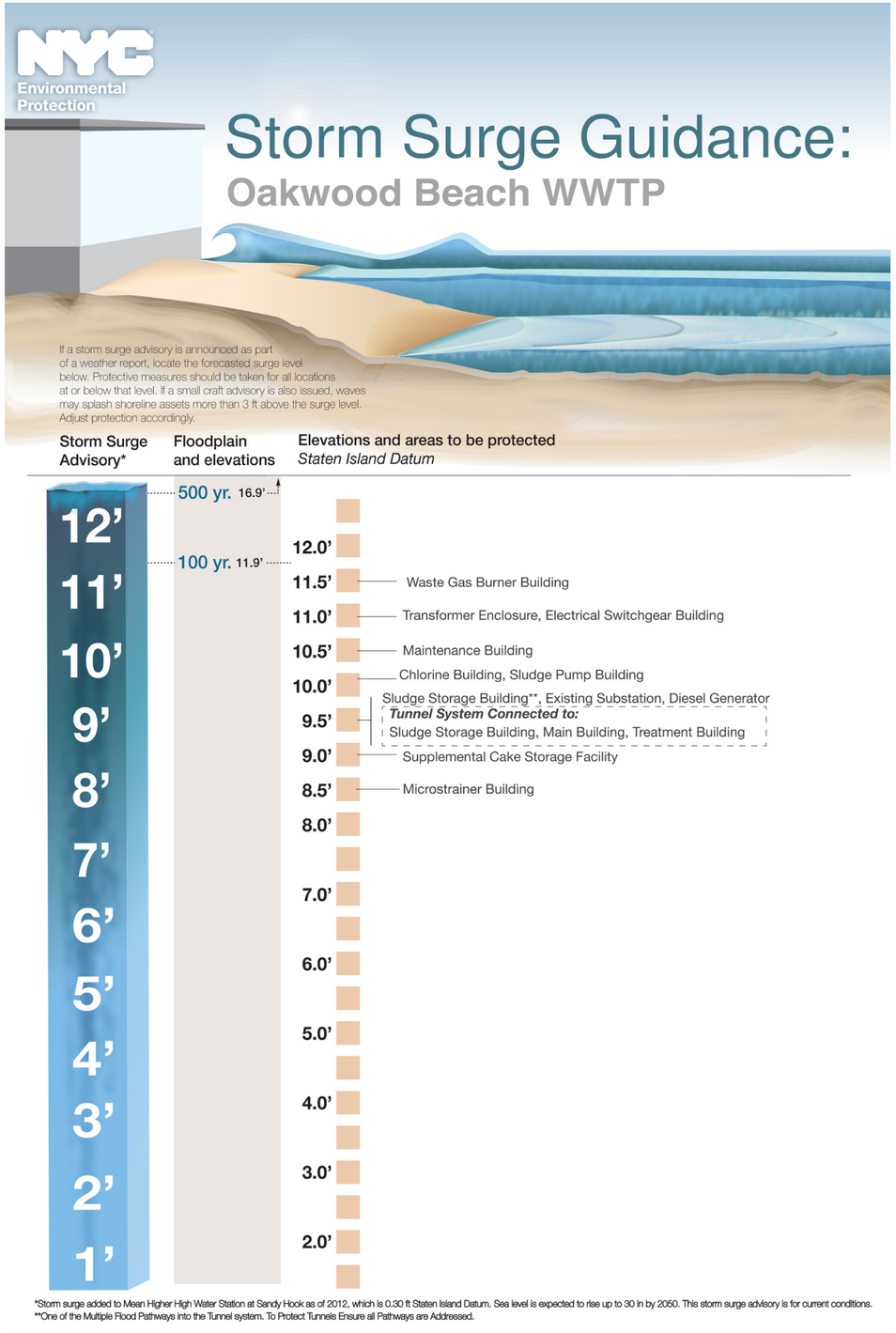
HURRICANE SANDY IMPACTS

Oakwood Beach experienced major flooding as a result of Hurricane Sandy. During the peak of the storm, floodwaters entered the site from the Lower New York Bay through the surrounding drainage canal and natural areas. Rising floodwaters surrounded the site on all sides, flooding the north lot storage yard with over 6 feet of water and the guard house at the north entrance with 3 feet of water. Vehicular access was obstructed for up to 5 hours.

The main disruption to the plant occurred when water entered the areaways and doorways of the Sludge Storage Building and spilled into the connected basements of the Main Building and Treatment Building through a tunnel. Roughly 8 inches of water accumulated in basements of the Sludge Storage Building, Main Building, Treatment Building, and connecting tunnel; however, equipment in these areas continued to function since they are elevated on concrete pads above the finished floor level. Sump pumps in the basements helped to contain rising floodwater. Other areas affected by the flood included the Sludge Pump Building, Chlorine Building, existing Electrical Switchgear Building, Emergency Generator, and the Microstrainer Building. Flooding of these areas resulted in damage to the electrical equipment, pumps, and motors. Processed water in the Chlorine Contact Tank and Effluent Channel overflowed even though they are above the Hurricane Sandy flood elevation. The overflow from the Effluent Channel flooded the Meter Building basement, resulting in partial damage to electrical equipment and the Chlorine Transfer Pumps.

Plant staff worked actively before, during, and after the storm to protect the plant and bring it back to normal operation. Power from one of the plant's two electrical service feeders was lost during the storm, forcing operators to partially operate on emergency generators and suspend power to the aeration blowers for a period of time. Sandbags were placed ahead of the storm to protect the low-lying temporary substation and temporary electrical generator. When power was restored, the plant resumed normal wet weather treatment with no apparent damage to critical equipment.

Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Owls Head Wastewater Treatment Plant

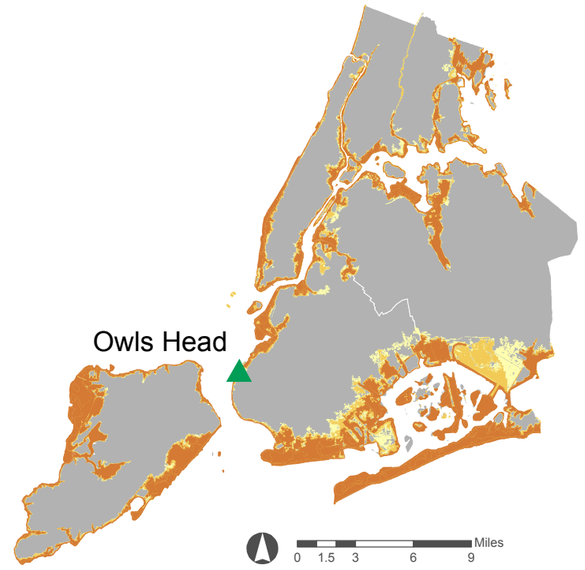
PLANT DESCRIPTION

The Owls Head Wastewater Treatment Plant is located at the intersection of Bay Ridge Avenue and Shore Road in west Brooklyn, Community District 10. The plant abuts Shore Parkway to the east and is bound by the Upper Bay on the north, west and south. General plant characteristics for Owls Head can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +14.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.3 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	No
Design Dry Weather Flow (MGD)	120
Maximum Wet Weather Flow (MGD)	240
Number of Residents Served	758,007
Discharge Waterbody	Upper New York Bay
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+14.5 ft NAVD88 (+13.0 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Elevation	+13.5 ft NAVD88 (+12.0 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Damage	Major
High Likelihood to Impact Beaches	No

FEMA Flood Zones near Owls Head Wastewater Treatment Plant



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

A pathway for flooding is around the perimeter of the Administration Building.

Floor grates near the Generator Room may allow floodwater to enter.

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Owls Head. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since the plant has a relatively flat terrain, some areas may be flooded by up to 4 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 762 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $48.4 million.

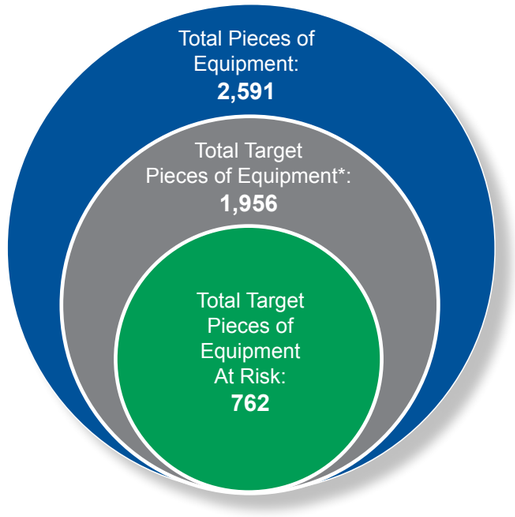
ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Owls Head. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

The Main Electrical Substations and Substations #2 and #4 in particular require robust protection as the extent of flooding ranges from 4 inches at the substations to 2 feet at the Main Electrical Substation. It is recommended that equipment be elevated and a static barrier be installed around the exterior of the Substations to protect the power feeds. Likewise, the Chlorine Contact Tanks may potentially flood during the critical flood event and elevating equipment may provide adequate protection. In addition, equipment located on the first floor and basement of the Chlorination Building is at-risk, with floodwater depth expected to reach approximately 4.5 feet under the critical flood scenario. It is recommended that electrical equipment be relocated to the second floor of the building, chemical tanks on the first floor to be filled prior to the event to prevent buoyancy issues, and for floor drains to be equipped with check valves to prevent water intrusion.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location. Since many of the at-risk areas at Owls Head contain critical infrastructure, often elevating and flood-proofing were chosen as strategies since they provide a high degree of protection. In locations where not all infrastructure could be elevated or flood-proofed, additional strategies were chosen that protect openings into the plant areas. In addition, since Owls Head is susceptible to flood damage from an interconnected tunnel system, it is recommended to flood-proof and elevate equipment within the tunnel system to provide adequate protection



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

In total, the cost to implement all recommended strategies at Owls Head is $11 million. While this cost is high, the potential damage cost that a large surge may impose totals $48.4 million. Furthermore, since Owls Head is at a relatively low elevation, smaller flood events could affect this site. As the recommended strategies would also protect infrastructure during these smaller events, the total value of risk avoided over a 50-year time span is estimated at $158.8 million, which is 14 times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Brooklyn during flood events, reduce sewage bypasses, and protect public health.

Table B: Owls Head Adaptation Strategy Recommendations

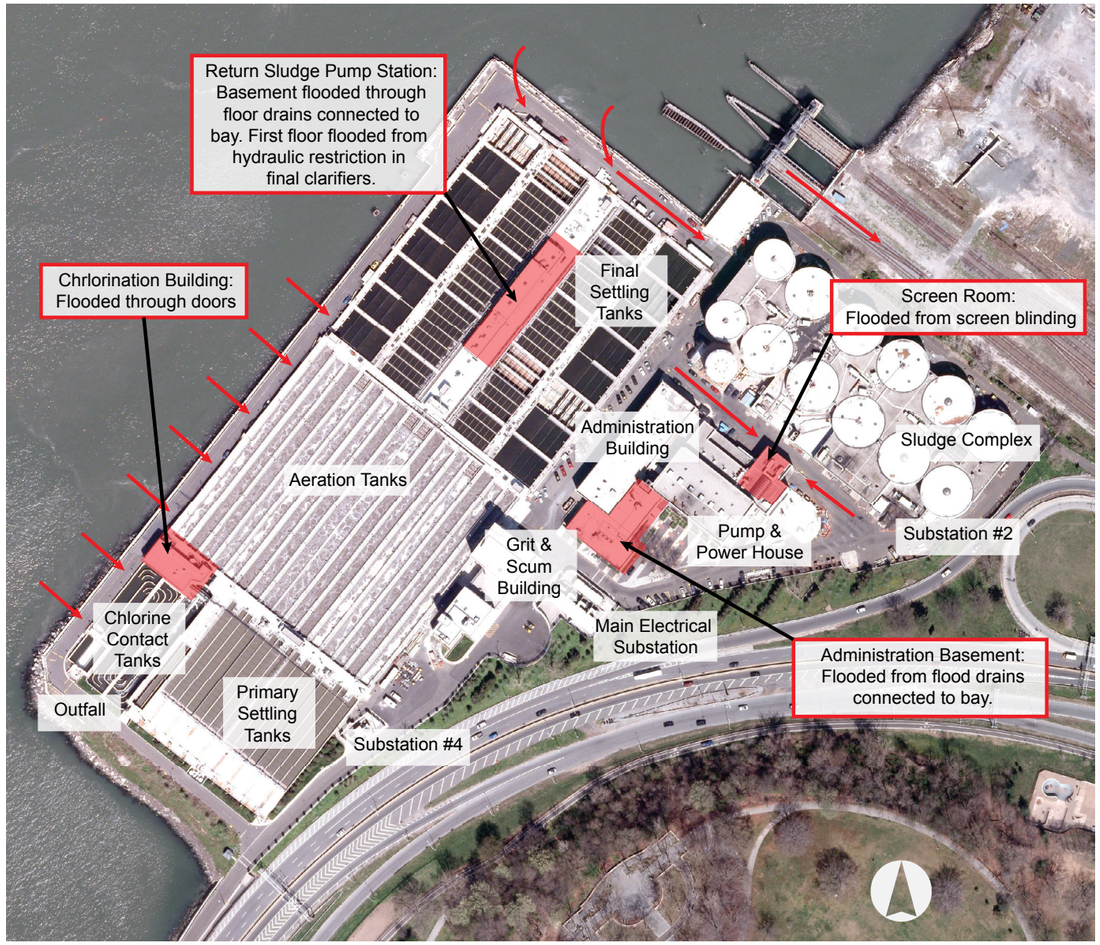
Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Administration Building	No Action Required	$0	$314,000	$0	No Protection
Chlorine Contact Tanks	Elevate Equipment	$45,000	$121,000	$69,000	Very High
Chlorination Building	Elevate Equipment and Seal Building	$1,284,000	$2,426,000	$12,031,000	High
Electrical Substation #2	Elevate Equipment	$394,000	$3,745,000	$1,210,000	Very High
Electrical Substation #4	Elevate Equipment and Construct Barrier	$1,146,000	$3,518,000	$1,379,000	Very High
Grit and Scum Building	Flood-proof Equipment	$34,000	$12,000	$12,000	High
Grit and Scum Tunnel	Flood-proof Equipment	$320,000	$733,000	$3,591,000	High
Main Electrical Substation	Elevate Equipment and Construct Barrier	$1,146,000	$4,271,000	$3,054,000	Very High
Primary Tank Tunnel	Flood-proof and Elevate	$3,218,000	$3,746,000	$18,382,000	High
Pump and Blower Building – Blower Room	Flood-proof Equipment and Seal Building	$2,963,000	$15,926,000	$71,289,000	Moderate
Solids Handling Complex	Seal Control Room	$460,000	$13,603,000	$47,795,000	Moderate
Total for All 11 At-Risk Locations		**$ 11.0 M**	**$ 48.4 M**	**$ 158.8 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

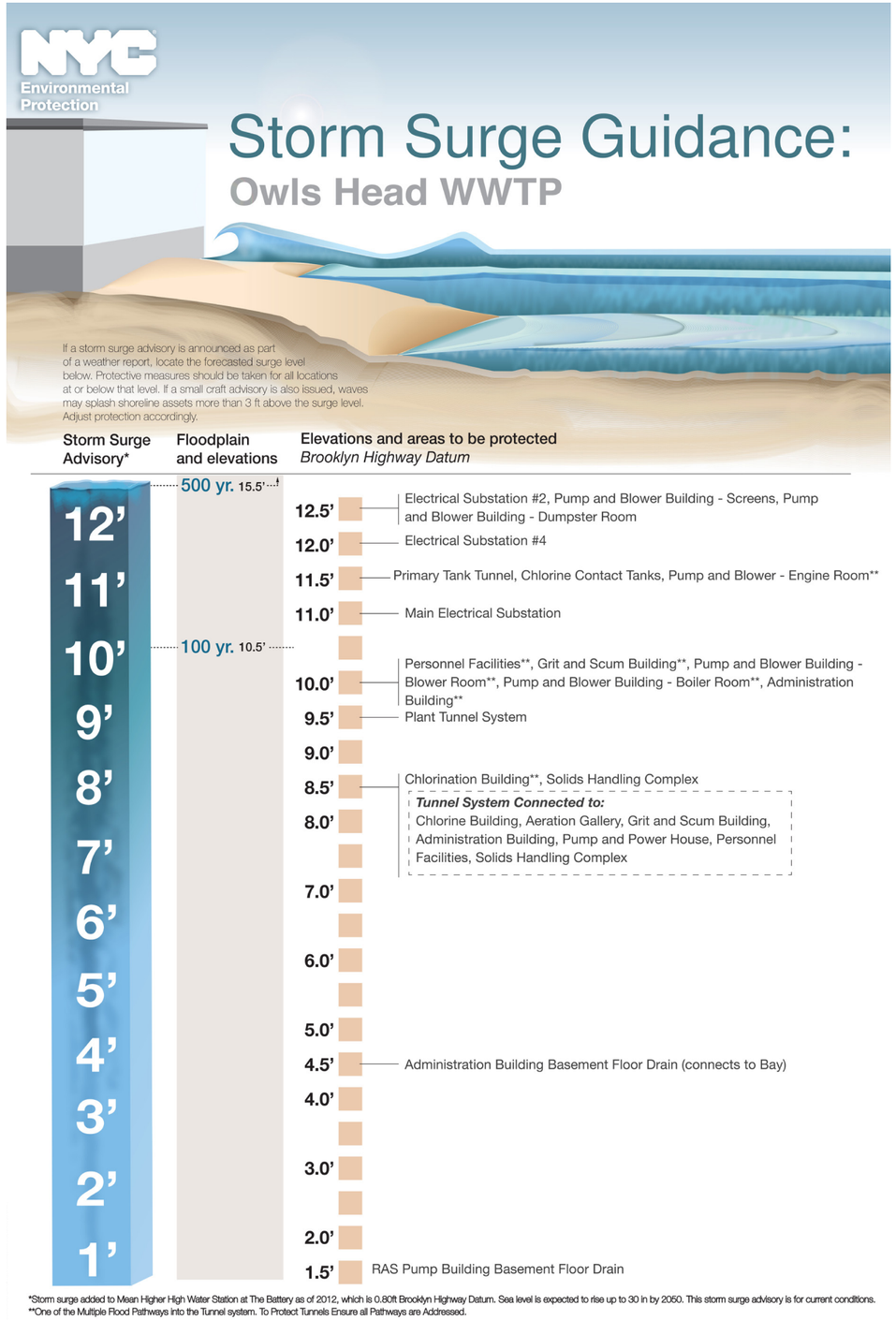
HURRICANE SANDY IMPACTS

Owls Head experienced major flooding as a result of Hurricane Sandy. During the peak of the storm, floodwaters rapidly entered the site over the bulkhead at the north and west sides of the plant. Additional flooding occurred overland as flow breached the railroad yard to the north, covering roadways around the Solids Handling Facility and Administration Building. Overland floodwater did not reach any of the exterior doors of the Administration Building, but the building's basement was flooded through a floor drain that backed up from the bay. Floodwater entered the plant's tunnel system which connects several buildings including the Chlorination Building and the Administration Building; however, flooding was confined to the Chlorination Building and did not reach the plant's main pumping equipment. Chemical-feed equipment for wastewater disinfection that is located in the basement of the Chlorination Building was flooded when sump pumps were unable to keep up with the rising water levels. Due to the high storm surge levels, both entrances to the plant were blocked which prevented staff from entering or exiting the site for two days after the storm.

Plant staff took precautions ahead of the storm which included sandbagging low-lying areas such as the Chlorination Building, Machine Shop, and Storage Room in the Administration Building. The plant lost power during the storm, but maintained normal wet weather operations using back-up generators. Plant staff successfully protected the Motor Control Centers located on the first floor of the disinfection facilities by opening the interior doorways to allow water to drain into the basement. The plant's ability to pump wastewater was uninterrupted during the storm event since the Pump and Blower Building and the plant's main pumping equipment were protected ahead of the storm.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Port Richmond Wastewater Treatment Plant

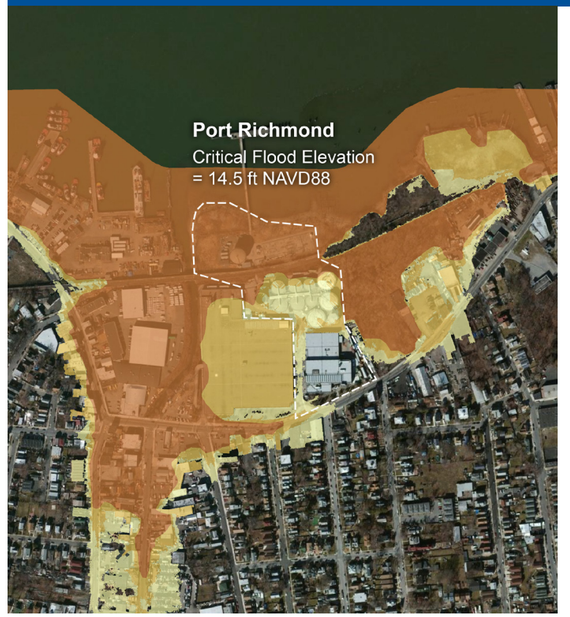
PLANT DESCRIPTION

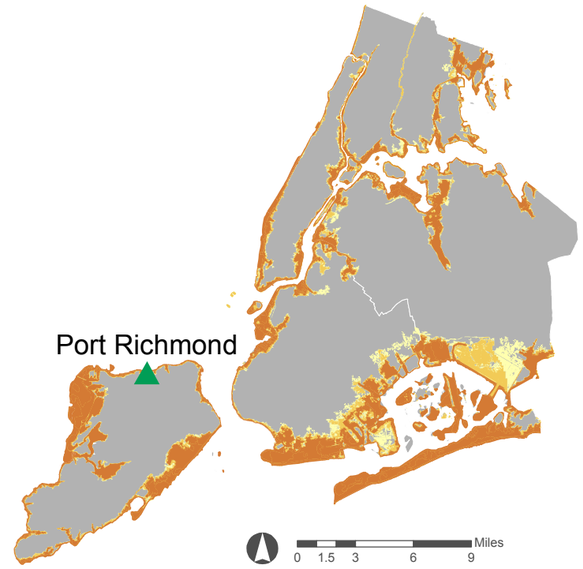
The Port Richmond Wastewater Treatment Plant is located at the intersection of Richmond Terrace and Bodine Street on the north side of Staten Island, NY. The plant abuts Richmond Terrace to the south, a creek to the west, and the Kill Van Kull waterway to the north. General plant characteristics for Port Richmond can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +14.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +1.9 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	No
Design Dry Weather Flow (MGD)	60
Maximum Wet Weather Flow (MGD)	120
Number of Residents Served	198,128
Discharge Waterbody	Kill Van Kull
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+14.5 ft NAVD88 (+12.4 ft Staten Island Datum)
Hurricane Sandy Flood Elevation	+12.1 ft NAVD88 (+10.0 ft Staten Island Datum)
Hurricane Sandy Flood Damage	Major
High Likelihood to Impact Beaches	No

FEMA Flood Zones near Port Richmond Wastewater Treatment Plant





2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Entrance to Main Building

Chlorine Contact Tanks are potentially at risk of flooding during a large storm event.

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Port Richmond. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since the plant has a relatively flat terrain, a few areas may be flooded with nearly 4 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 536 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power would be approximately $54.8 million.

ADAPTATION STRATEGIES

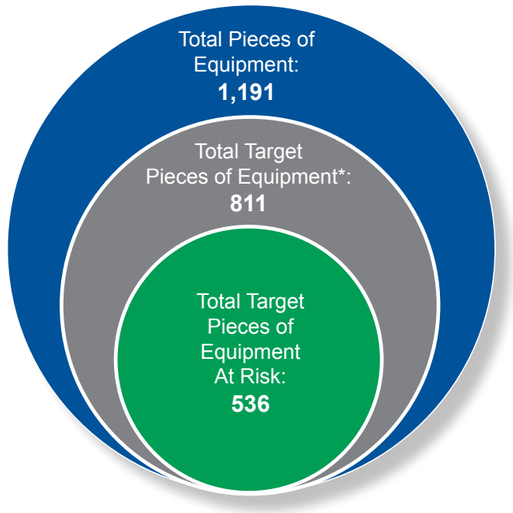
A combination of recommended strategies to reduce damage and recovery time after a surge event were proposed for each at-risk location at Port Richmond. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Since many of the at-risk areas at Port Richmond contain critical infrastructure, often elevating and flood-proofing were chosen as strategies since they provide a high degree of protection. In locations where not all infrastructure could be elevated or flood-proofed, additional strategies were chosen to protect openings into the plant areas. The Chlorine Contact Tanks, as the closest structure to the Kill Van Kull waterway, is the most at-risk from storm surge. In order to provide uninterrupted primary treatment operations, it is recommended to elevate the equipment around the Chlorine Contact Tanks to protect against floodwaters. It is also recommended to seal the building that houses the raw sewage pumps, and flood-proof equipment associated with raw sewage pumping and primary settling, to reduce the risk of flooding.

In total, the cost to implement all recommended strategies at Port Richmond is $10.4 million. This cost is relatively low considering that the potential damage cost that a large surge may impose totals $54.8 million. As the recommended strategies would also protect infrastructure during smaller events, the total value of risk avoided over a 50 year time span is estimated at $60.4 million, which is almost 6 times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Staten Island during flood events, reduce sewage bypasses, and protect public health.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

Table B: Port Richmond Adaptation Strategy Recommendations

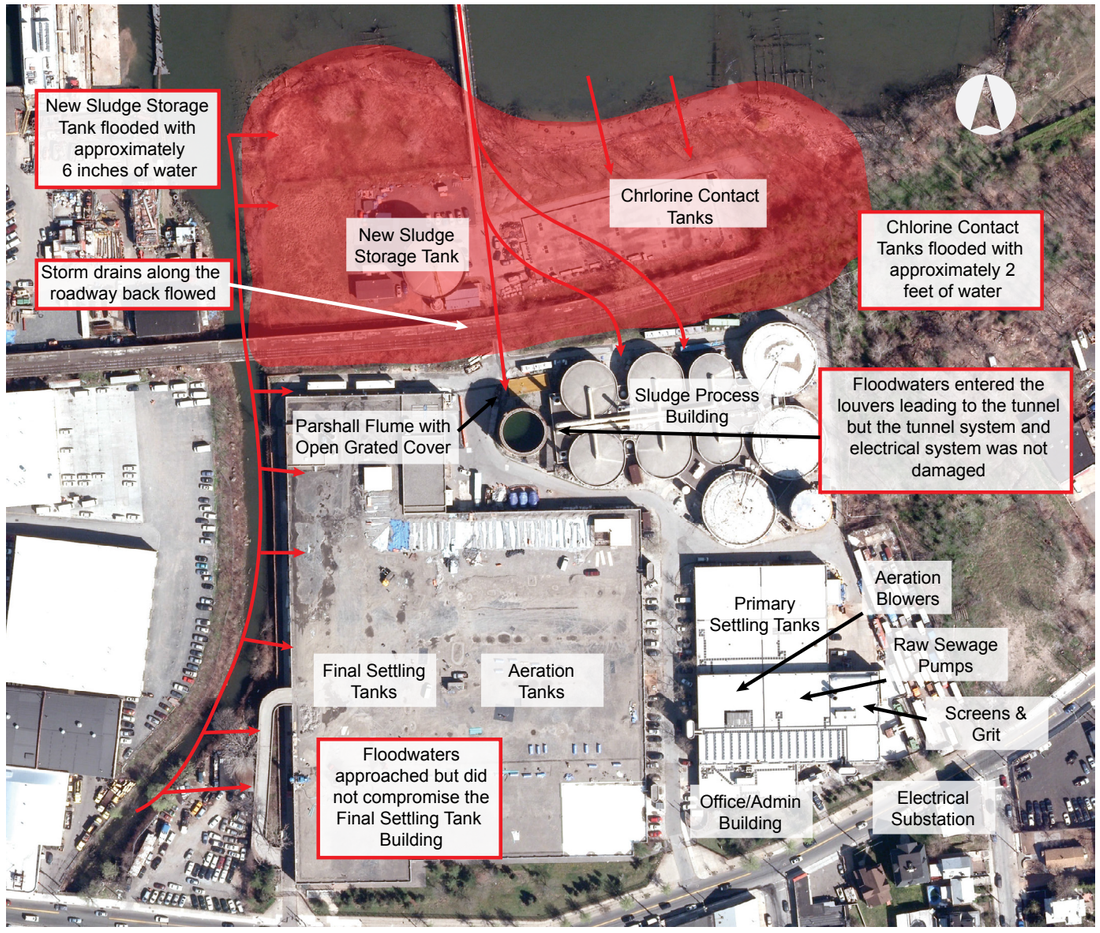
Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Aeration Blowers	Sandbag	$213,000	$1,371,000	$363,000	Moderate-Low
Chlorine Contact Tanks	Elevate Equipment	$63,000	$73,000	$380,000	Very High
Distributed Equipment	No Action Required	$0	$410,000	$0	No Protection
Electrical Substation	Elevate Equipment and Construct Barrier	$1,834,000	$6,129,000	$4,129,000	Very High
New Sludge Storage Tank	Construct Barrier	$347,000	$4,278,000	$20,920,000	High
Office / Admin Building	Construct Barrier	$482,000	$2,623,000	$776,000	High
Primary Settling Tank	Flood-proof Equipment	$2,214,000	$3,983,000	$974,000	High
Raw Sewage Pumps	Flood-proof Equipment and Seal Building	$2,127,000	$9,145,000	$2,204,000	Moderate
Screens and Grit	Flood-proof Equipment and Construct Barrier	$1,898,000	$9,761,000	$3,723,000	High
Service Tunnel 1 and 2	No Action Required	$0	$83,000	$0	No Protection
Sludge Process Building	Seal Building	$659,000	$14,851,000	$23,503,000	Moderate
Sludge Pumping Station	Seal Building	$557,000	$2,143, 000	$3,389,000	Moderate
Total for All 12 At-Risk Locations		**$ 10.4 M**	**$ 54.8 M**	**$ 60.4 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

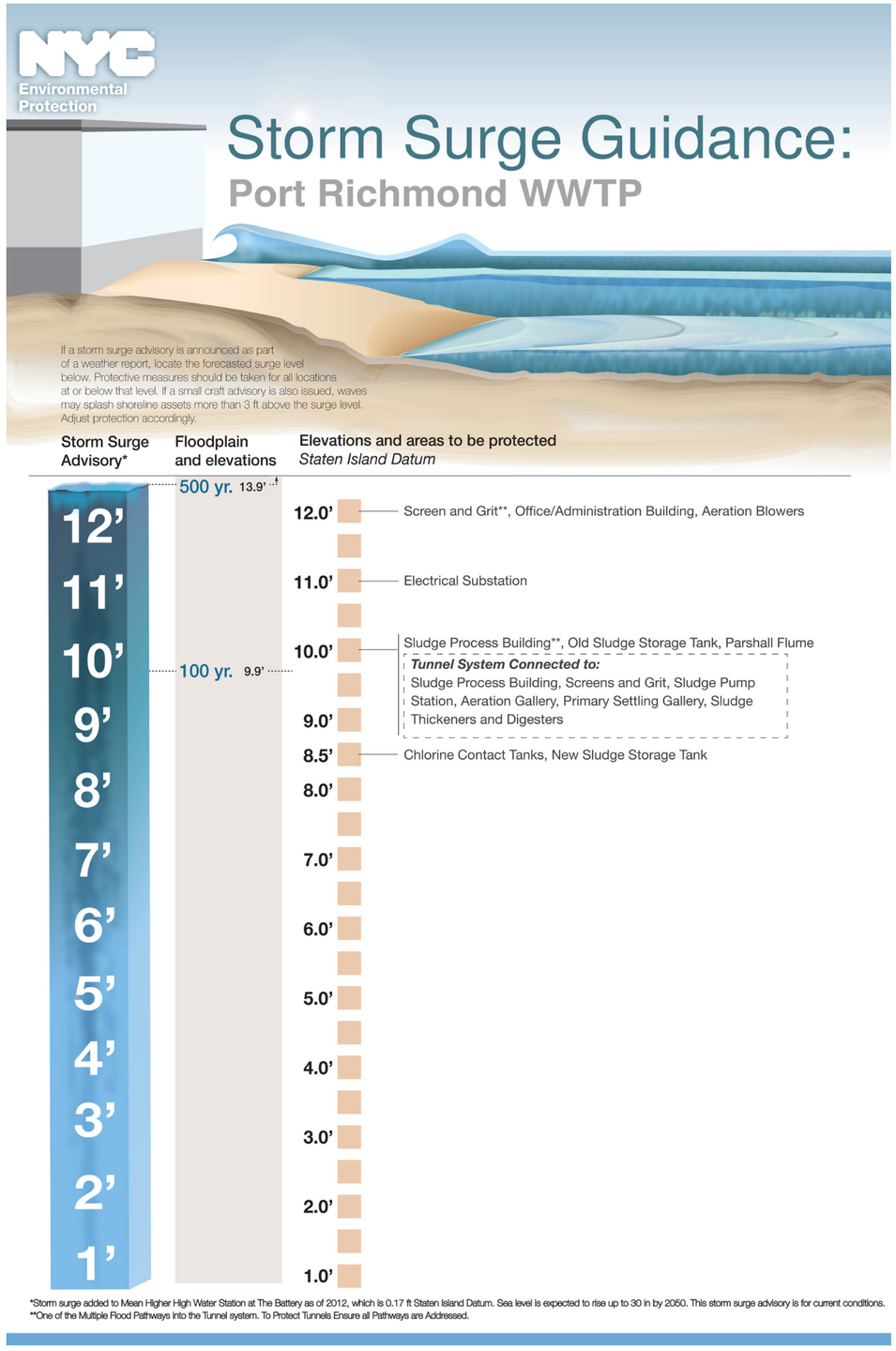
HURRICANE SANDY IMPACTS

Port Richmond experienced major flooding as a result of Hurricane Sandy. During the peak of the storm, floodwaters entered the site from the Kill Van Kull over the sea wall along the waterway. As water levels in the Kill Van Kull began to rise, initial flooding occurred due to backflow through storm sewers to the roadway adjacent to the new Sludge Storage Tank and Thickeners. Floodwaters also approached the Final Settling Tanks Building from the creek bank to the west of the plant, although water did not compromise the structure. Vehicular access was obstructed on the west side of the plant due to floodwaters. Floodwaters also entered the underground tunnel system through various pull-boxes and manholes, but significant flooding within the tunnel system was avoided. One power feed was lost, causing one of the boilers to shut down, but the flood levels did not reach levels that would immediately damage Motor Control Centers and other electrical equipment.

The plant staff worked actively before, during, and after the storm to protect the plant and quickly resume normal operation. Just prior to the hurricane, plant staff placed sandbags at multiple locations on the site. Sandbag placement at the New Sludge Storage Facility provided adequate protection and only allowed a minimal amount of water to enter the building, protecting pumps and most electrical equipment. Large intake louvers to the heaters located on the west side of the Sludge Process Building were also protected with sandbags, which prevented water from entering the tunnel system. Power was out for three days, and the on-site generator was used to power the primary treatment facilities during that time.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Red Hook Wastewater Treatment Plant

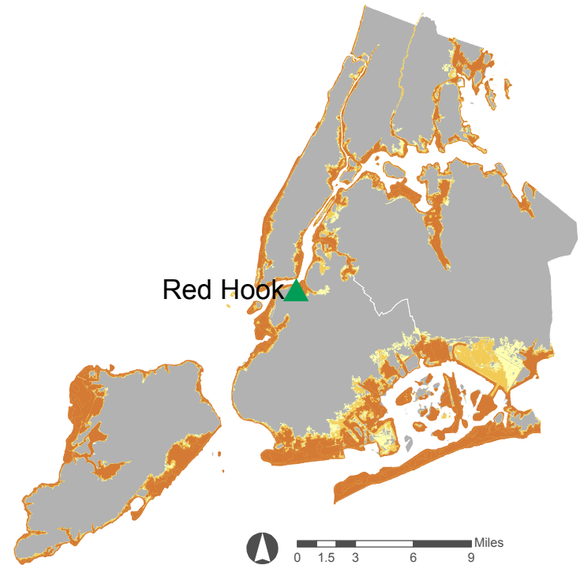
PLANT DESCRIPTION

The Red Hook Wastewater Treatment Plant is located at the former Brooklyn Navy Yard in northwestern Brooklyn, Community District 6. The plant abuts the Lower East River on the north, West Street to the west, Ship Ways to the south, and the East Way and the Lower East River to the east. General plant characteristics for Red Hook can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +14.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.3 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	Yes
Design Dry Weather Flow (MGD)	60
Maximum Wet Weather Flow (MGD)	120
Number of Residents Served	192,050
Discharge Waterbody	Lower East River
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+14.5 ft NAVD88 (+13.0 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Elevation	+11.7 ft NAVD88 (+10.2 ft Brooklyn Highway Datum)
Hurricane Sandy Flood Damage	Minor
High Likelihood to Impact Beaches	No

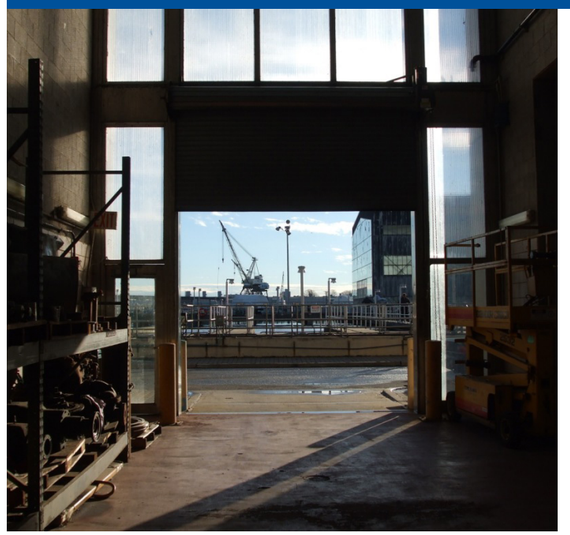
FEMA Flood Zones near Red Hook Wastewater Treatment Plant



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways



Rollup doors at the Main Building

Fencing surrounding the outdoor Electrical Substation

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Red Hook. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation.

While much of the plant was unaffected during Hurricane Sandy, because the critical flood elevation is approximately 3 feet higher than the recorded Sandy elevation, most of the plant is projected to be flooded in the critical flood event. Most locations will be flooded with a foot of water or less; however, the Truck Loading Area and Ferric Chloride Storage Area may be flooded with up to 6 feet of water.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 1,281 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment. Of particular concern are many of the pumps which convey sewage and sludge through the plant. This equipment is located below ground in the tunnel system, which is at-risk through a number of pathways, including vaults, conduits, and the Solids Handling Facility near the northern seawall that flooded during Hurricane Sandy.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power, would be approximately $67.4 million.

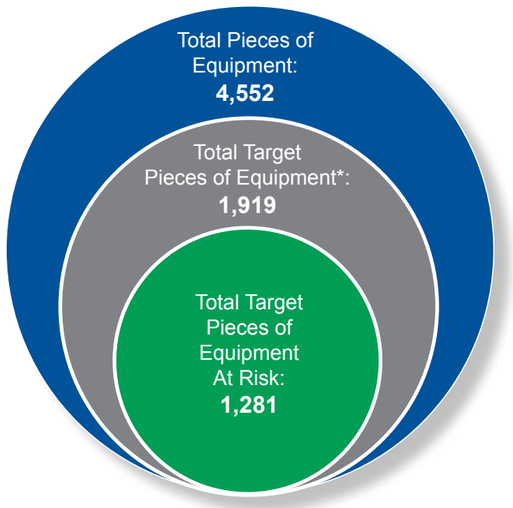
ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Red Hook. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Since many of the at-risk areas at Red Hook contain critical infrastructure, often elevating and flood-proofing were chosen as strategies since they provide a high degree of protection. In locations where not all infrastructure could be elevated or flood-proofed, additional strategies were chosen that protect openings into the plant areas. Given the space constraints within basements and the tunnel system, it is recommended that the transfer pumps be replaced with submersible pumps at the end of their life cycle. In the interim, as applicable depending on location, the infrastructure can be effectively protected by sandbagging, providing watertight doors, or constructing barriers across flood pathways. In particular, the Thickener and Centrifuge Buildings can be protected to reduce the likelihood of flooding in the tunnels.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

In total, the cost to implement all recommended strategies at Red Hook is $18.6 million. While this cost is high, the potential damage cost that a large surge may impose totals $67.4 million. As the recommended strategies would also protect infrastructure during smaller storm events, the total value of risk avoided over a 50-year time span is estimated at $25 million, which is 33 percent more than the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Brooklyn during flood events, reduce sewage bypasses, and protect public health.

Table B: Red Hook Adaptation Strategy Recommendations

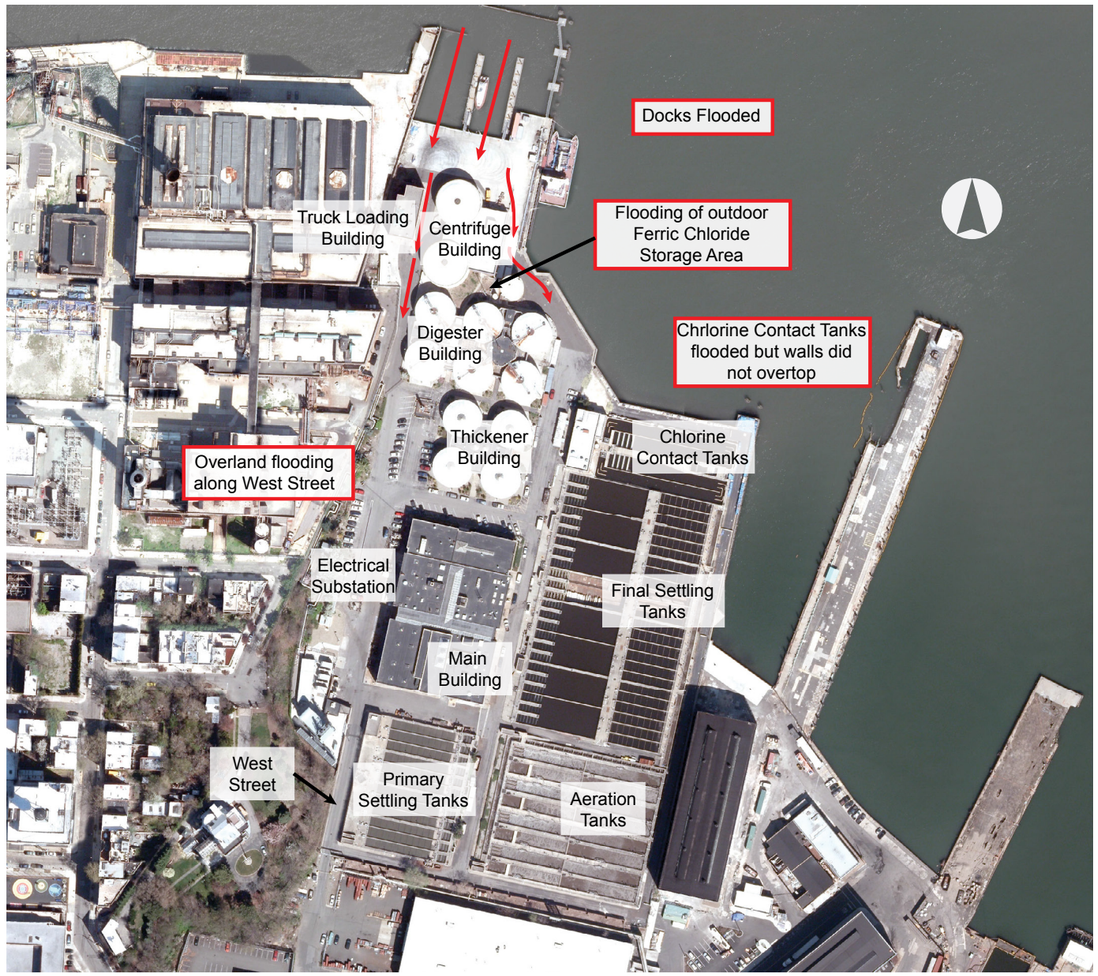
Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Aeration Tanks	No Action Required	$0	$301,000	$0	No Protection
Chlorine Contact Tanks	Elevate Equipment	$44,000	$24,000	$11,000	Very High
Centrifuge Building	Sandbag	$320,000	$5,061,000	$1,571,000	Moderate-Low
Chlorination Building	Elevate Equipment	$511,000	$651,000	$220,000	Very High
Digester Building	Seal Building	$557,000	$7,068,000	$2,324,000	Moderate
Electrical Substation	Elevate Equipment and Construct Barrier	$993,000	$8,220,000	$3,842,000	Very High
Main Building	Elevate Equipment and Seal Building	$8,896,000	$33,561,000	$11,998,000	High
Primary Settling Tank	Flood-proof Equipment and Construct Barrier	$5,891,000	$4,635,000	$2,448,000	Very High
Thickener Building	Flood-proof Equipment and Seal Building	$1,352,000	$7,299,000	$2,536,000	High
Truck Loading Building	No Action Required	$0	$556,000	$0	No Protection
Total for All 10 At-Risk Locations		**$ 18.6 M**	**$ 67.4 M**	**$ 25.0 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

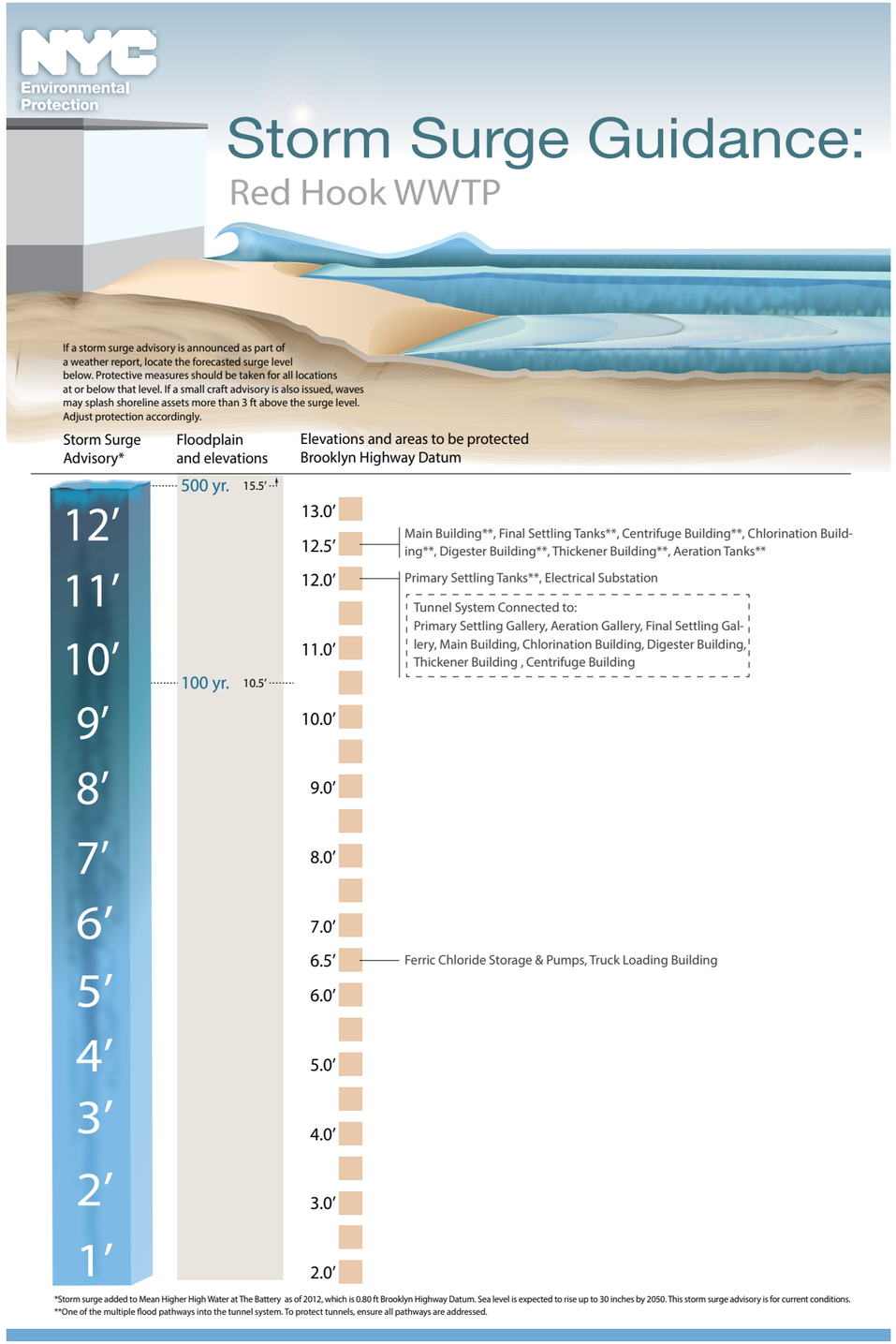
HURRICANE SANDY IMPACTS

Red Hook experienced minor flooding as a result of Hurricane Sandy. During the peak of the storm, floodwaters entered the plant from the northern seawall, flooding the barge docks and the Ferric Chloride Storage Area with over 3.5 feet of flood water. Overland flooding occurred along West Street near the Sludge Storage Tanks, Gas Holder Tank, and Sludge Digester Building near the Digester and Thickener Tanks. Floodwaters did not reach the Main Building or Solids Handling Facility, both of which contain numerous pumps and electrical equipment.

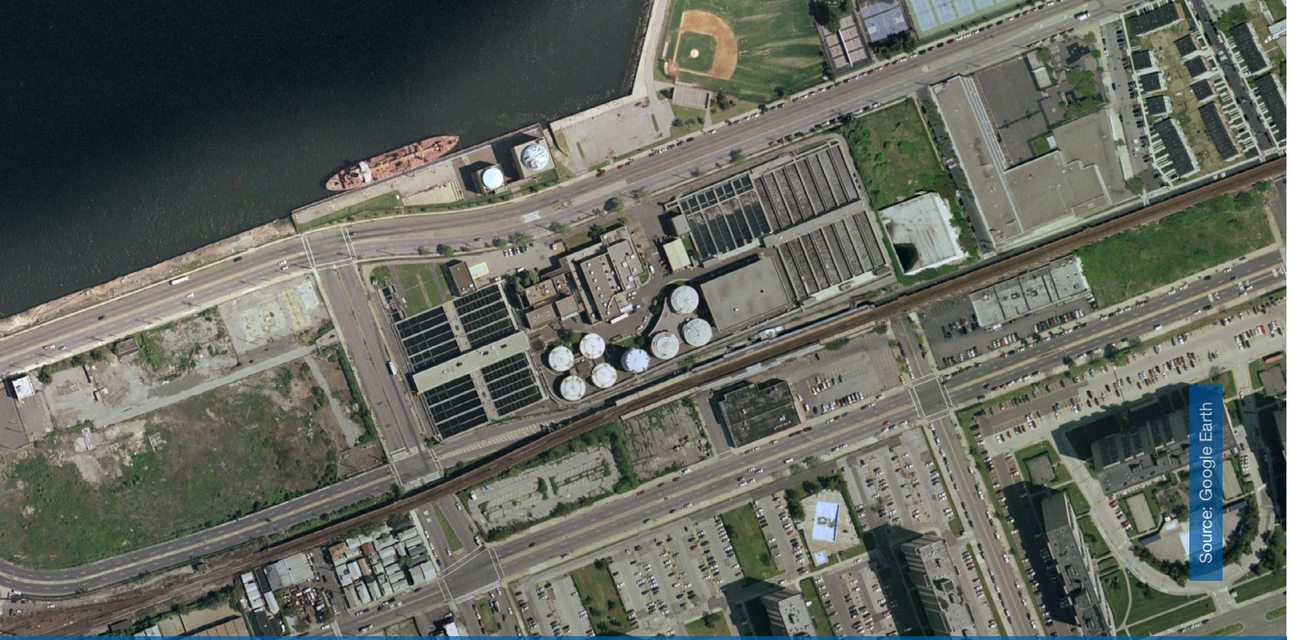
Floodwater that entered through the plant outfall caused build up in the Chlorine Contact Tanks, but did not overtop the tank walls. The plant staff worked actively before, during, and after the storm to protect the plant by sandbagging doors in locations at the north end of the plant, including the Sludge Storage Tanks, Dewatered Sludge Truck Loading Building, Centrifuge Building and Digester Building. Critical equipment needed to perform basic (primary) treatment at the plant was not damaged.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.



Rockaway Wastewater Treatment Plant

PLANT DESCRIPTION

The Rockaway Wastewater Treatment Plant is located on Beach Channel Drive on the south side of Rockaway, NY. The plant abuts Rockaway Freeway to the south, Beach Channel Drive to the north, and lies between Beach 108th Street and Beach 104th Street. The plant is located between two waterbodies, Jamaica Bay to the north and the Atlantic Ocean to the south. General plant characteristics for Rockaway can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +14.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +2.4 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	No
Design Dry Weather Flow (MGD)	45
Maximum Wet Weather Flow (MGD)	90
Number of Residents Served	90,474
Discharge Waterbody	Jamaica Bay
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+14.5 ft NAVD88 (+12.9 ft Queens Datum)
Hurricane Sandy Flood Elevation	+11.4 ft NAVD88 (+9.8 ft Queens Datum)
Hurricane Sandy Flood Damage	Major
High Likelihood to Impact Beaches	Yes

FEMA Flood Zones near Rockaway Wastewater Treatment Plant

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Rollup doors on the Sludge Storage Building adjacent to Jamaica Bay are potential pathways for flooding as experienced during Hurricane Sandy. The Sludge Storage Building is also an access point into the plant's interconnected tunnel system.

Rollup doors at the Electrical Substation Building

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Rockaway. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation.

Since the plant has a relatively flat terrain and it is located between two waterbodies, several areas may be flooded by up to 7 feet of water during the critical flood event. There is also an extensive underground tunnel system that connects all locations (except the Electrical Substation and the Heating Plant) that can convey water throughout the plant if not properly protected. The main at-risk pathways to the tunnel are doorways in the new and old Sludge Storage Buildings, which will require robust protection. Lastly, a number of open tanks would be flooded during the critical flood, and could contribute to cleanup costs on site.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 689 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment.

Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power, would be approximately $49.3 million.

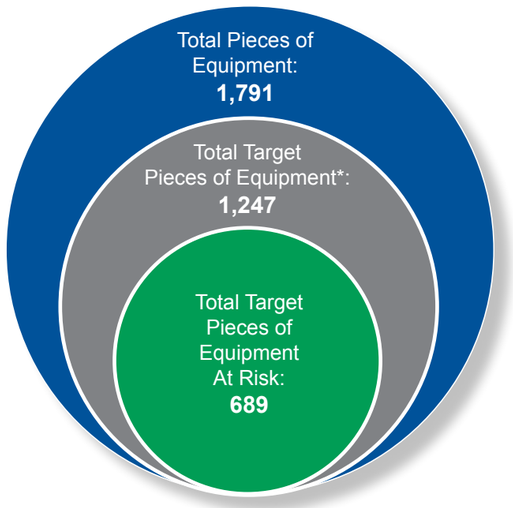
ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Rockaway. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Since many of the at-risk areas at Rockaway contain critical infrastructure, often elevating equipment was the chosen strategy since it provides a high degree of protection. In locations where not all infrastructure could be elevated, additional strategies were chosen that protect openings into the plant areas. For example, since Rockaway is susceptible to flood damage from an interconnected, underground tunnel system, constructing barriers around grates and hatches leading into the tunnel is recommended. These barriers, combined with watertight doors and windows in buildings with basements leading to the tunnels, will greatly reduce the plant's risk and prevent floodwaters from traveling throughout the plant, and damaging target pieces of equipment. In addition, when replacing old pumps, plant staff may consider installing submersible pumps to provide further resiliency.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

DEP is also investigating the feasibility and logistics of converting Rockaway into a pumping station, amongst other alternatives, which may reduce the need to fund substantial capital projects to heavily protect and reinforce many of the buildings and equipment on site. Regardless of the alternative selected, some resiliency upgrades will likely be needed at Rockaway.

If all recommended resiliency upgrades are implemented at the Rockaway Wastewater Treatment Plant, the total cost of implementation is $15.1 million. While this cost is high, the potential damage cost that a large surge may impose totals $49.3 million. Furthermore, since Rockaway is at a relatively low elevation, smaller flood events could affect this site. As the recommended strategies would also protect infrastructure during these smaller events, the total value of risk avoided over a 50-year time span is estimated at $198.1million, which is more than 13 times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Queens during flood events, reduce sewage bypasses, and protect public health.

Table B: Rockaway Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Chlorination Building	Elevate Equipment	$2,048,000	$1,729,000	$8,900,000	Very High
Chlorine Contact Tanks (N. of Beach Channel Dr.)	Elevate Equipment	$58,000	$127,000	$660,000	Very High
Electrical Substation	Elevate Equipment and Construct Barrier	$1,604,000	$4,558,000	$23,453,000	Very High
Final Setting Tanks	No Action Required	$0	$1,382,000	$0	No Protection
Heating Plant	Elevate Equipment	$37,000	$1,169,000	$815,000	Low
Main Sewage Pump Station	Seal Building	$751,000	$5,135,000	$23,778,000	Moderate
New Digester Building	No Action Required	$0	$1,139,000	$0	No Protection
New Sludge Storage Building	Seal Building	$493,000	$404,000	$1,872,000	Moderate
Old Digester Building	Sandbag	$158,000	$1,569,000	$662,000	Moderate-Low
Primary Scum Building	Flood-proof and Elevate	$2,142,000	$2,872,000	$14,270,000	High
Pump and Compressor Building	Elevate Equipment and Seal Building	$2,594,000	$9,694,000	$48,094,000	High
Return and Waste Sludge Pump Building	Elevate Equipment and Seal Building	$3,147,000	$8,248,000	$40,822,000	High
Sludge Thickener Building	Seal Building	$1,332,000	$7,300,000	$33,804,000	Moderate
Tunnels	Construct Barrier	$752,000	$3,957,000	$967,000	High
Total for All 14 At-Risk Locations		**$ 15.1 M**	**$ 49.3 M**	**$ 198.1 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

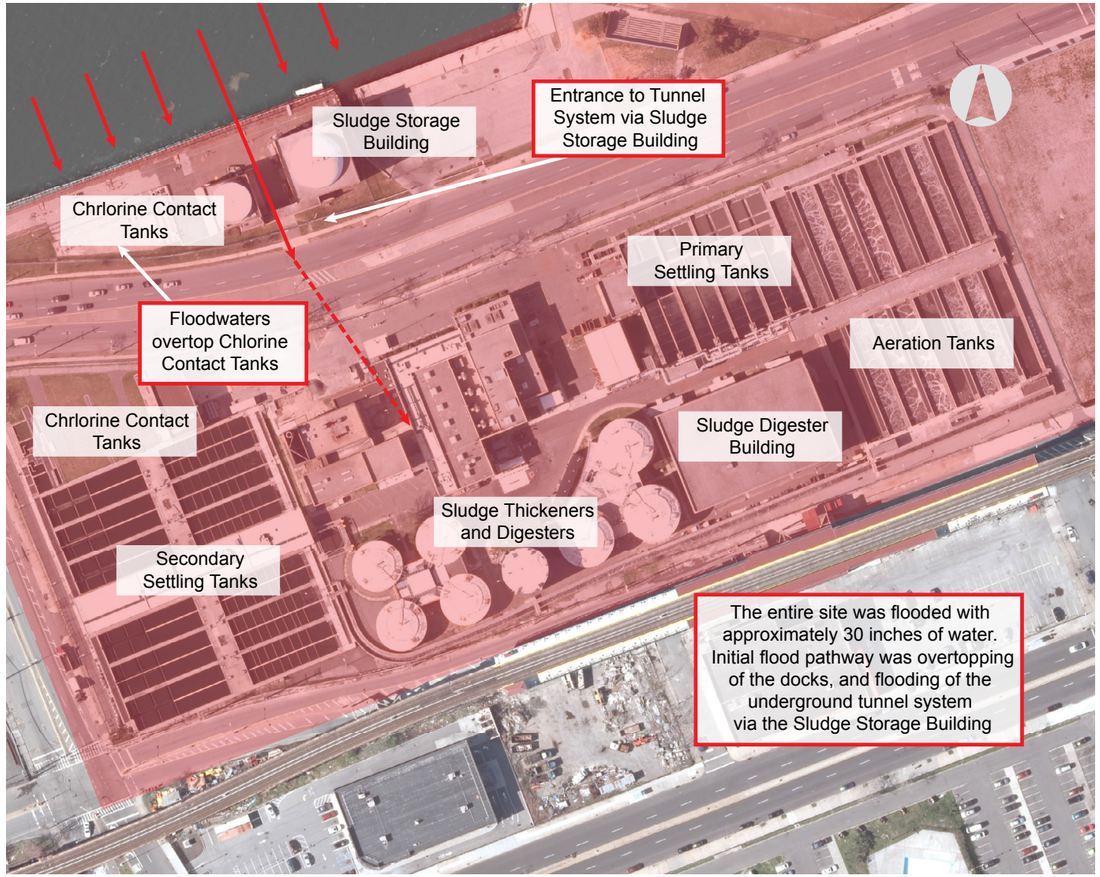
HURRICANE SANDY IMPACTS

Rockaway experienced major flooding as a result of Hurricane Sandy. During the peak of the storm, storm surge water from Jamaica Bay entered the plant by overtopping the dock on the north side of the plant. Initially, water flooded the underground tunnel system via doorways and conduits in the Solids Storage Facility, and as the storm progressed, floodwater traveled over Beach Channel Drive and into the plant, flooding the entire site with approximately 30 inches of water. Due to the plant's interconnected underground tunnel system, all equipment located in the basement levels of plant buildings endured significant damage. The main sewage pumps and their control systems were damaged, aeration piping in basements was detached from its supports, numerous motors and sludge transfer pumps were submerged, and electrical equipment and conduits in the tunnels were exposed to floodwaters (which willl likely advance their corrosion over time). Plant staff took precautions ahead of the storm by placing sandbags at all doorways and rollup doors, but due to numerous access ways into the tunnel system, and the significant amount of floodwater that entered the plant, the sandbags were not adequate to protect the buildings.

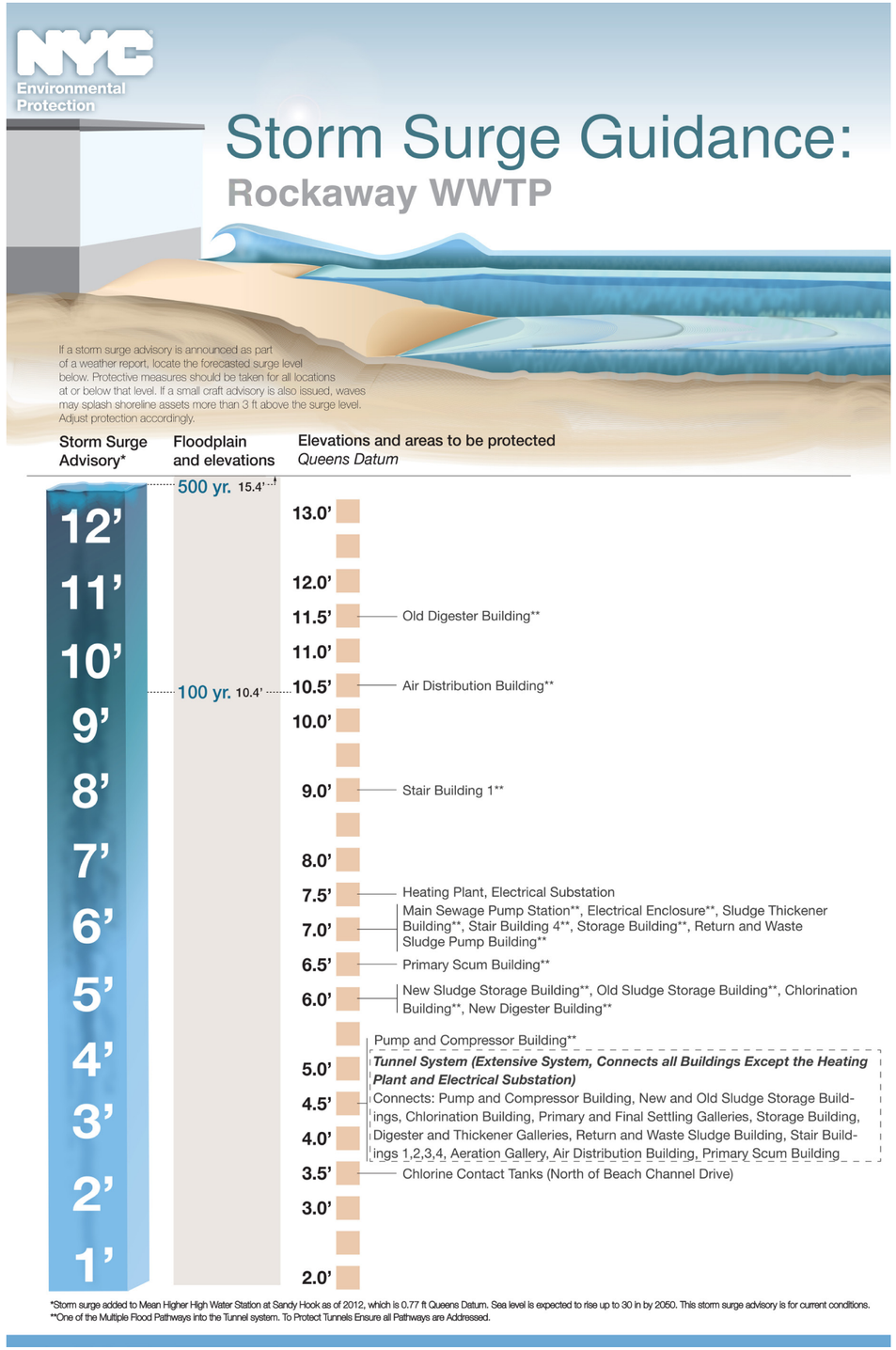
Following the flood event, major dewatering and temporary pumping operations were required. In addition, major equipment replacement and repair commenced.

Based on the flood damages incurred during this storm surge, it is evident that a comprehensive adaptation plan will be required to protect the plant under the critical flood elevation, which is approximately 3 feet higher than the elevation experienced during Hurricane Sandy.

DEP is also investigating the feasibility and logistics of converting Rockaway into a pumping station, amongst other alternatives, which would reduce the need to fund substantial capital projects to heavily protect and reinforce many of the buildings on site.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Tallman Island Wastewater Treatment Plant

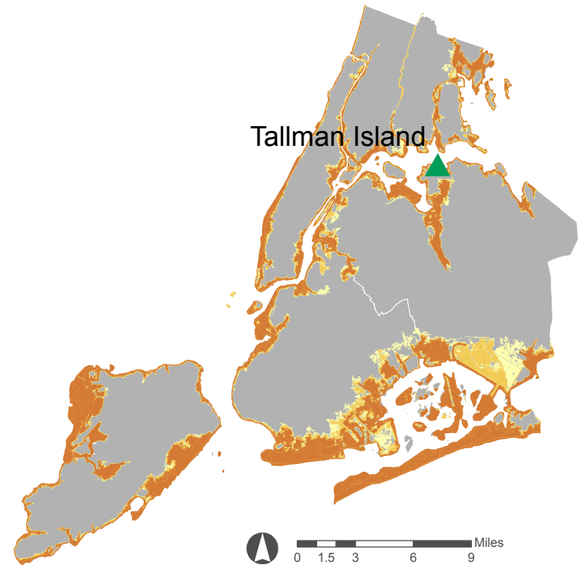
PLANT DESCRIPTION

The Tallman Island Wastewater Treatment Plant is located on a 31-acre site at 127-01 Powell's Cove Boulevard, College Point, in north central Queens, Community District 7. The plant abuts Powell's Cove Boulevard and residential areas to the south, a marina and boatyard to the west, Powell's Cove to the east, and the East River to the north. General plant characteristics for Tallman Island can be found in Table A. The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater at the plant may reach +15.5 feet NAVD88. In contrast, the typical high tide elevation nearby is +8.5 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	Yes
Design Dry Weather Flow (MGD)	80
Maximum Wet Weather Flow (MGD)	120
Number of Residents Served	410,812
Discharge Waterbody	East River
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	+15.5 ft NAVD88 (+13.9 ft Queens Highway Datum)
Hurricane Sandy Flood Elevation	+10.1 ft NAVD88 (+8.5 ft Queens Highway Datum)
Hurricane Sandy Flood Damage	Minor
High Likelihood to Impact Beaches	No

FEMA Flood Zones near Tallman Island Wastewater Treatment Plant



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Grate and windows leading to the basement of the Sludge Thickener Building and tunnel system

Basement access ways into the Chlorine Building

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood event at Tallman Island. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation. Since the plant has a relatively flat terrain on the north, some areas may be flooded by up to 7 feet of water during the critical flood event.

An infrastructure-level assessment identified whether certain pieces of equipment needed to meet basic levels of service are located in plant areas that are at risk. There is a total of 773 target pieces of equipment located in these at-risk facilities that are below the critical flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment. Of particular note, various critical pumps are located in the basements of a number of buildings, including the Preliminary Sludge Pump Station, Digesters, North and South Thickener Buildings, and Grit Building, all of which are connected by a tunnel system. In addition, both the Final Settling and Chlorination Tanks would be flooded. Table B provides a complete list of plant areas containing critical equipment at risk in the 100-year flood with 30 inches of sea level rise. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power, would be approximately $45.2 million.

ADAPTATION STRATEGIES

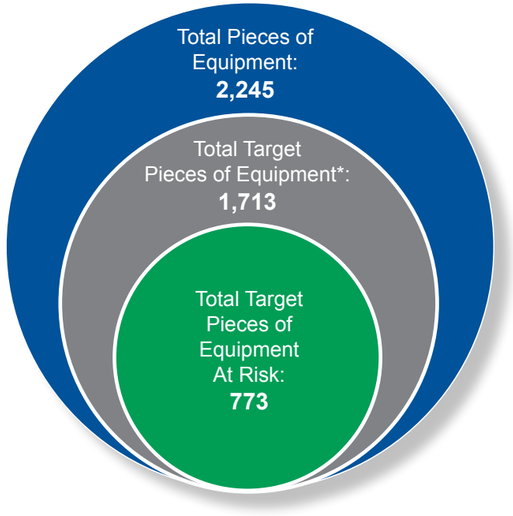
A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Tallman Island. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

Since many of the at-risk areas at Tallman Island contain critical infrastructure, often elevating and flood-proofing were chosen as strategies since they provide a high degree of protection. In locations where not all infrastructure could be elevated or flood-proofed, additional strategies were chosen that protect openings into the plant areas.

The Chlorine Building, in particular, requires robust protection as it would experience several feet of flooding under the critical flood event and contains numerous pieces of equipment needed to disinfect wastewater. As such, waterproofing chemical feed pumps and sealing the building with water-tight windows and doors is recommended. Likewise, the Grit Building and Thickener Building are also key locations that require several protection measures, since they have thresholds below the critical flood which lead to the tunnel system.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

In total, the cost to implement all recommended strategies at Tallman Island is $11 million. While this cost is high, the potential damage cost that a large surge may impose totals $45.2 million. As the recommended strategies would also protect infrastructure during smaller storm events, the total value of risk avoided over a 50-year time span is estimated at $32.8 million, which is approximately three times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Queens during flood events, reduce sewage bypasses, and protect public health.

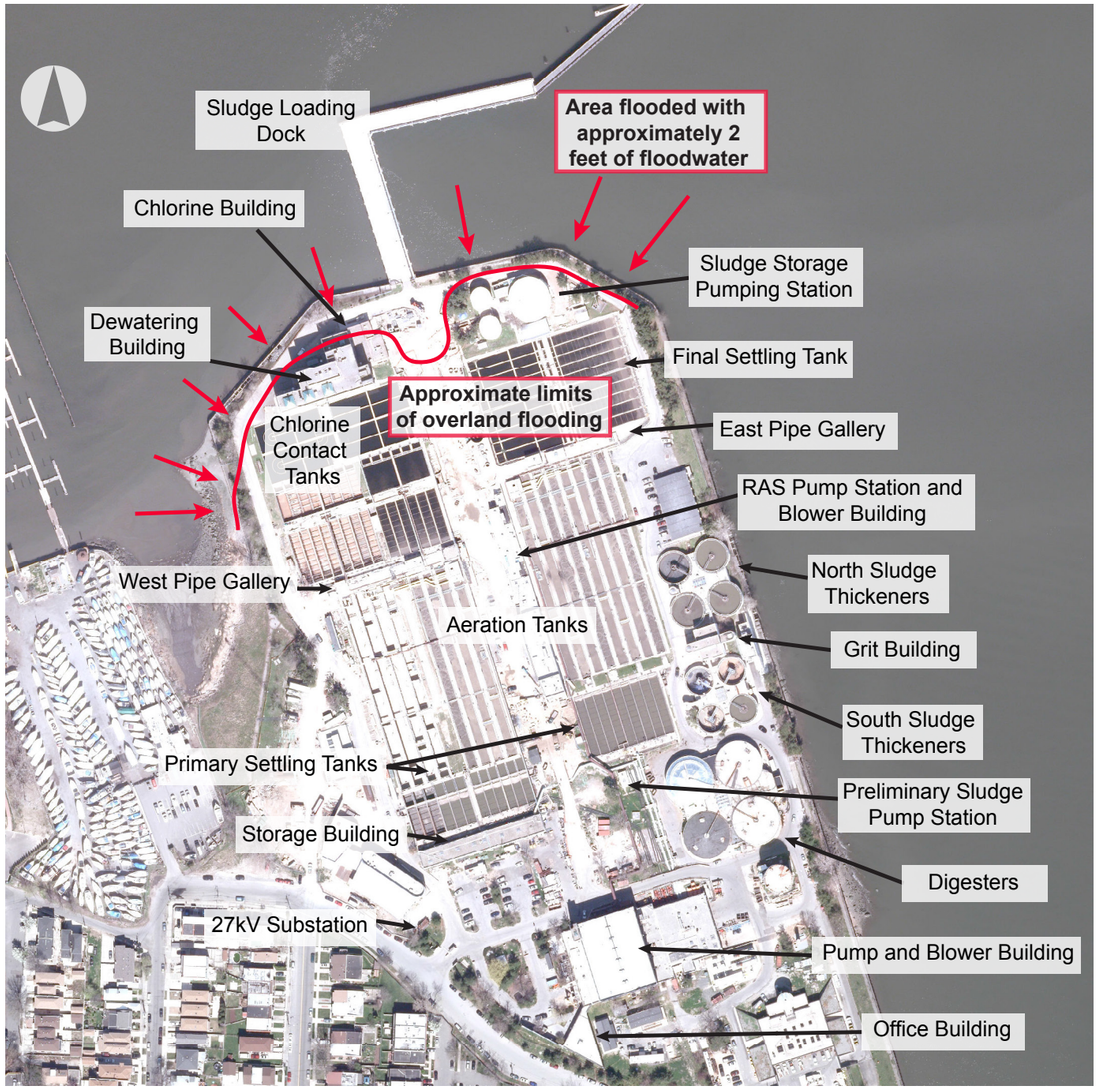
Table B: Tallman Island Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Chlorine Building	Flood-proof Equipment and Seal Building	$1,792,000	$1,298,000	$6,372,000	High
Chlorine Contact Tanks	Elevate Equipment	$37,000	$84,000	$28,000	Very High
Dewatering Building	Seal Control Room	$460,000	$11,023,000	$3,799,000	Moderate
Final Settling Tank	No Action Required	$0	$2,162,000	$0	No Protection
Grit Building	Sandbag	$320,000	$542,000	$190,000	Low
Mixed Flow Pump Station	Flood-proof and Elevate and Construct Barrier	$846,000	$1,550,000	$5,045,000	High
Sludge Storage Tanks	Construct Barrier	$347,000	$2,833,000	$7,037,000	High
South and North Thickener Buildings	Seal Building	$804,000	$12,163,000	$4,531,000	Moderate
Storage Building	Flood-proof and Elevate and Seal Building	$6,417,000	$13,521,000	$5,800,000	Very High
Total for All 9 At-Risk Locations		**$ 11.0 M**	**$ 45.2 M**	**$ 32.8 M**	

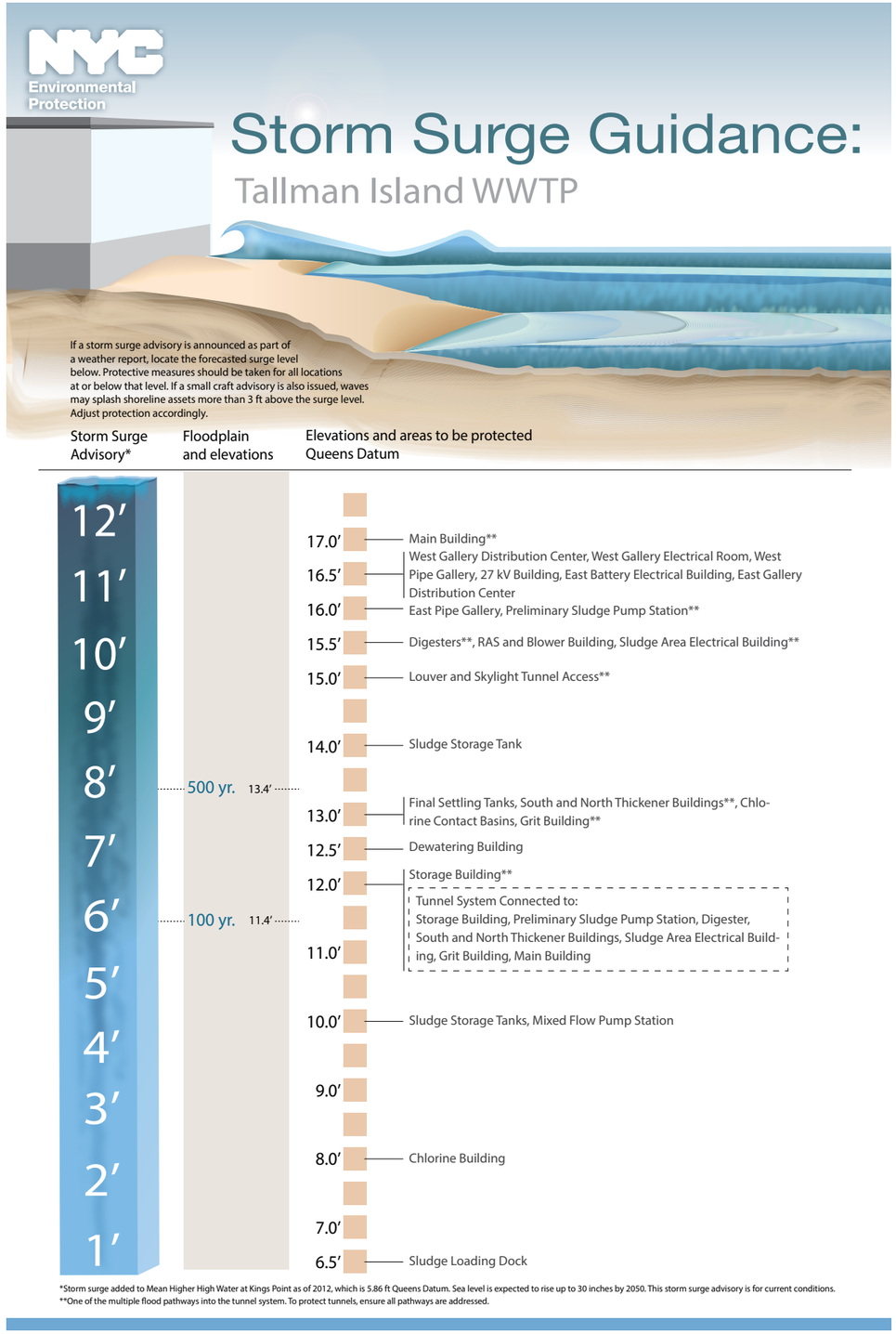
1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

HURRICANE SANDY IMPACTS

Tallman Island experienced minor flooding as a result of Hurricane Sandy. During the peak of the storm, floodwater submerged the sludge loading dock and inundated the roadway along the north end of the plant along the waterfront. Rising waters also encroached upon the central plant roadway, and approached the doorway of the Sludge Storage Building and some transformers mounted on pads next to the building; however, no damage was incurred. Floodwaters did enter the Chlorine Building through a few doors and basement access ways. However, flooding was reduced by plant staff who took precautions ahead of the storm by placing temporary slide gates and sandbags coupled with concrete traffic barriers across flood pathways. In addition, the sump pumps within the Chlorine Building maintained operation during the flood and no equipment in the building was significantly affected. While the plant did not endure significant flood damage, the wooden boardwalk surrounding the plant was severely damaged in the areas where the storm surge overtopped the perimeter bulkhead.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

Wards Island Wastewater Treatment Plant

PLANT DESCRIPTION

The Wards Island Wastewater Treatment Plant is located on the southwest side of Randall's and Wards Island between the Harlem and East Rivers. The plant occupies approximately a quarter of the island's total land area and is part of the borough of Manhattan, Community District 11. The plant abuts the New York City Fire Department Training Academy on the north and Hell Gate Circle to the south and west. The East River separates the site from Queens to the east.

Before entering the plant, sewage is pumped and screened at the Manhattan and Bronx Grit Chambers. The Manhattan Grit Chamber is at the eastern end of 110th Street in Manhattan, next to the FDR Drive. The Bronx Grit Chamber is located in the Bronx at 158 Bruckner Blvd, adjacent to 133rd Street. General plant characteristics for Wards Island can be found in Table A.

Table A: Wastewater Treatment Plant Characteristics

Characteristic	Value
Plant Type	Activated Sludge
Dewatering Facilities	Yes
Design Dry Weather Flow (MGD)	275
Maximum Wet Weather Flow (MGD)	550
Number of Residents Served	1,061,558
Discharge Waterbody	Upper East River
Critical 100-year Flood Elevation + 30 inches of Sea Level Rise	Wards Island and Manhattan Grit Chamber: +17.5 ft NAVD88 (+15.8 ft Manhattan Highway Datum) Bronx Grit Chamber: +14.5 ft NAVD88 (+13.0 ft Bronx Datum)
Hurricane Sandy Flood Elevation	+10.7 ft NAVD88
Hurricane Sandy Flood Damage	Minor
High Likelihood to Impact Beaches	No

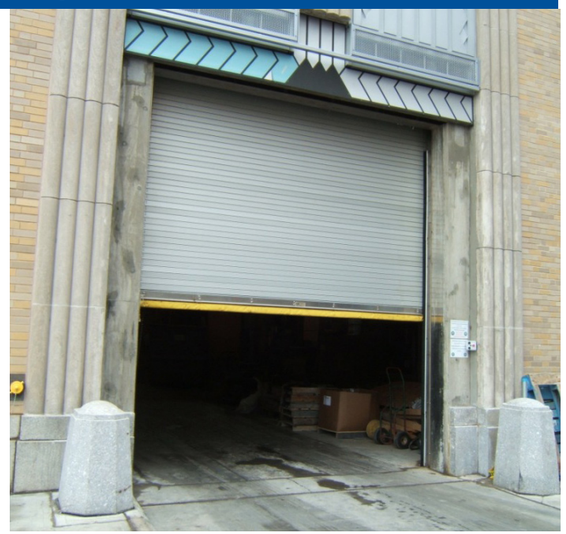
FEMA Flood Zones near Wards Island Wastewater Treatment Plant

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Flood Pathways

Access door leading to the equipment rooms in the Sludge Storage Tank Building



This rollup door at the Manhattan Grit Chamber was a pathway for flooding during Hurricane Sandy and may be flooded during the critical flood event.

The critical flood elevation used in the analysis is the FEMA March 2013 advisory base flood elevation (ABFE) with 30 inches of projected sea level rise. The ABFE maps were developed to guide rebuilding efforts after Hurricane Sandy, and were replaced by the FEMA Preliminary Work Maps (PWM) in June 2013. Although it was not feasible to reassess all wastewater facilities using the PWMs, the critical flood elevations are in most cases very similar to the ABFE maps, and using the updated maps would not affect the results of this analysis. In the critical flood scenario, based on the 100-year flood event (from the ABFE) with 30 inches of sea level rise, floodwater my reach +17.5 feet NAVD88 at Wards Island and the Manhattan Grit Chamber and +14.5 feet NAVD88 near the Bronx Grit Chamber. In contrast, the typical high tide elevation nearby is +2.26 feet NAVD88.

RISK ASSESSMENT

A risk assessment was performed in two steps to determine the potential level of damage DEP might expect under the critical flood scenario at Wards Island. First, as part of the building-level assessment, potential flood pathways were identified at each location of the plant and determined to be at risk if located below the critical flood elevation.

Since the plant is at a relatively high elevation, only one area, the Sludge Storage Tanks, may be flooded by up to 6 feet of water during the design flood event. However, since the Manhattan Grit Chamber is at a relatively low elevation it may be flooded by up to 8 feet during the critical flood event. These areas are listed in Table B and were found to be at risk in a 100-year flood with 30 inches of sea level rise.

An infrastructure-level assessment identified what pieces of equipment needed to meet basic levels of wastewater pollutant removal are located in the Sludge Storage Tanks and Manhattan Grit Chamber. There is a total of 46 target pieces of equipment located in these at-risk facilities that are below the design flood elevation and are at risk of flooding. This equipment includes pumps, motors, electrical equipment, and other infrastructure associated with primary treatment. Immediately following a large flood event, the cost to replace this infrastructure, plus clean the plant and provide temporary pumping and power, would be approximately $8.7 million.

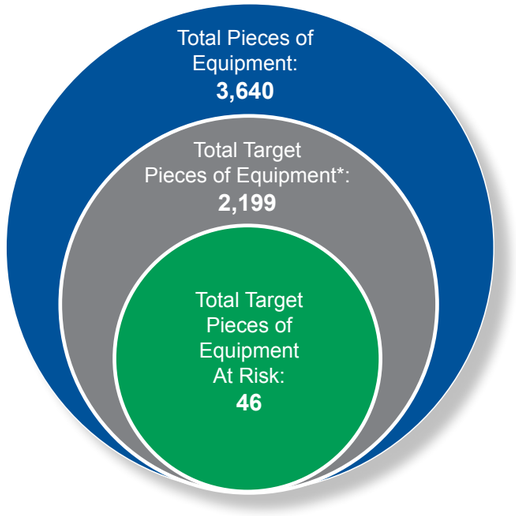
It was also found that the Bronx Grit Chamber may be flooded by approximately 6 inches of water under the critical flood event; however, since the infrastructure within the facility is high enough to be above the critical flood event, it is not considered at risk.

ADAPTATION STRATEGIES

A combination of recommended strategies to reduce damage and recovery time after a surge event was proposed for each at-risk location at Wards Island. Strategy selection was based on a feasibility analysis accounting for current site configurations and DEP's existing database (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing the strategy to the potential damage avoided. Strategy selection also accounted for the importance of infrastructure within a location for meeting basic treatment requirements.

When resiliency upgrades are planned, the proposed recommendations should be evaluated with consideration to other ongoing capital improvements and may be modified to account for new and changing site conditions and infrastructure.

Table B lists all plant locations containing target at-risk equipment, recommended planning-level strategies and the associated cost of implementation, cost of damage potentially incurred during an individual storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.



*All components needed to meet basic (primary) level of treatment and all electrical equipment, motors, and pumps

The two main rooms that need protection at the Manhattan Grit Chamber are the electrical room and generator room, both of which can be sealed with watertight doors and windows. Since some equipment does not reside in these rooms, this equipment should be flood-proofed individually. Likewise, the Wards Island Sludge Storage Tank contains a control room which can be sealed to protect valuable electrical equipment. Plant staff might also consider flood-proofing assets outside the electrical room to provide even higher resiliency.

In total, the cost to implement all recommended strategies at Wards Island and the Manhattan Grit Chamber is $1.5 million. While this cost is high, the potential damage cost that a large surge may impose totals $8.7 million. As the recommended strategies would also protect infrastructure during smaller storm events, the total value of risk avoided over a 50-year time span is estimated at $40.5 million, which is 27 times the cost of implementation. This favorable cost comparison provides strong economic support for implementing robust adaptation strategies, especially considering they would also minimize service disruptions in Manhattan during flood events, reduce sewage bypasses, and protect public health.

Table B: Wards Island Adaptation Strategy Recommendations

Location	Recommended Protective Measure	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]	Resiliency Level
Manhattan Grit Chamber	Flood-proof Equipment and Seal Building	$1,017,000	$4,489,000	$20,839,000	Moderate
Wards Island Sludge Storage Tank	Seal Control Room	$460,000	$4,238,000	$19,620,000	Moderate
Total for 2 At-Risk Locations		**$ 1.5 M**	**$ 8.7 M**	**$ 40.5 M**	

1) All cost estimates are presented in 2013 US Dollars
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence

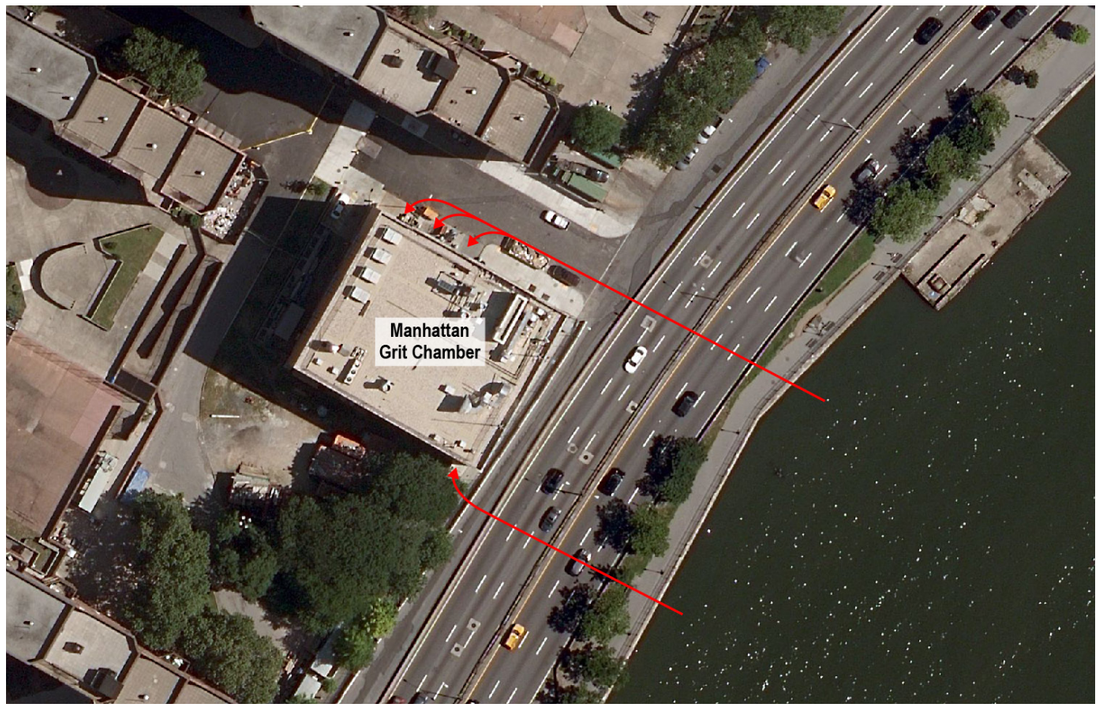
HURRICANE SANDY IMPACTS

Wards Island experienced minor flooding as a result of Hurricane Sandy. During the peak of the storm, water overtopped the eastern seawall near the Sludge Storage Tanks, which resulted in a small amount of flooding on the roadway. The water from the storm surge reached up to approximately 3 steps (21 inches) alongside the Chlorination Basin, but did not compromise the system. Plant staff took precautions ahead of the storm, that included sandbagging low-lying areas such as the doorway to the Sludge Storage Tanks, which successfully prevented floodwater from entering the structures.

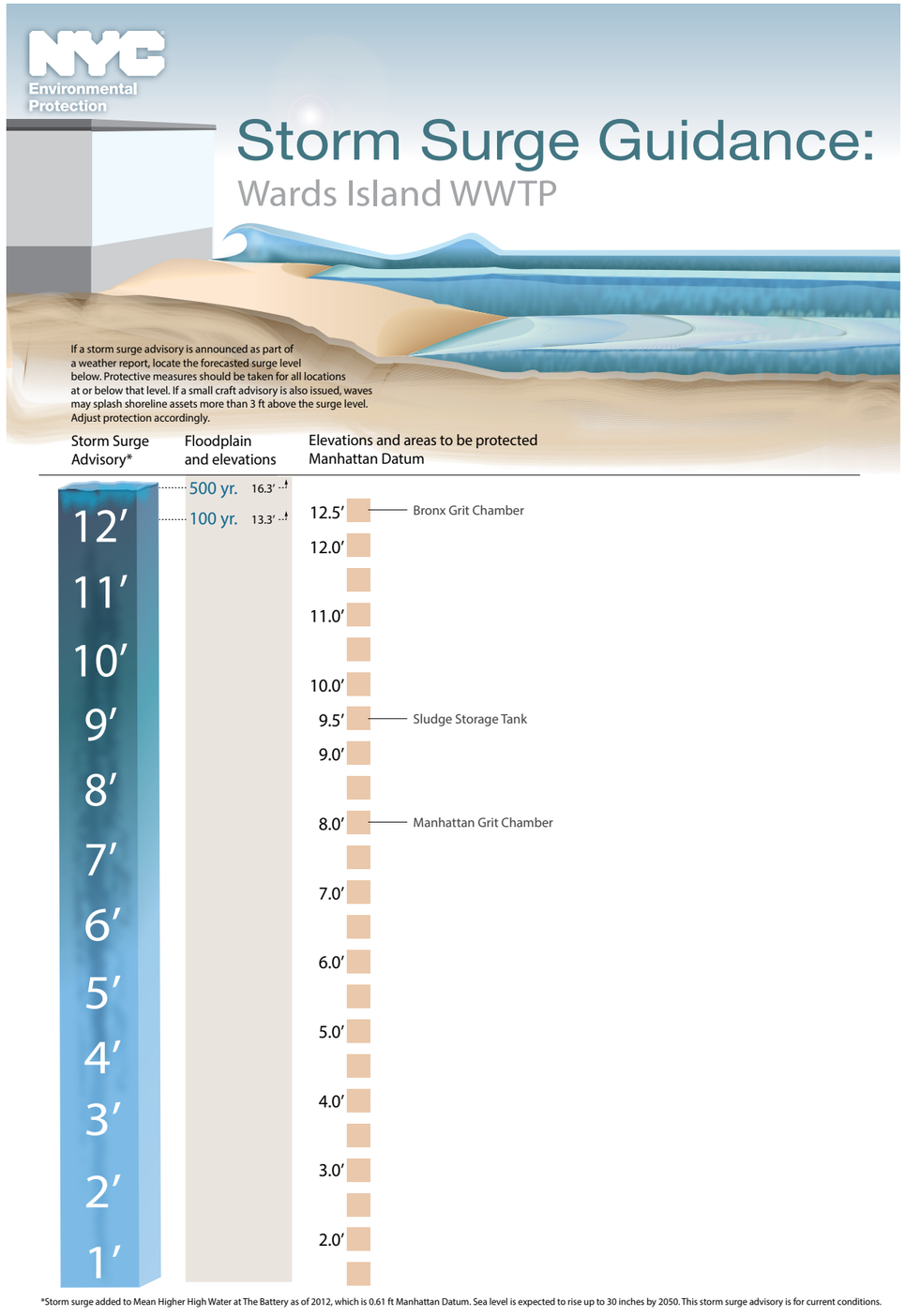
Greater impact was experienced across the river at the Manhattan Grit Chamber facility, which screens half the wastewater inflow before it enters the Wards Island Wastewater Treatment Plant. Water from the storm surge reached approximately 2 feet along the eastern exterior wall. While a concrete barrier provided protection along certain flood pathways, floodwaters still managed to penetrate the building via a rollup door and access door at grade. Fortunately, plant staff were able to protect the electrical room and emergency generator rooms at grade by opening floor hatches, which redirected flow to the basement.

However, had the storm surge reached the lower window sills and filled the basement, valuable electrical equipment including motor control centers for grit screening and associated backup power, may have been compromised.

The Bronx Grit Chamber experienced no flood damage as a result of Hurricane Sandy.



Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.



This storm surge placard provides a quick reference for operators to prepare their plant in advance of a surge event. The guidance enables an operator to rapidly locate at-risk locations based on storm surge warnings. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.

CANNON AVENUE PUMPING STATION, STATEN ISLAND, NY

CHAPTER 3: PUMPING STATIONS

Introduction

The New York City Department of Environmental Protection (DEP) own and operates 96 pumping stations. These facilities are critical in transporting wastewater and stormwater from low-lying areas of the city and maintaining drainage and sanitation. As such, New York City's intricate system of pumping stations is fundamental to protecting the environment and public heath, and DEP is committed to ensuring its continued performance and reliability.

One of DEP's priorities in the coming years will be hardening its wastewater infrastructure to increase resiliency against flood damage. Many of the City's pumping stations are located within close proximity to the waterfront and are at-risk from flooding and power outages, as was evident during Hurricane Sandy. Flooding and power outages at pumping stations can have negative impacts for residents and businesses, including sewage overflows and backups and impacts on bathing beaches. It should be noted that while backups may result from pumping station failure, loss of power to an electric sump pump at a home or business can also cause or prolong backups.

Given that the risk of flooding is likely to increase over time with sea level rise, DEP performed the 2013 Climate Risk Assessment and Adaptation Study to identify pumping station risks and protective measures that will reduce flood damage and the time needed to restore normal operating conditions following a flood event.

The critical flood elevation examined in this study is based on the Federal Emergency Management Agency (FEMA) Advisory Base Flood Elevation (ABFE) for the 100-year flood due to storm surge plus an additional 30 inches to account for potential sea level rise. At the time the analysis was completed, the March 2013 ABFE was the best available data. This data only represents flooding due to storm surge, therefore some stations which have been historically been inundated due to localized or riverine flooding may not have been captured in this study.

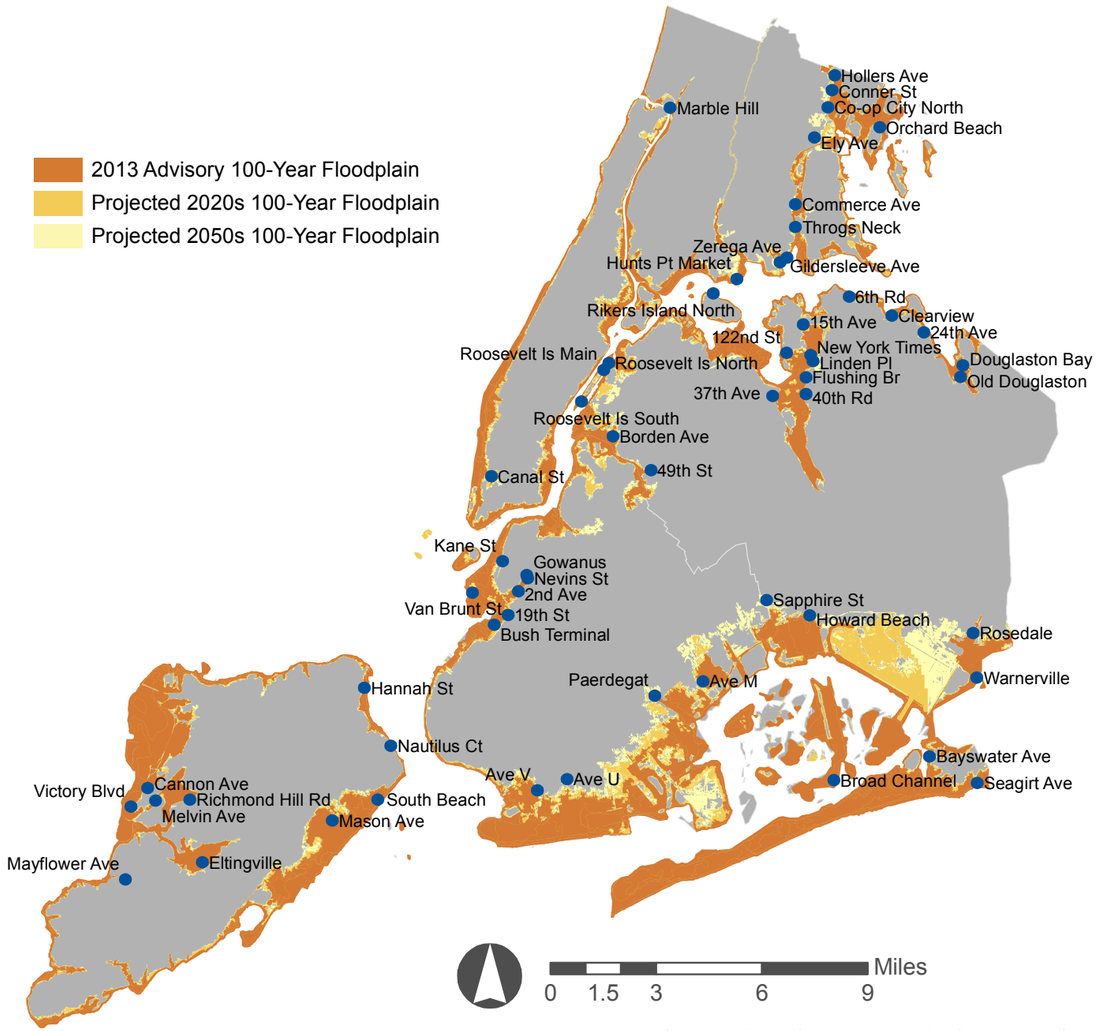
The study revealed that 58 of 96 pumping stations are at risk of flood damage during the critical flood event, totaling $218 million in at-risk infrastructure. The recommended protective measures, totaling $128 million in improvements, are also costly but will significantly reduce risk to the equipment, environment, and public health, and will maximize the likelihood of continued service through and immediately following a flood event.

DEP plans to implement the protective measures systematically through capital projects in the coming years, with added consideration given to those pumping stations that meet some or all of the following criteria:

- Bathing beaches affected by loss of function at pumping station
- Historic flooding issues, beyond flooding caused by Hurricane Sandy
- Historic power outage problems (i.e., loss of power without flooding, lack of backup power)
- Locations that serve critical facilities (e.g., hospitals, fire stations, schools)

This chapter provides additional information regarding individual pumping stations, their risks, and which measures DEP may implement in the future to protect them.

Pumping Stations At-Risk of Storm Surge Inundation



Source: FEMA; CUNY Institute for Sustainable Cities

Pumping Station Estimated Cost			
Pumping Stations	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]
122nd Street	$0.28	$1.85	$0.62
15th Avenue	$2.66	$3.51	$1.00
19th Street	$0.30	$3.66	$1.43
24th Avenue	$1.48	$5.03	$15.75
2nd Avenue	$1.91	$1.32	$6.78
37th Avenue	$0.06	$3.51	$3.85
40th Road	$0.51	$1.77	$8.32
49th Street	$2.87	$2.12	$10.91
6th Road	$2.87	$1.37	$6.77
Avenue M	$1.07	$3.84	$19.75
Avenue U	$2.60	$3.70	$19.04
Bayswater Avenue	$0.17	$1.14	$5.29
Borden Avenue	$1.94	$3.24	$15.22
Broad Channel	$2.40	$2.34	$12.03
Bush Terminal	$0.59	$3.47	$17.84
Canal Street	$2.42	$2.71	$13.33
Cannon Avenue	$1.43	$4.39	$20.46
Clearview	$4.71	$7.82	$16.80
Commerce Avenue	$0.63	$1.04	$5.34
Conner Street	$5.46	$6.57	$32.13
Co-op City North	$0.35	$3.70	$3.26
Douglaston Bay	$7.39	$1.80	$9.26
Eltingville	$0.59	$9.51	$5.44
Ely Avenue	$0.47	$2.02	$3.58
Flushing Bridge	$1.26	$1.74	$8.51
Gildersleeve Avenue	$0.89	$1.14	$3.97
Hannah Street	$1.37	$12.80	$63.24
Hollers Avenue	$2.48	$2.82	$14.53
Howard Beach	$8.16	$17.44	$20.65
Hunts Point Market	$0.73	$1.86	$5.65
Kane Street	$4.80	$6.23	$11.93
Linden Place	$1.15	$4.03	$4.41
Marble Hill	$0.62	$3.38	$15.67
Mason Avenue	$0.55	$3.37	$15.60
Mayflower Avenue	$0.04	$6.50	$28.43
Melvin Avenue	$2.54	$1.78	$9.14
Nautilus Court	$2.42	$3.28	$16.85
Nevins Street	$1.09	$1.31	$6.75
New York Times	$5.56	$1.99	$10.23

Pumping Station Estimated Cost			
Pumping Stations	Cost of Protective Measures ($M)[1]	Damage Cost for Critical Flood without Protection ($M)[1,2]	Cumulative Risk Avoided Over 50 Years ($M)[1,3]
Old Douglaston	$0.74	$4.07	$20.95
Orchard Beach	$0.66	$1.15	$3.05
Paerdegat	$16.96	$15.41	$19.21
Richmond Hill Road	$0.01	$5.49	$1.20
Rikers Island North	$2.87	$3.14	$6.35
Roosevelt Island Main	$0.27	$3.02	$0.70
Roosevelt Island North	$2.54	$1.66	$8.56
Roosevelt Island South	$0.66	$1.66	$0.51
Rosedale	$9.94	$5.22	$26.84
Sapphire Street	$0.80	$3.70	$19.04
Seagirt Avenue	$2.30	$4.23	$21.75
South Beach	$0.29	$2.36	$10.93
Throgs Neck	$5.92	$10.67	$53.00
Van Brunt Street	$2.74	$0.93	$4.79
Victory Boulevard	$0.88	$1.85	$9.52
Warnerville	$0.88	$1.14	$5.87
Zerega Avenue	$0.66	$1.28	$6.60
Total	**$128 M**	**$218 M**	**$709 M**

Notes: Avenue V and Gowanus Pumping Stations are considered at-risk, but are already undergoing extensive protective upgrades and are not considered in this cost estimate.
1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical in New Building**

Adaptation Cost: **$1,910,000**

Below grade Pumping Station Running on Bypass

2nd Avenue Pumping Station

STATION CHARACTERISTICS

The 2nd Avenue combined pumping station is located near the intersection of 2nd Avenue and 5th Street in Brooklyn. It is a below grade station that was running on a bypass pump at the time of the site visit.

The Pumping Station Summary table lists the general characteristics of the 2nd Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. Failure of the station would affect an area of approximately 376 acres. There are 20 critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

At the time of the station visit in March 2013, the station was running on a bypass pump due to damage caused by flooding during Hurricane Sandy. Streets nearby the station flood during smaller storm events, but the station itself does not have a history of flooding.

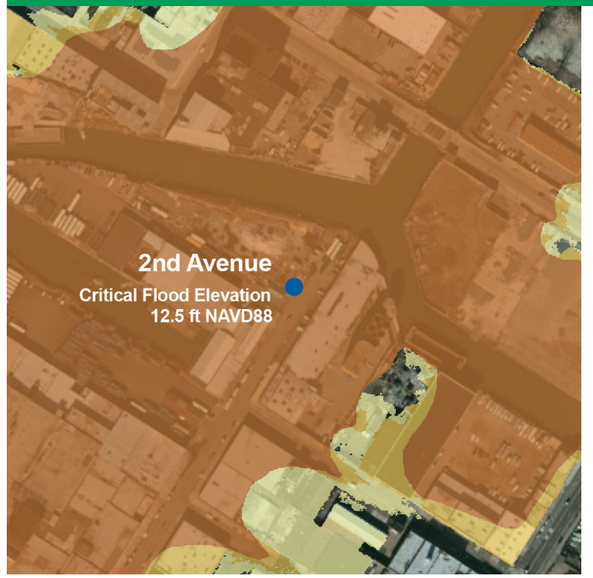
RISK ASSESSMENT

The risk of the 2nd Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). The critical flood elevation would completely inundate the below grade station; the surrounding flood would be more than 6 feet above local grade. This would flood and damage the electrical controls. The submersible pumps should withstand flooding. A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

ADAPTATION STRATEGIES

The 2nd Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the critical flood depth of more than 6 feet, the recommended strategy at 2nd Avenue is to elevate controls in a new building. Residual risk is related to the potential for larger storms or more extreme climate change.

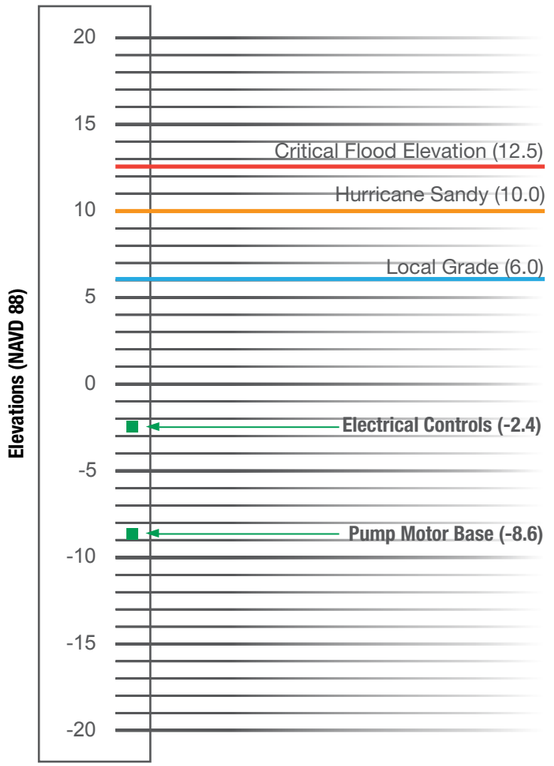
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	1.0
	Affected Area (Acres)	376
Risk	Population in Affected Area	34,003
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	20
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$1,910,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,318,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$6,783,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical in New Building**

Adaptation Cost: **$2,866,000**

6th Road Pumping Station

STATION CHARACTERISTICS

The 6th Road sanitary pumping station is located near the intersection of 6th Road and 151st Street in Queens. It is entirely below grade and is accessible through hatches in the sidewalk along 6th Road.

The Pumping Station Summary table lists the general characteristics of the 6th Road pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a mixed residential and industrial area. Failure of the station would affect an area of approximately 8 acres. There are no critical facilities in the area that could be affected if the station fails.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The 6th Road pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

The risk of the 6th Road pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings. Submersible pumps were confirmed but the condition of the pumps and the resiliency of supporting equipment is not known.

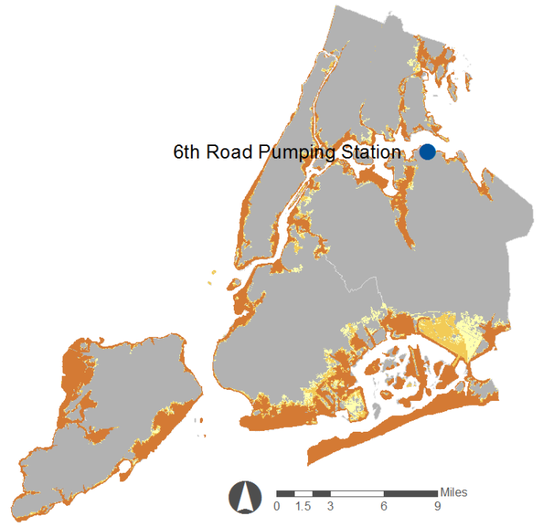
The critical flood elevation would completely inundate the below grade station, and the surrounding flood would be nearly 5 feet above local grade. Water would flood and damage the pump controls. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The 6th Road pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. The significant flood depth of about five feet and the station's location in an industrial area led to the selection of the most resilient option; the recommended strategy at 6th Road is to elevate the pumping station's controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

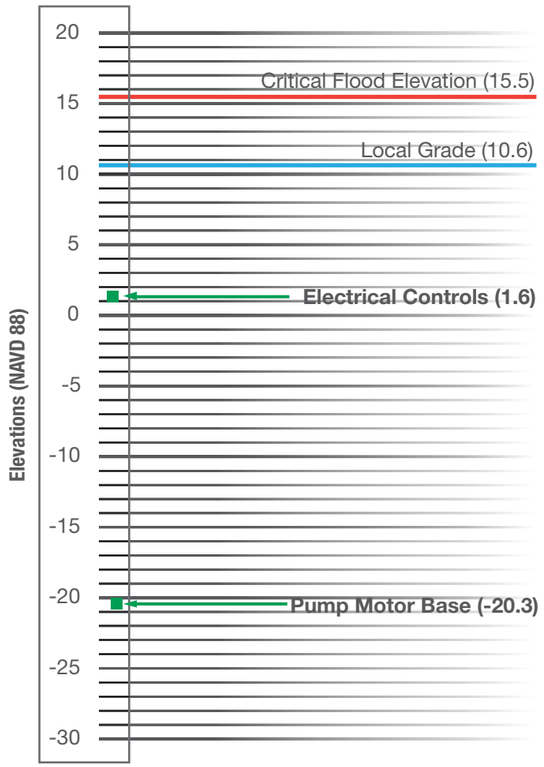
FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	0.7
	Affected Area (Acres)	8
Risk	Population in Affected Area	163
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$2,866,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,370,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$6,773,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

15th Avenue Pumping Station

STATION CHARACTERISTICS

The 15th Avenue sanitary pumping station is located near the southeast corner of 15th Avenue and 131st Street in Queens. The station is completely below grade with grates and hatch entryways located in the sidewalk along 15th Avenue. There is a small grassy area between the pumping station and a concrete wall.

The Pumping Station Summary table lists the general characteristics of the 15th Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a mixed-use residential, industrial, and commercial area and services an area of approximately 46 acres and a population of more than 700. There is one critical facility in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The 15th Avenue Pumping Station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

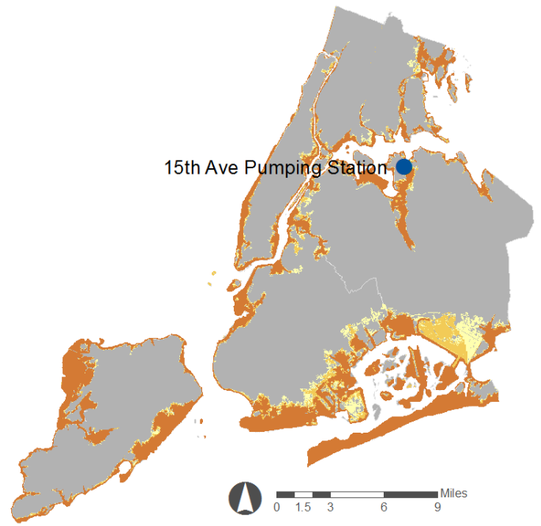
The risk of the 15th Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would flood the local grade to a depth of about 4 inches. Because the station is entirely below grade, and access hatches and grating are very near to grade level, even this minor flood could significantly affect the station. Electrical controls and non-submersible pumps could be damaged if flood waters enter the pumping station.

ADAPTATION STRATEGIES

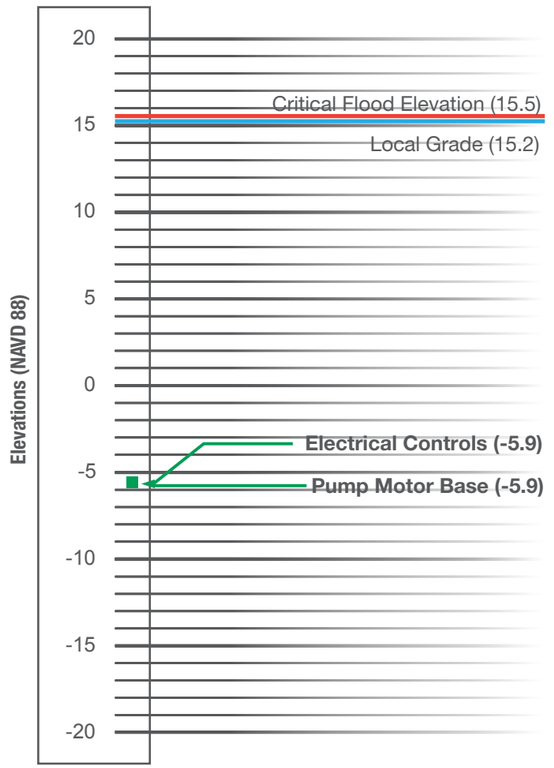
The 15th Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. The station entrances are currently located in a sidewalk, there is a plot of vacant land bordering the sidewalk, and a concrete wall approximately 15 feet high runs along the back of the lot. With space available and no apparent limitations on structure height, the recommended strategy at 15th Avenue is to elevate the electrical controls in a new building and install submersible pumps. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	2.9
	Affected Area (Acres)	46
Risk	Population in Affected Area	793
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building & Submersible Pump Motors
	Cost of Protective Measures[1]	$2,664,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,510,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$995,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Seal Building

Adaptation Cost:
$300,000

Brick structure with elevated entrances

19th Street Pumping Station

STATION CHARACTERISTICS

The 19th Street sanitary pumping station is located near the northwest corner of 19th Street and 3rd Avenue in Brooklyn. The pumping station has a brick structure that houses the motor control center; pumps are located three floors below grade in the dry well. The doorway to the structure and hatches to the wet well are elevated on a concrete slab 1–2 feet above grade.

The Pumping Station Summary table lists the general characteristics of the 19th Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The 19th Street pumping station is located in an industrial area. Failure of the station would affect an area of approximately 25 acres. There are no critical facilities in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The 19th Street Pumping Station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

The risk of the 19th Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

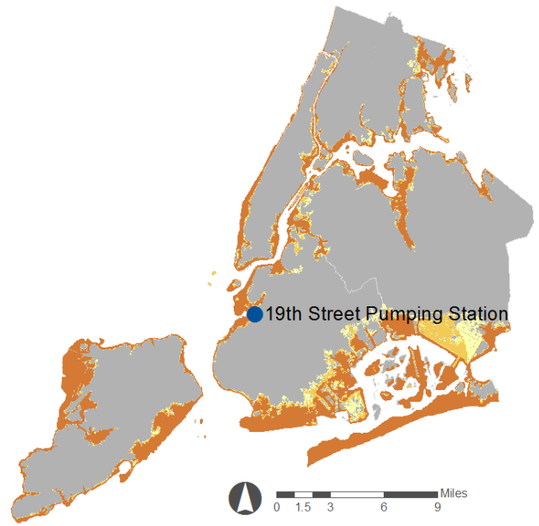
The critical flood elevation would flood the local grade to a depth of about 6 inches above local grade. This would not reach the electrical controls, which are located nearly 3 feet above grade. If water enters the building, it could damage the non-submersible pumps located well below grade.

ADAPTATION STRATEGIES

The 19th Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a substantial existing structure with entrances above the critical flood elevation, the recommended strategy at 19th Street is to seal the building. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

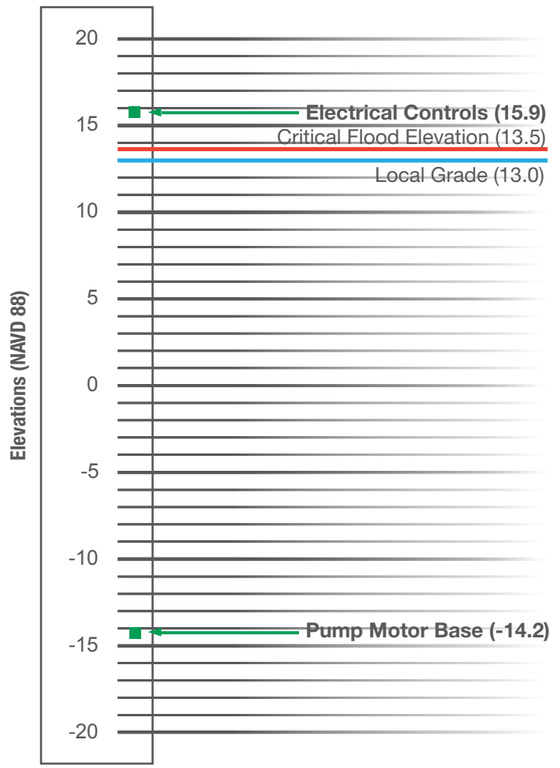
FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	5.0
	Affected Area (Acres)	25
Risk	Population in Affected Area	0
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$300,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,660,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$1,432,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Elevated Electrical on a Platform/Pad & Elevate Motor and Controls

Adaptation Cost:
$1,482,000

24th Avenue Pumping Station

STATION CHARACTERISTICS

The 24th Avenue sanitary pumping station is located near the intersection of 24th Avenue and 217th Street in Queens, near the dead end of 24th Avenue; 217th Street is labeled Waters Edge Drive on street signs. The motor control center (MCC) sits above grade in a fenced-in stainless-steel enclosure. There are hatch entryways to the wells in the roadway of Waters Edge Drive as well as in the adjacent sidewalk.

The Pumping Station Summary table lists the general characteristics of the 24th Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area and failure would affect an area of approximately 75 acres. There is one critical facility within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The 24th Avenue pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

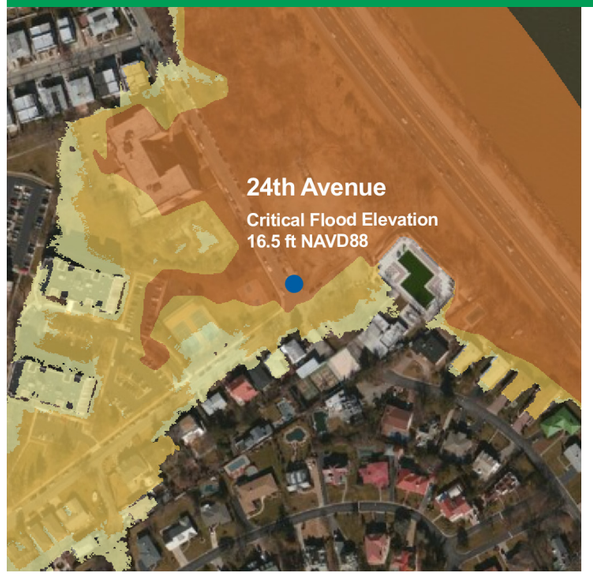
The risk of the 24th Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station revealed the MCC and other components, which were shown below grade in all drawings, had been moved to a slab at grade level.

The critical flood elevation would flood the local grade to a depth of nearly 4 feet. This would completely inundate the wells, damaging the non-submersible pumps. It would also submerge and damage the MCC and other grade-level electrical components.

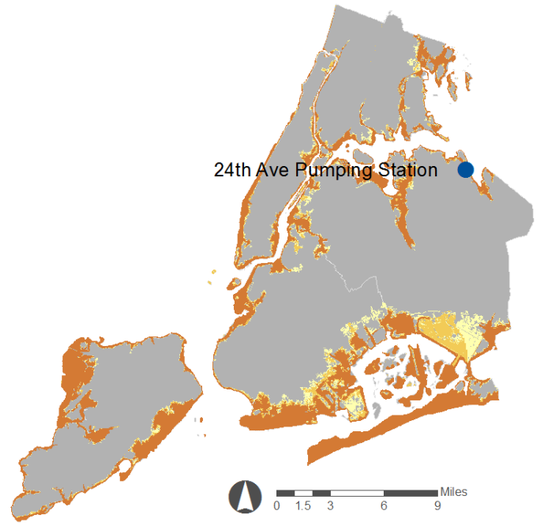
ADAPTATION STRATEGIES

The 24th Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. The pumping station's electrical components are visible in their current location above grade, and the station borders an empty lot. Because the appearance of elevated components should not be a concern, the recommended strategy at 24th Avenue is to elevate both the electrical controls and the pump motors on a platform. This would achieve resiliency without the expense of constructing a building or replacing pumps. Elevating pump motors and replacing existing motors with submersibles are both acceptable solutions, however elevating pump motors may be a more cost-effective adaptation for this pumping station. Residual risk is related to the potential for greater storms or climate change impacts.

FEMA Flood Zones

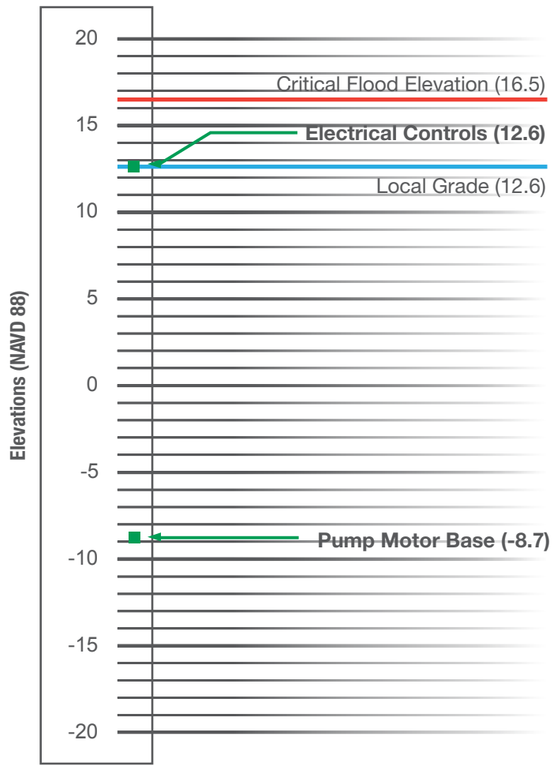


2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	4.3
	Affected Area (Acres)	75
Risk	Population in Affected Area	1,500
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad & Elevate Motors and Controls
	Cost of Protective Measures[1]	$1,482,000
	Damage Cost for Critical Flood without Protection[1, 2]	$5,029,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$15,751,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

37th Avenue Pumping Station

STATION CHARACTERISTICS

The 37th Avenue combined sanitary and storm pumping station is located on park land near the intersection of 37th Avenue and 114th Street in Queens. The station is entirely below grade with access hatches at grade level.

The Pumping Station Summary table lists the general characteristics of the 37th Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. Failure of the station would affect an area of approximately 78 acres. There is one critical facility within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The 37th Avenue pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

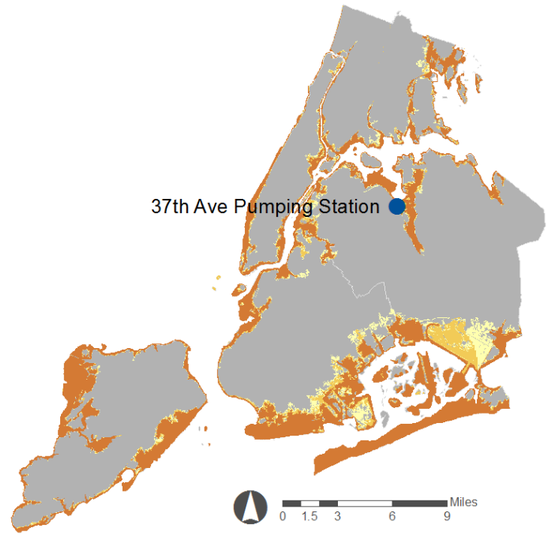
The risk of the 37th Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would result in a flood depth of 1.6 feet above grade, and it would inundate the below grade station. This would damage electrical controls but would not affect the submersible pumps.

ADAPTATION STRATEGIES

The 37th Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the shallow flood depth and the station's location, in park land out of the way of vehicles and pedestrians, the recommended strategy is to place sandbags around potential water-entry points prior to flooding events. Residual risk is related to sandbags being stacked improperly or being disturbed by residents.

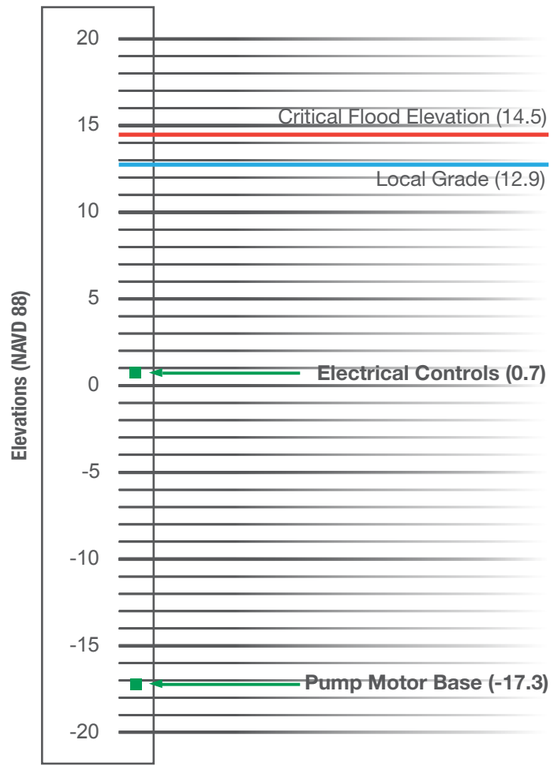
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	5.0
	Affected Area (Acres)	78
Risk	Population in Affected Area	6,183
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Sandbagging
	Cost of Protective Measures[1]	$59,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,510,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$3,850,000
	Resiliency Level	Moderate-Low

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Seal Building**

Adaptation Cost: **$509,000**

Structure between roadway and shopping center

40th Road Pumping Station

STATION CHARACTERISTICS

The 40th Road sanitary pumping station is near the corner of 40th Road and College Point Boulevard, between 40th Road and a shopping plaza, in Queens. Controls are located in a small metal structure next to the sidewalk. The dry and wet wells are accessible through hatches in the sidewalk. The Pumping Station Summary table lists the general characteristics of the 40th Road pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial area. Failure of the station would affect an area of approximately 66 acres. There are four critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

This pumping station flooded during Hurricane Sandy. The control room flooded to a depth of approximately 3 inches, and the surrounding area was flooded to a depth of 2 to 3 feet. The station suffered damage to lighting and ventilation equipment, but the submersible pumps remained operating throughout the storm and were not damaged. There is no history of flooding aside from Hurricane Sandy.

RISK ASSESSMENT

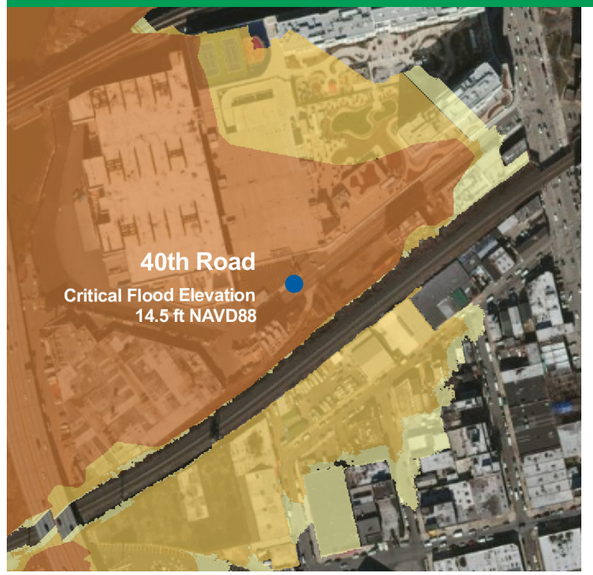
The risk of the 40th Road pumping station was first assessed based on a review of the pumping station's plan drawings, comparing the elevation of critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room and wells.

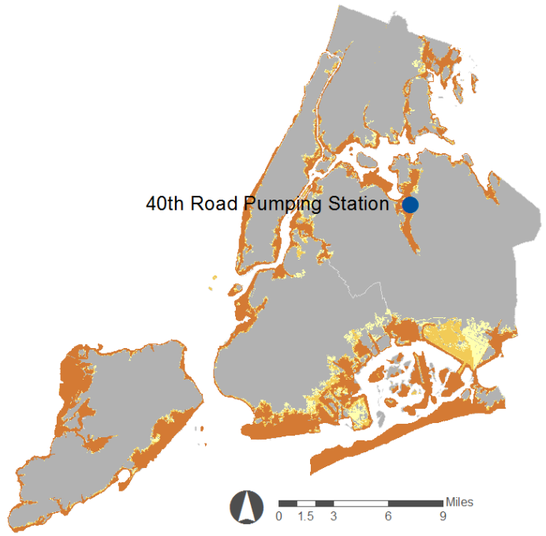
The critical flood elevation would completely inundate the station, and the surrounding flood would be more than 6 feet above local grade. This would flood and damage the pump controls, a compressor, and the lighting panel. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The 40th Road pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Pumps are submersible and do not require any modifications, but electrical controls, located in the existing above grade structure, are vulnerable to flood water. Property size and location limits the potential for a new, larger structure. Viable strategies include moving controls to the walls or roof of the existing structure as well as sealing the building; these strategies were reviewed to identify the most cost-effective, resilient option. The recommended strategy at 40th Road is to seal the existing building and add sluice gates to restrict inflows. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

FEMA Flood Zones

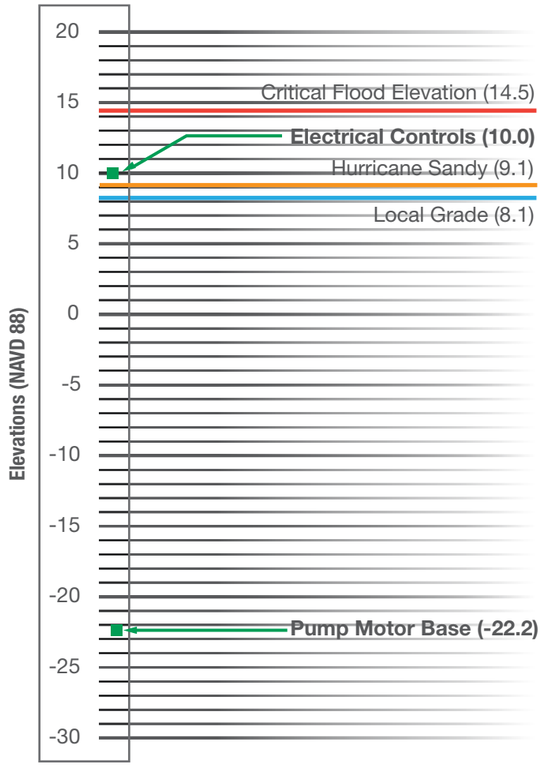




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	2.0
	Affected Area (Acres)	66
Risk	Population in Affected Area	13,895
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	4
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$509,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,766,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$8,316,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical in New Building**

Adaptation Cost: **$2,866,000**

Pumping station under construction due to Hurricane Sandy damage

49th Street Pumping Station

STATION CHARACTERISTICS

The 49th Street sanitary pumping station is near the southeast corner of 57th Avenue and 49th Street in Queens. It is entirely below grade and is accessible through hatches in the sidewalk along 49th Street. At the time of the visit the station was under construction and it was running on a bypass pump.

The Pumping Station Summary table lists the general characteristics of the 49th Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in an industrial area. Failure of the station would affect an area of approximately 91 acres. There are no known critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

This station experienced significant flooding during Hurricane Sandy and was undergoing a complete rehabilitation at the time of the visit. DEP staff indicated there was a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

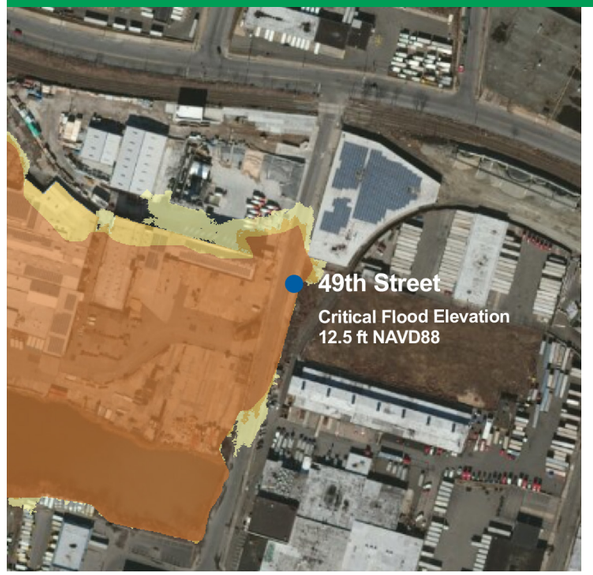
The risk of the 49th Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings. Discussion with an engineer from D&B present on site for the station's repairs provided further details on the station's flooding history and vulnerability.

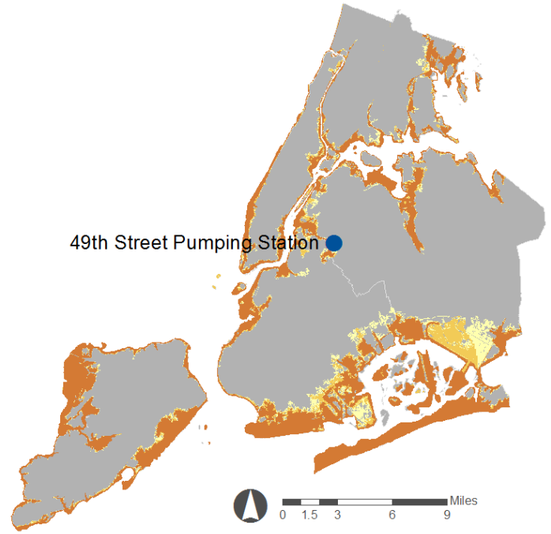
The critical flood elevation would flood the local grade to a depth of nearly 7 feet and would completely inundate the below grade station. This would flood and damage the pump controls. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The 49th Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Viable options included elevating electrical controls on a platform, on the adjacent wall, or in a new building. The station's flooding history and the significant depth of the critical flood contributed to the selection of the most resilient option; the recommended strategy at 49th Street is to elevate the pumping station's controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

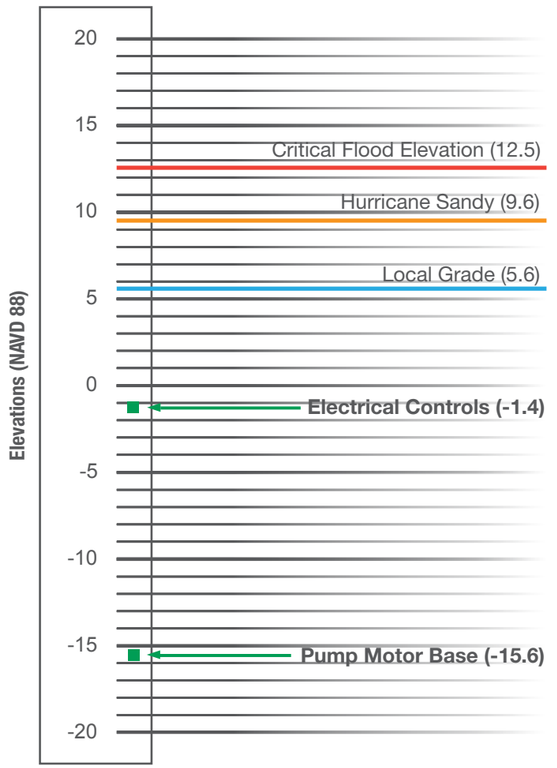




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	7.9
	Affected Area (Acres)	91
Risk	Population in Affected Area	360
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$2,866,000
	Damage Cost for Critical Flood without Protection[1, 2]	$2,120,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$10,911,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

122nd Street Pumping Station

STATION CHARACTERISTICS

The 122nd Street sanitary pumping station is near the intersection of 122nd Street and 28th Avenue in Queens. The hatch entryways to the below grade station are located in the sidewalk between the roadway and a concrete plant. A chain-link fence runs along the back of the sidewalk.

The Pumping Station Summary table lists the general characteristics of the 122nd Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in an industrial area and failure would affect an area of approximately 13 acres. There are no known critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The 122nd Street pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

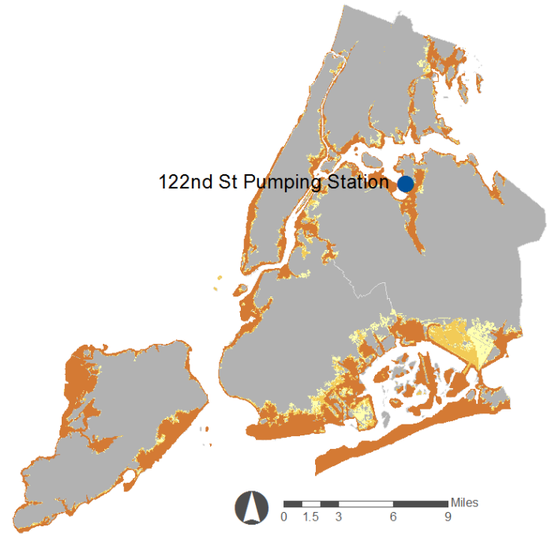
The risk of the 122nd Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would flood the surrounding area to a depth of just over 7 inches above grade. This would affect the station's electrical components; near-grade-level access hatches could serve as entryways for water to reach the below grade controls. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

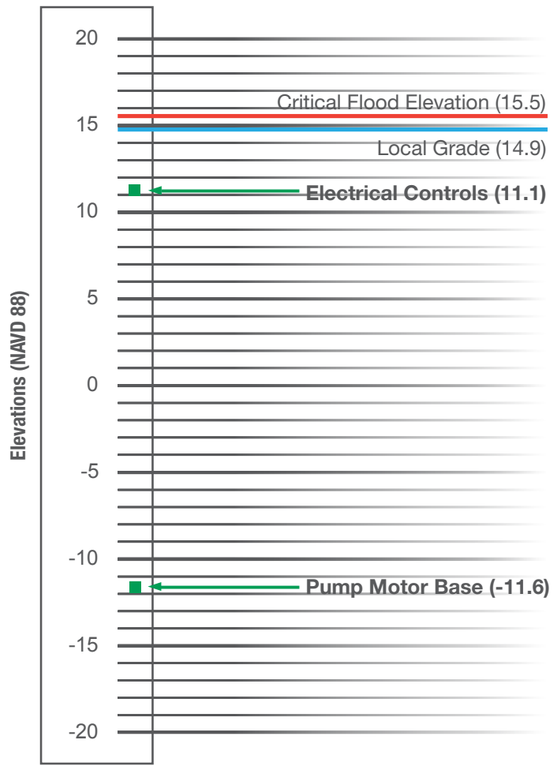
The 122nd Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because the below grade pumping station's entrances are located within a sidewalk, any strategy that requires an above grade structure, such as elevating controls or constructing a barrier, is not feasible. The recommended strategy at 122nd Street is to flood-proof electrical controls. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the seals could fail. Therefore, residual risk is related to the potential for water pressure to exceed the rating of the flood-proofing enclosures.

FEMA Flood Zones



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	1.5
	Affected Area (Acres)	13
Risk	Population in Affected Area	0
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Flood-Proof Controls
	Cost of Protective Measures[1]	$276,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,849,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$616,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Elevate Electrical on a Platform/Pad & Submersible Pump Motors

Adaptation Cost:
$1,066,000

Below grade pumping station in residential neighborhood

Avenue M Pumping Station

STATION CHARACTERISTICS

The Avenue M sanitary pumping station is near the intersection of Avenue M and East 99th Street in Brooklyn. It is an entirely below grade station with hatch entryways located in the sidewalk.

The Pumping Station Summary table lists the general characteristics of the Avenue M pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 375 acres with a population of nearly 19,000. There are six critical facilities within that area that could be affected if the station fails.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Avenue M pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

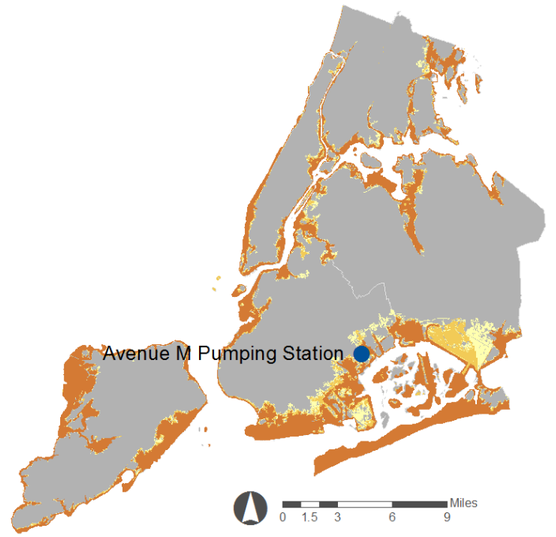
The risk of the Avenue M pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would completely inundate the station, and the surrounding flood would be nearly 4 feet above grade. Water would flood and damage the pump controls and the non-submersible pumps. The Avenue M pumping station is connected to another station; however it discharges to this station, rather than receiving flow from it. Therefore, loss of function at Avenue M does not increase the vulnerability of an additional pumping station.

ADAPTATION STRATEGIES

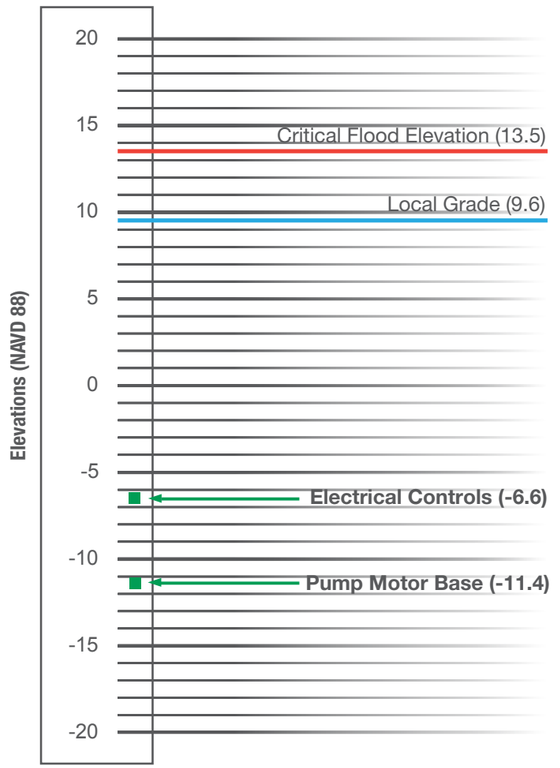
The Avenue M pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the critical flood depth of nearly 4 feet, the controls must be elevated to withstand the flood. Because the station is located beneath a sidewalk in a residential neighborhood, the recommended strategy at Avenue M is to elevate the pumping station's controls on a platform and install submersible pumps. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	7.1
	Affected Area (Acres)	375
Risk	Population in Affected Area	18,753
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	6
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad & Submersible Pump Motors
	Cost of Protective Measures[1]	$1,066,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,837,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$19,745,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Equipment in Building & Submersible Pump Motors**

Adaptation Cost: **$2,600,000**

Pumping station in sidewalk between roadways in residential neighborhood

Avenue U Pumping Station

STATION CHARACTERISTICS

The Avenue U sanitary pumping station is located near the intersection of Ocean Parkway and Avenue U in Brooklyn. The station is below grade in a sidewalk that runs between Ocean Parkway and its parallel service road. A vent in a decorative housing sits above grade.

The Pumping Station Summary table lists the general characteristics of the Avenue U pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area and services an area of approximately 719 acres with a population of over 50,000. There are 37 critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Avenue U pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

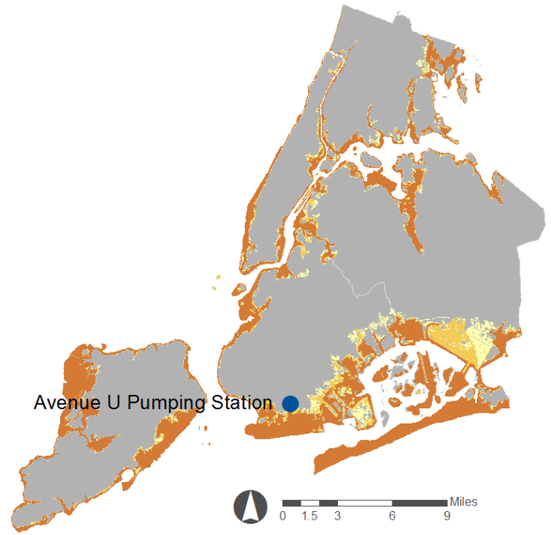
The risk of the Avenue U pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would completely inundate the station, and the surrounding flood would be more than 3 feet above grade. This would flood and damage the pump controls and the non-submersible pumps.

ADAPTATION STRATEGIES

The Avenue U pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because the station is located in a sidewalk and is below grade, to withstand the flood, electrical components must be elevated, and to do this, the station must be moved to another location. The options for above grade components will likely be limited by aesthetic requirements of the surrounding residential neighborhood. Therefore, the recommended strategy at Avenue U is to elevate the pumping station's controls in a new building and install submersible pumps. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

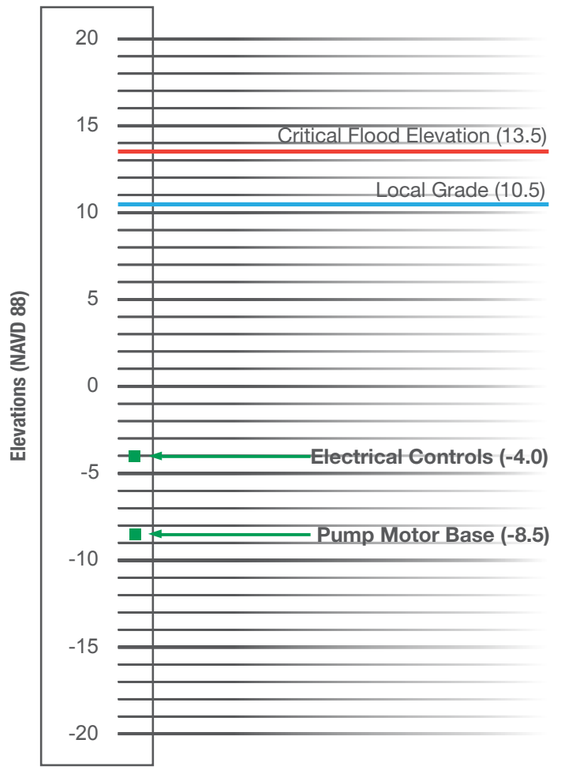
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

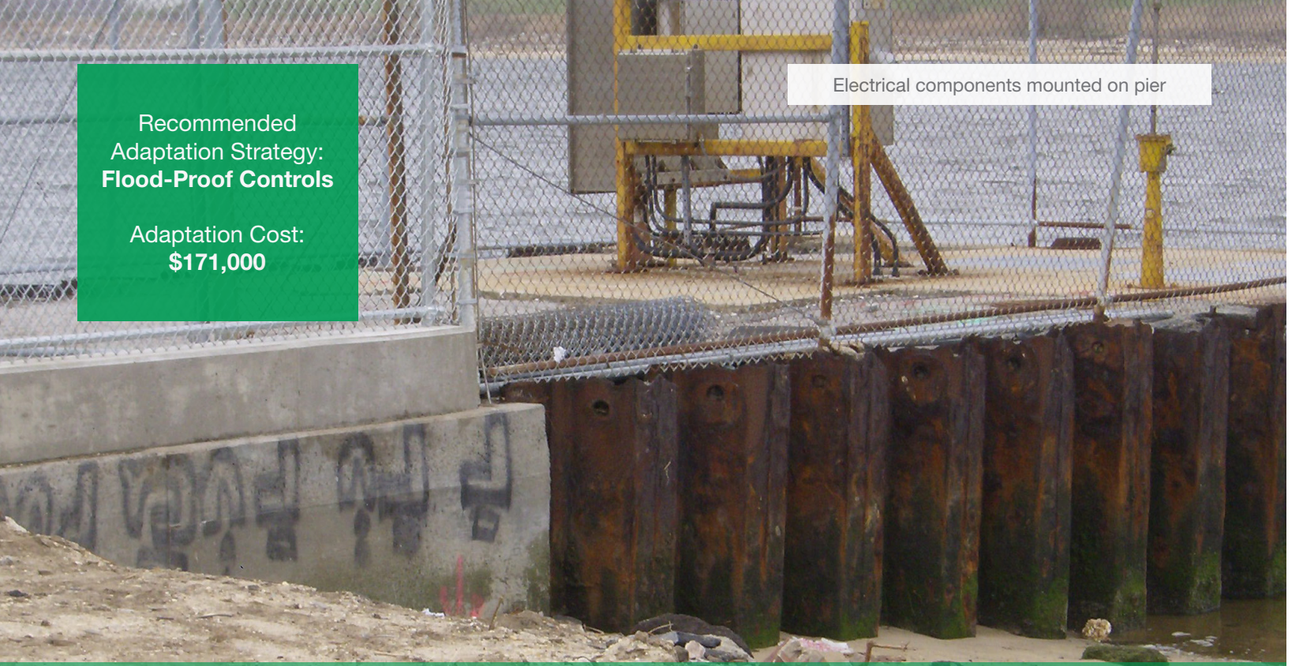
Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	11.5
	Affected Area (Acres)	719
Risk	Population in Affected Area	50,793
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	37
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in Building & Submersible Pump Motors
	Cost of Protective Measures[1]	$2,600,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,700,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$19,040,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.



Recommended Adaptation Strategy: **Flood-Proof Controls**

Adaptation Cost: **$171,000**

Electrical components mounted on pier

Bayswater Avenue Pumping Station

STATION CHARACTERISTICS

The Bayswater Avenue sanitary pumping station is near the intersection of Bayswater Avenue and Norton Drive in Queens. It is adjacent to an inlet off of Jamaica Bay, and its controls are mounted above grade on a pier that juts into the water.

The Pumping Station Summary table lists the general characteristics of the Bayswater Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 167 acres. There is one critical facility in the area that could be affected if the station fails.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

Flood waters from Hurricane Sandy were about 2 inches above grade in the area surrounding the Bayswater Avenue pumping station and the facility experienced minor impacts. DEP indicated there was a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

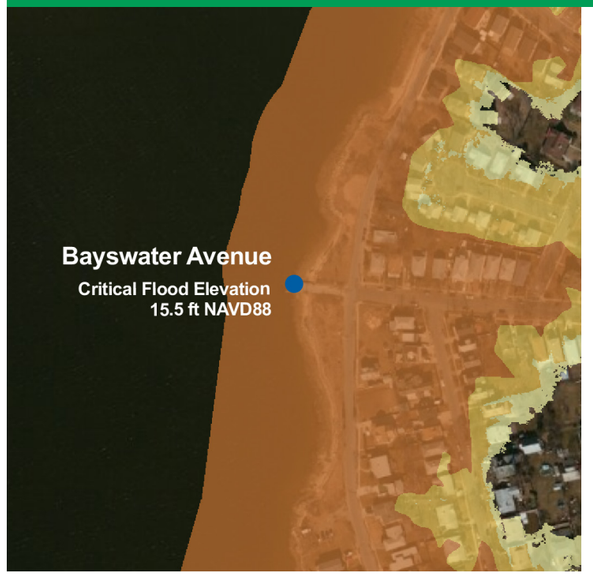
The risk of the Bayswater Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be nearly 9 feet above grade. The electrical controls, mounted about 6 feet above grade, would be flooded and would sustain damage. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The Bayswater Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because controls are currently exposed but would be submerged by the critical flood, the recommended strategy at Bayswater Avenue is to waterproof controls. Further review and design may indicate that this option is not sufficiently resilient in which case electrical controls will be elevated on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

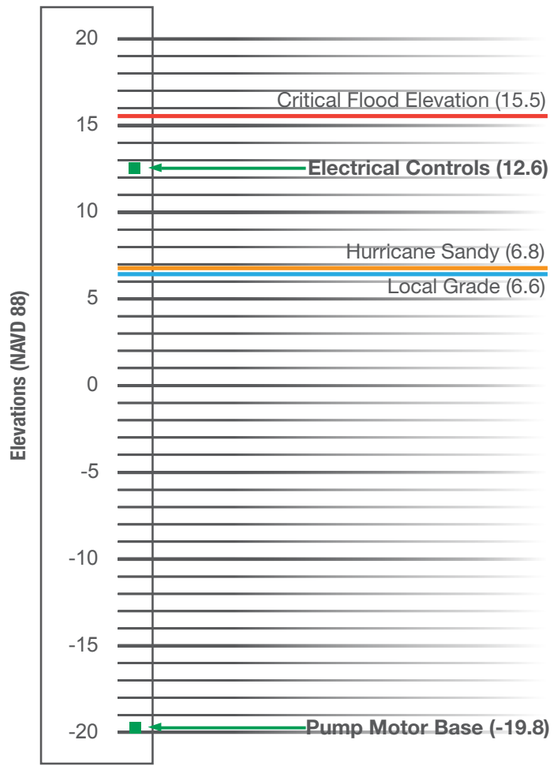
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	2.2
	Affected Area (Acres)	168
Risk	Population in Affected Area	2,383
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Flood-Proof Controls
	Cost of Protective Measures[1]	$171,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,143,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$5,292,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Borden Avenue Pumping Station

STATION CHARACTERISTICS

The Borden Avenue combined pumping station is located near the northeast corner of Borden Avenue and Review Street in Queens. Its one-story structure sits directly underneath an elevated section of the Long Island Expressway.

The Pumping Station Summary table lists the general characteristics of the Borden Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial area. It services an area of approximately 63 acres and a population of nearly 600. There is one critical facility within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Borden Avenue pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

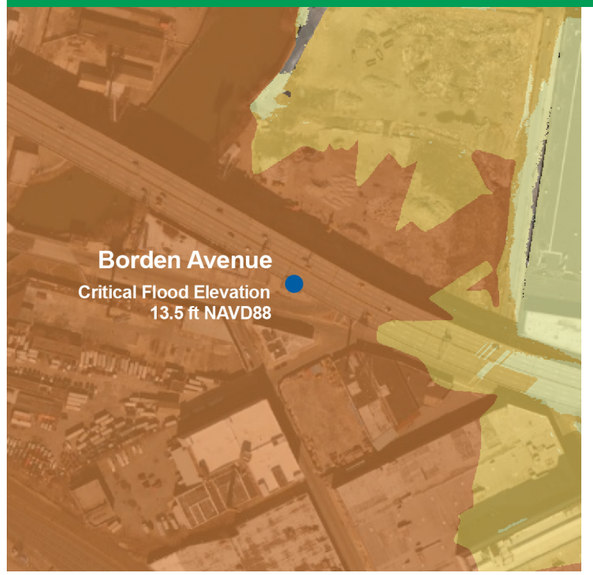
The risk of the Borden Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

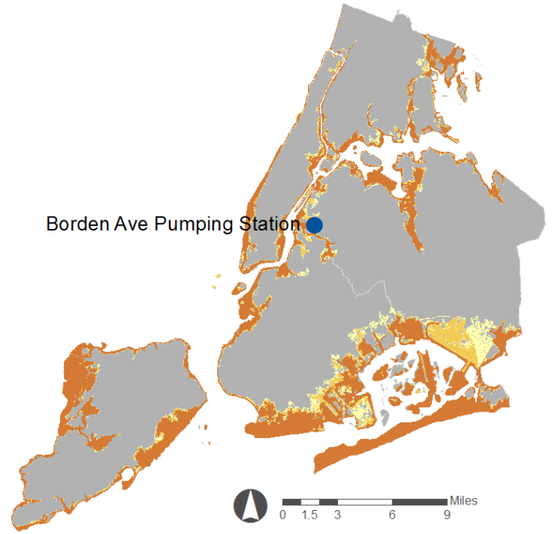
The critical flood elevation would be 4 feet above grade. It would also flood and damage the control panels, which are located on the main floor of the structure less than 2 feet above grade. The non-submersible pumps located below grade would also be damaged.

ADAPTATION STRATEGIES

The Borden Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a substantial existing building but non-submersible pumps are below grade, the recommended strategy at Borden Avenue is to seal the building and install submersible pumps.

FEMA Flood Zones

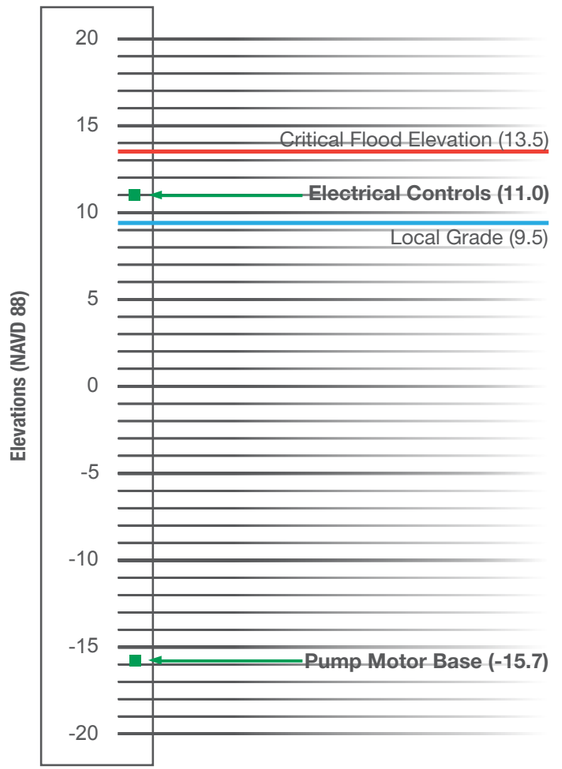




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Non-submersible
	Operating Capacity (MGD)	3.9
	Affected Area (Acres)	63
Risk	Population in Affected Area	590
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building & Submersible Pump Motors
	Cost of Protective Measures[1]	$1,943,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,241,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$15,218,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevated Electrical in New Building**

Adaptation Cost: **$2,400,000**

Pumping station adjacent to flooded lot

Broad Channel Pumping Station

STATION CHARACTERISTICS

The Broad Channel sanitary pumping station is near the intersection of West 22nd Street and Shad Creek Road in Queens. It is adjacent to both Cross Bay Boulevard and a parking lot for the Broad Channel American Park, and is less than 500 feet from the open water of Jamaica Bay. The pumping station is predominantly below grade, with control panels mounted above grade.

The Pumping Station Summary table lists the general characteristics of the Broad Channel pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in an open area and services an area of approximately 145 acres. There is one critical facility within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The area surrounding the pumping station is flat and at risk of experiencing overland flooding. Hurricane Sandy caused flooding more than 3.5 feet above grade.

RISK ASSESSMENT

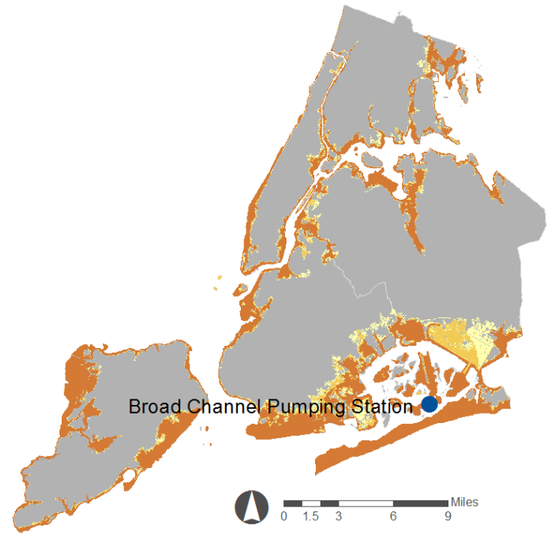
The risk of the Broad Channel pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a visit to the pumping station.

The critical flood elevation would be nearly 9 feet above grade, inundating all components both above and below grade. This would damage the pump controls, but the submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The Broad Channel pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because space is available and flood depth is extreme at 9 feet, the most resilient option was selected; the recommended strategy at Broad Channel is to elevate the pumping station's controls in a new building.

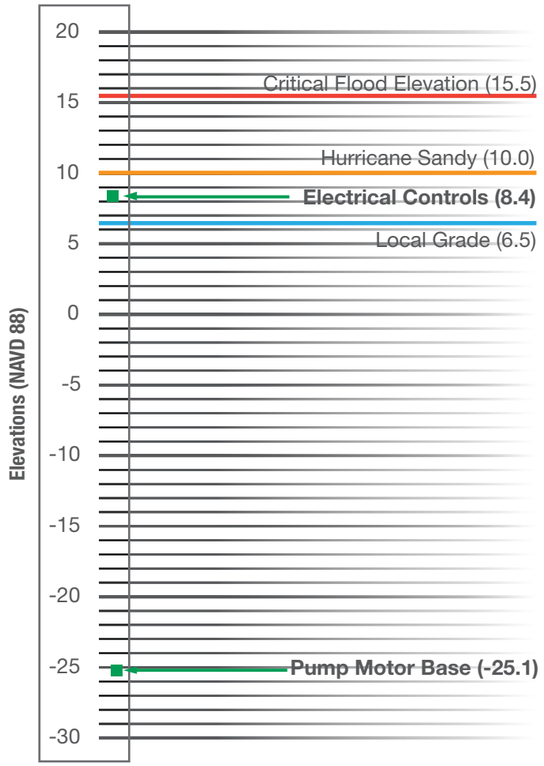
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

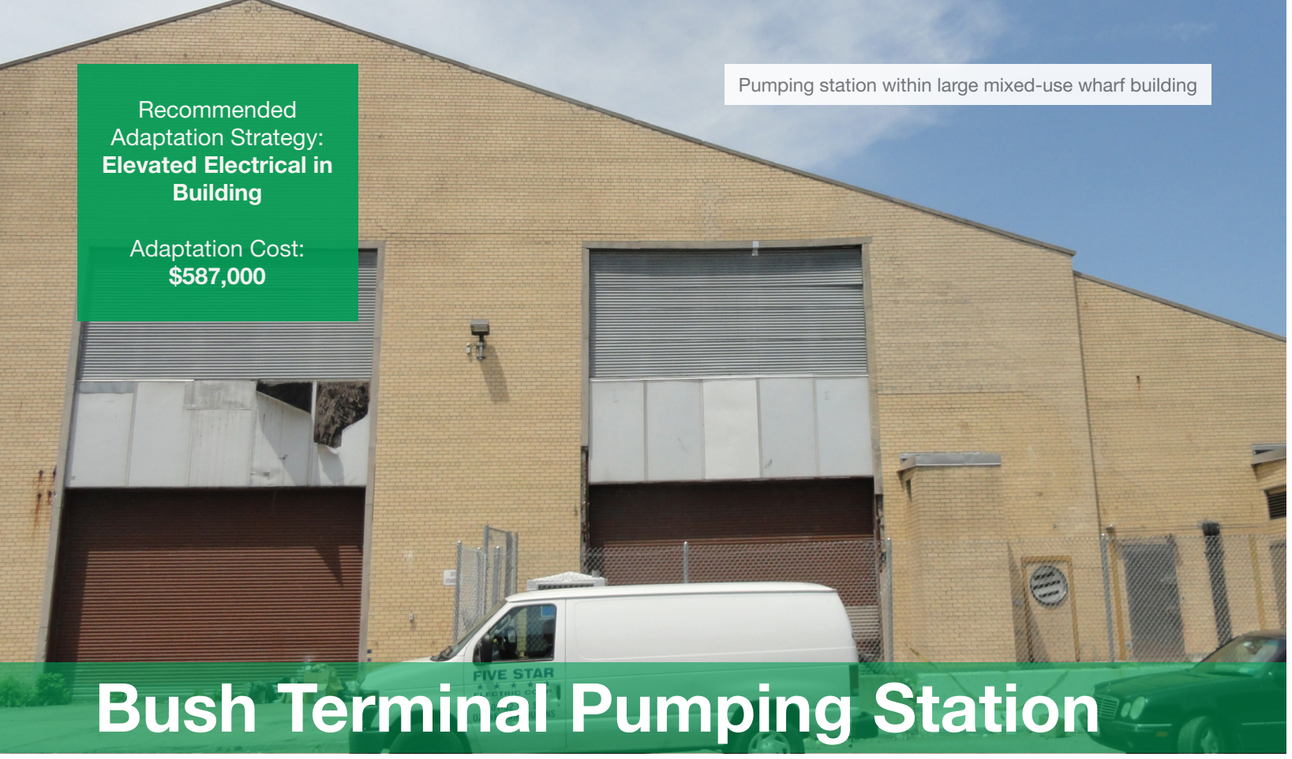
Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	4.1
	Affected Area (Acres)	145
Risk	Population in Affected Area	1,730
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$2,400,000
	Damage Cost for Critical Flood without Protection[1, 2]	$2,337,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$12,028,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.



Recommended Adaptation Strategy: **Elevated Electrical in Building**

Adaptation Cost: **$587,000**

Bush Terminal Pumping Station

STATION CHARACTERISTICS

The Bush Terminal combined sanitary and stormwater pumping station is located on 2nd Avenue, north of 29th Street, in Brooklyn. The pumping station is located in a wharf building that juts into Gowanus Bay. The age of the plans (dated 1985) and the cost involved with rehabilitating a 7.2-million-gallon-per day facility prompted a thorough inspection.

The Pumping Station Summary table lists the general characteristics of the Bush Terminal pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in an industrial area. Failure of the station would affect an area of approximately 57 acres. There is one known critical facility within the area.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

This station was inundated during Hurricane Sandy; flood depth was 2 feet above grade. Electrical equipment was damaged, and repairs were in progress at the time of the inspection. While the motors were not damaged during the storm, they were not in operation at the time of the inspection due to electrical problems. A portable diesel pump was running the station. DEP indicated there is also a history of flooding at this location due to smaller storms.

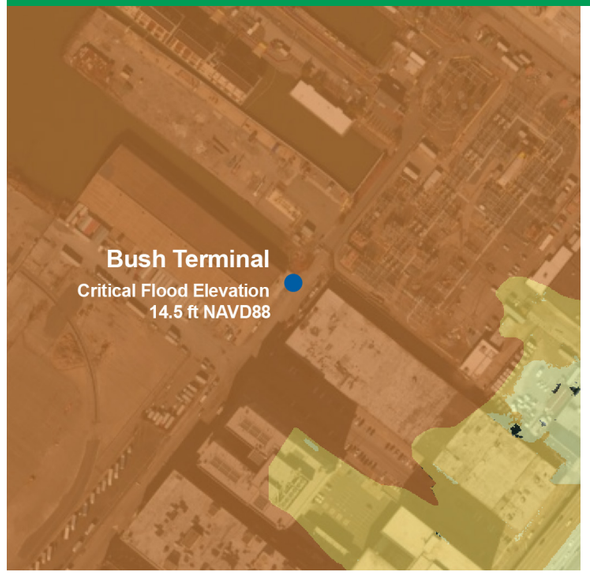
RISK ASSESSMENT

The risk of the Bush Terminal pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room and the dry well. The critical flood elevation would cause a flood more than 8 feet above grade. This would flood and damage all of the pump controls. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

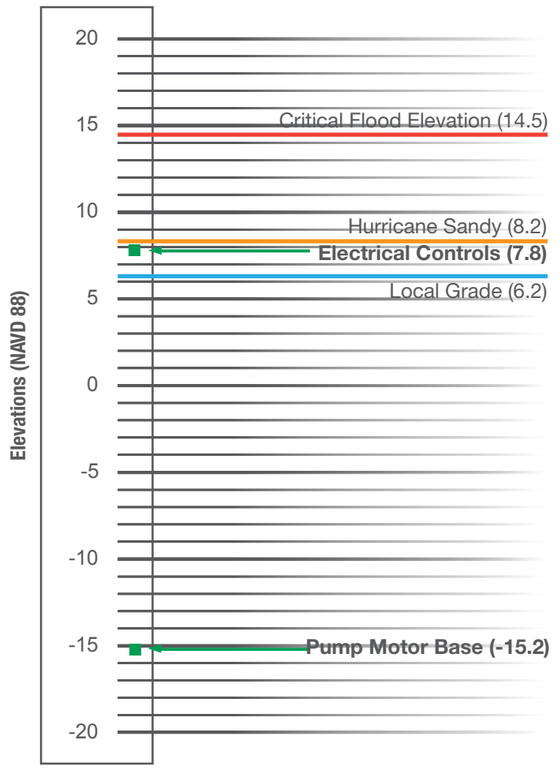
The Bush Terminal pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Controls must be elevated to withstand the critical flood. The existing building is large and may be able to accommodate the controls to the second floor or roof. Therefore, the recommended strategy at Bush Terminal is to elevate the electrical controls to one of these locations in the existing building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	7.2
	Affected Area (Acres)	57
Risk	Population in Affected Area	118
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on Building Roof
	Cost of Protective Measures[1]	$587,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,467,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$17,839,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical on a Platform/Pad & Submersible Pump Motors**

Adaptation Cost: **$2,419,000**

Pumping station beneath sidewalk, adjacent to small park

Canal Street Pumping Station

STATION CHARACTERISTICS

The Canal Street sanitary pumping station is located on the northeast side of Canal Street between Varick Street and 6th Avenue in Manhattan. It is an entirely below grade station with access hatches in the sidewalk.

The Pumping Station Summary table lists the general characteristics of the Canal Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a dense, mixed-use area adjacent to a small park. Failure of the station would affect an area of approximately 37 acres and a population of nearly 3,200. There are two critical facilities within the area.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Canal Street pumping station experienced minor impacts due to Hurricane Sandy but there is no history of flooding at this location.

RISK ASSESSMENT

The risk of the Canal Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be approximately 4 feet above local grade, completely inundating the entire station. The electrical controls and non-submersible pumps are all located below grade and would be flooded and damaged.

ADAPTATION STRATEGIES

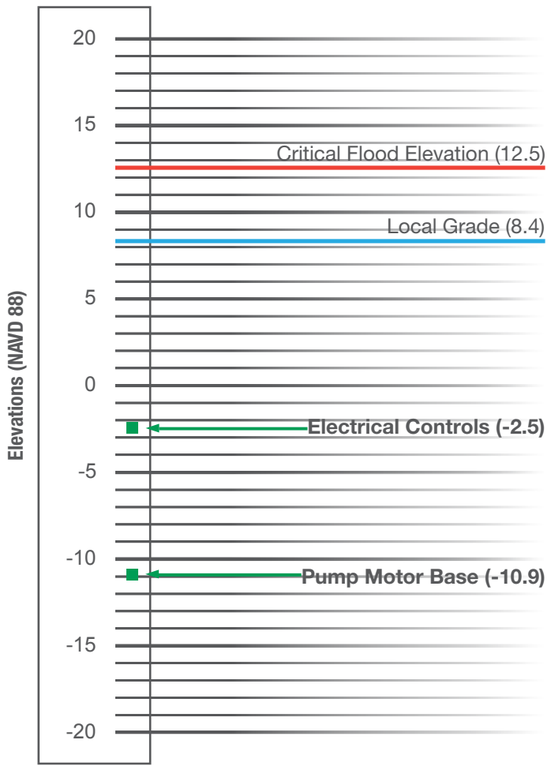
The Canal Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the depth of the critical flood, controls must be elevated and pumps must be submersible to withstand the flood. The pumping station's entrances are located in a sidewalk, but there is a small park directly behind the sidewalk; the recommended strategy at Canal Street is to elevate electrical controls on a platform and install submersible pumps. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	2.2
	Affected Area (Acres)	37
Risk	Population in Affected Area	3,193
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	2
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/ Pad & Submersible Pump Motors
	Cost of Protective Measures[1]	$2,419,000
	Damage Cost for Critical Flood without Protection[1, 2]	$2,710,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$13,332,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Seal Building & Submersible Pump Motors**

Adaptation Cost: **$1,428,000**

Brick structure with elevated entrances

Cannon Avenue Pumping Station

STATION CHARACTERISTICS

The Cannon Avenue sanitary pumping station is located on Cannon Avenue near Glen Street, close to the western shore of Staten Island. A brick building houses the motor control center, and wet and dry wells are located below grade.

The Pumping Station Summary table lists the general characteristics of the Cannon Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 76 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, flood depth in the area surrounding the Cannon Avenue pumping station was 2.5 feet above grade. Flood waters from the storm surge did not enter the station, but loss of power caused the wet well to flood into the dry well during the event. At the time of the inspection, pumps and some electrical components were under repair, and an emergency pump-around was in place. DEP indicated there is also a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

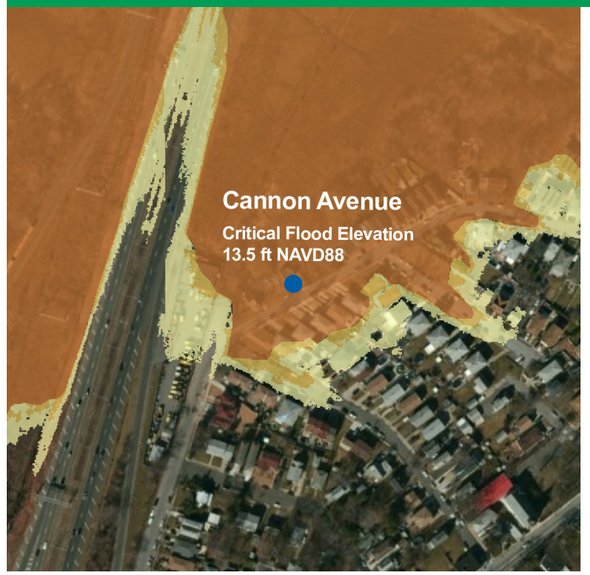
The risk of the Cannon Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room.

The critical flood elevation would be nearly 7 feet above local grade. Water would likely enter the building, flooding and damaging the electrical controls and the non-submersible pumps, all of which are below the critical flood elevation. The Cannon Avenue pumping station is connected to other stations; however it discharges to these stations, rather than receiving flow from them. Therefore, loss of function at Cannon Avenue does not increase the vulnerability of an additional pumping station.

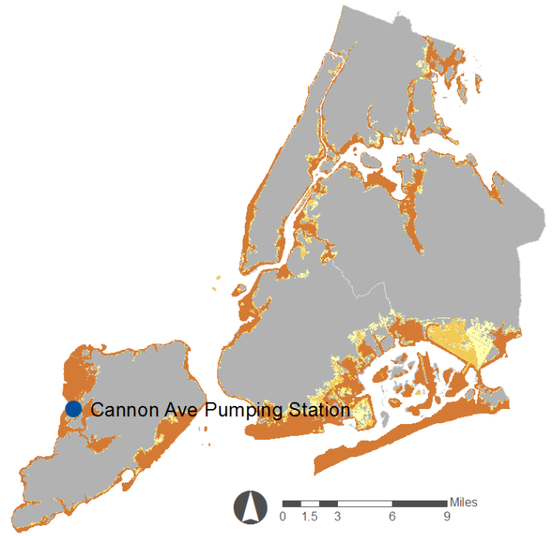
ADAPTATION STRATEGIES

The Cannon Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a substantial existing structure, but non-submersible pumps are well below grade, the recommended strategy at Cannon Avenue is to seal the building and install submersible pumps. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

FEMA Flood Zones

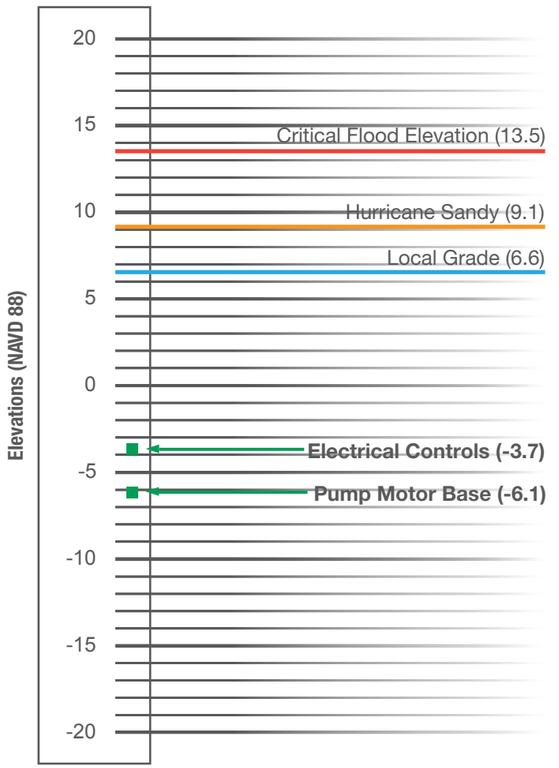


2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	1.1
	Affected Area (Acres)	76
Risk	Population in Affected Area	1,388
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building & Submersible Pump Motors
	Cost of Protective Measures[1]	$1,428,000
	Damage Cost for Critical Flood without Protection[1, 2]	$4,388,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$20,460,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Elevate Electrical in New Building

Adaptation Cost:
$4,710,000

Motor control center above grade in stainless-steel enclosure; hatch entryways to wells

Clearview Pumping Station

STATION CHARACTERISTICS

The Clearview pumping station is located in Queens along the Clearview Expressway service road, in a triangle of land that runs between the service road, the expressway, and an exit ramp from the expressway. The motor control center and other electrical components sit on a grade level concrete slab in stainless steel enclosures, and the wells are accessible through hatches.

The Pumping Station Summary table lists the general characteristics of the Clearview pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located between major roadways. Failure of the station would affect an area of approximately 523 acres and a population of more than 22,450. There are two critical facilities within that area that could be affected if the station failed, and a nearby bathing beach would also be affected.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

Clearview has experienced infrequent flooding in the past, but the station was not affected by Hurricane Sandy. Sandbags were onsite at the time of the visit in March 2013, indicating a possible recent flooding event

RISK ASSESSMENT

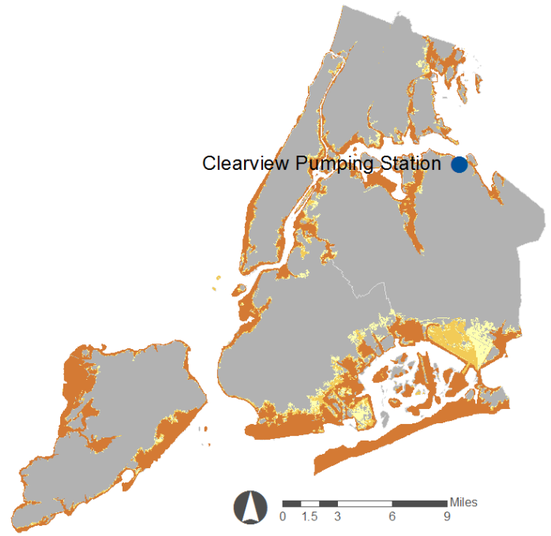
The risk of the Clearview pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the March 2013 FEMA Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior revealed that the Motor Control Center (MCC) and other electrical controls, which were shown below grade in the drawings, had been moved to a slab above grade. DEP data also indicate that the pumps had been replaced with submersibles.

The critical flood elevation would be more than 3 feet above grade. This would flood and damage the grade-level motor control center and pump.

ADAPTATION STRATEGIES

The Clearview pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the critical flood depth and the lack of an existing structure, the recommended strategy at Clearview is to elevate the pumping station's controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

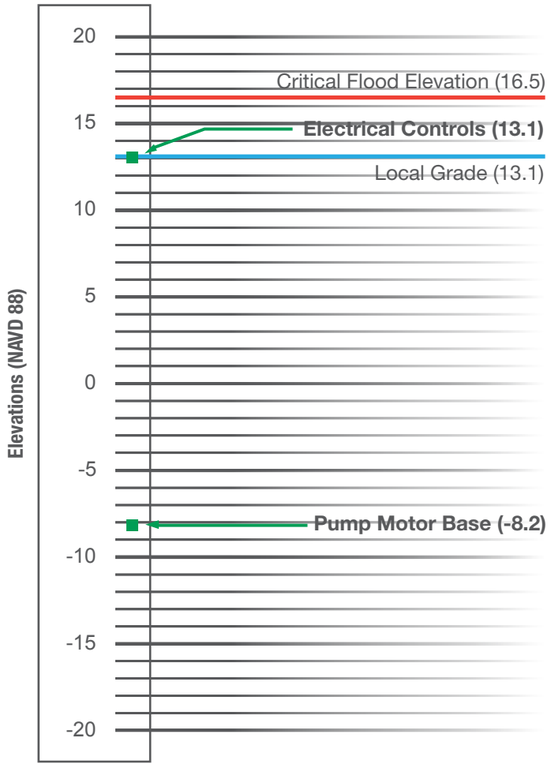
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	13.0
	Affected Area (Acres)	523
Risk	Population in Affected Area	22,450
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	2
	Historic Flooding	Y
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$4,710,000
	Damage Cost for Critical Flood without Protection[1, 2]	$7,818,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$16,802,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical on Platform/Pad**

Adaptation Cost: **$634,000**

Motor control center above grade in stainless-steel enclosure; hatch entryways to wells

Commerce Avenue Pumping Station

STATION CHARACTERISTICS

The Commerce Avenue pumping station is located in a triangle of land between Commerce Avenue, Seabury Avenue, and Ellis Avenue in the Bronx. It is primarily below grade and accessible through hatches in the concrete, but the motor control center is mounted above grade on a small concrete slab. Power appears to lead from overhead lines to a transformer.

The Pumping Station Summary table lists the general characteristics of the Commerce Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in an industrial area. Failure of the station would affect an area of approximately 7 acres. There are no critical facilities within the area.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, flood depth in the surrounding area was about 1 foot above the street level but the pumping station operation was not affection. DEP staff indicated that historic flooding has been an issue at this pumping station.

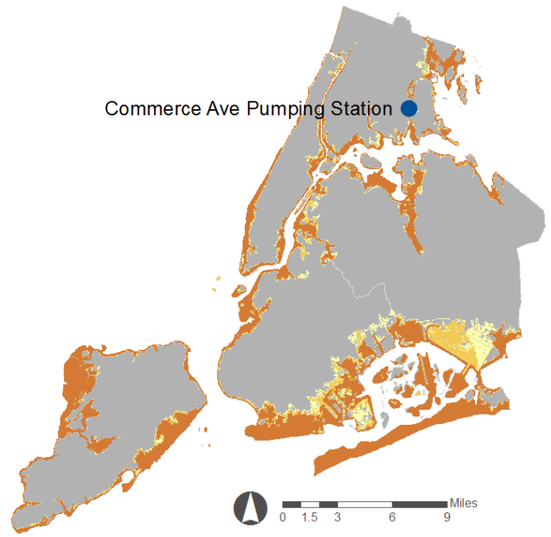
RISK ASSESSMENT

The risk of the Commerce Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior revealed that the electrical controls, which are shown below grade in the drawings, have been moved to a slab above grade. The critical flood elevation would be 5 feet above grade. Water would flood and damage the motor control center. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The Commerce Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Controls should be elevated to withstand the critical flood, and there is ample space to do so on the current lot. Because the station is located in an industrial area, a building is not necessary for aesthetic reasons. Components are currently exposed above grade, and there have been no known incidents of vandalism, so a building should not be necessary for security reasons, either. Therefore, the recommended strategy at Commerce Avenue is to elevate electrical controls onto a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

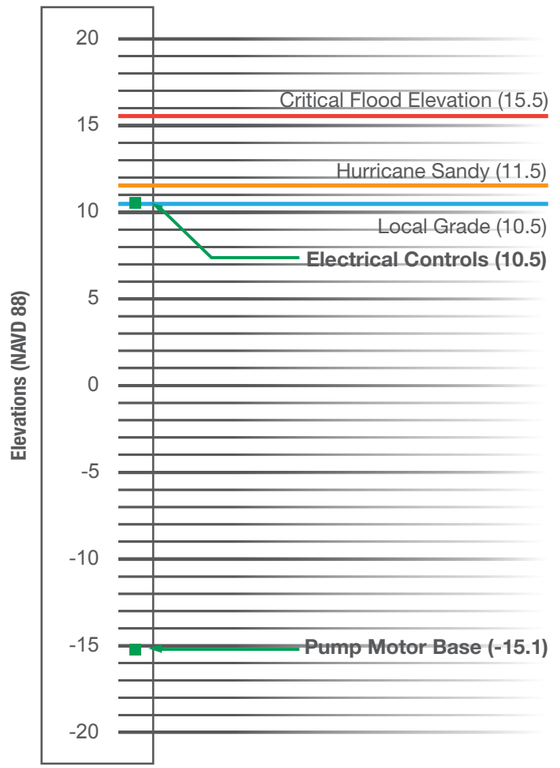
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	1.4
	Affected Area (Acres)	7
Risk	Population in Affected Area	0
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	Y
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on Platform/Pad
	Cost of Protective Measures[1]	$634,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,037,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$5,337,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Construction Barrier

Adaptation Cost:
$5,456,000

Concrete structure on paved lot adjacent to Hutchinson River

Conner Street Pumping Station

STATION CHARACTERISTICS

The Conner Street combined sanitary and stormwater pumping station is near the end of Conner Street in the Bronx; the property is bounded by Conner Street to the west and the Hutchinson River to the east. Controls are located on the main floor of the station's concrete structure. Overhead power lines connect to buried power lines near the western edge of the lot, and the buried lines run under the station's parking lot to two transformers on the main floor.

The Pumping Station Summary table lists the general characteristics of the Conner Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in an industrial area. Failure of the station would affect an area of approximately 1,336 acres and a population of nearly 46,000. There are 36 critical facilities in the service area that could be affected if the station fails. Additionally, failure of this pumping station could affect a nearby bathing beach.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

This station has experienced multiple flooding events during which water approached the station from the adjacent Hutchinson River. During Hurricane Sandy, the lot surrounding the station flooded to a depth of around 1 foot. Fuses on the poles supporting the overhead power lines blew out, cutting power before it reached the transformers. At the time of the visit, ventilation in the wet well was not working due to flooding damage.

RISK ASSESSMENT

The risk of the Conner Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room and wells.

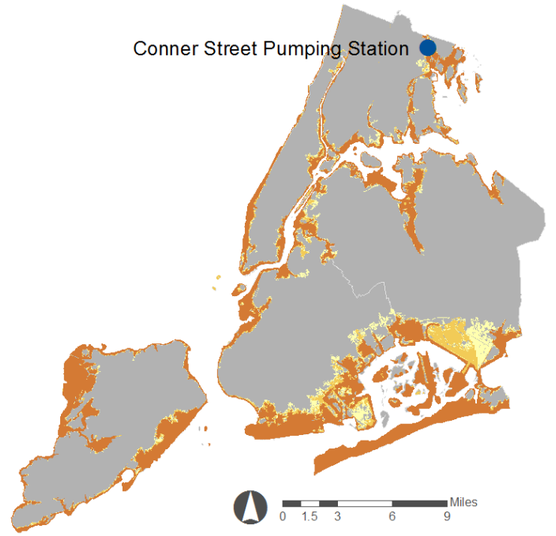
The critical flood elevation would be about 6 feet above local grade. Water would likely enter the building, flooding and damaging the electrical controls as well as the non-submersible pumps, all of which are located below the critical flood elevation. The Conner Street pumping station has the ability to receive flow from another pumping station. Therefore, loss of function at Conner Street increases the vulnerability of an additional pumping station, tributary area, and population.

ADAPTATION STRATEGIES

The Conner Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is an existing structure, but there are extensive controls which could not easily be moved, the recommended strategy at Conner Street is to construct a barrier. The installation of a backup generator is also recommended, and when pumps need to be replaced as part of regular maintenance, submersible pumps should be installed. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

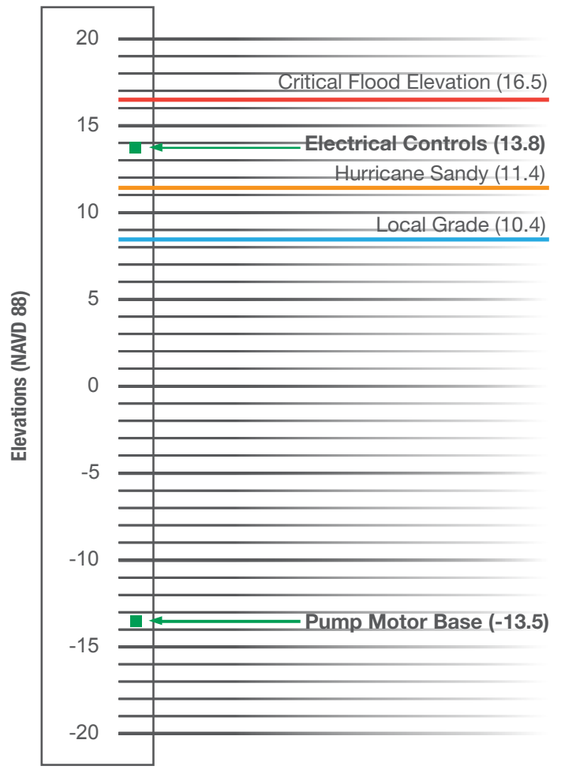
FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Non-submersible
	Operating Capacity (MGD)	11.5
	Affected Area (Acres)	1,336
Risk	Population in Affected Area	45,885
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	36
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	Y
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Construct Barrier
	Cost of Protective Measures[1]	$5,456,000
	Damage Cost for Critical Flood without Protection[1, 2]	$6,573,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$32,135,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Seal Building**

Adaptation Cost: **$350,000**

Co-op City North Pumping Station

STATION CHARACTERISTICS

The Co-op City North sanitary pumping station is located at the corner of Co-op City Blvd. and Bellamy Loop. The Hutchinson River runs behind the station. The pumping station has a cinder block structure as well as concrete-housed vents atop a concrete slab.

The Pumping Station Summary table lists the general characteristics of the Co-op City North pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a densely-populated residential area. Failure of the station would affect an area of approximately 210 acres and a population of over 27,000. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Co-op City North pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

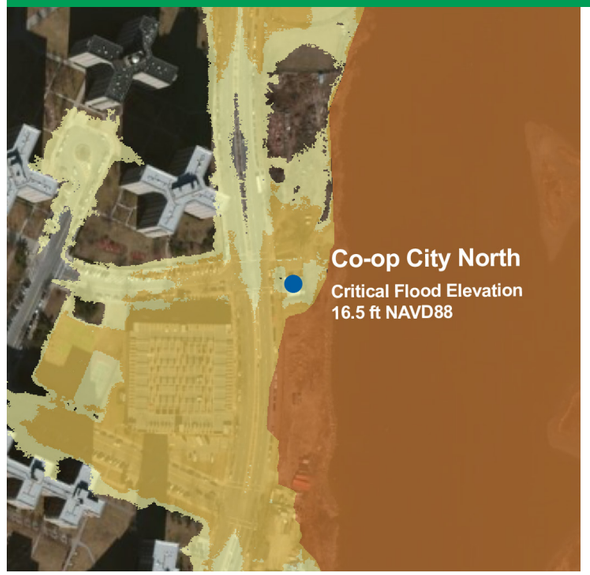
The risk of the Co-op City North pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

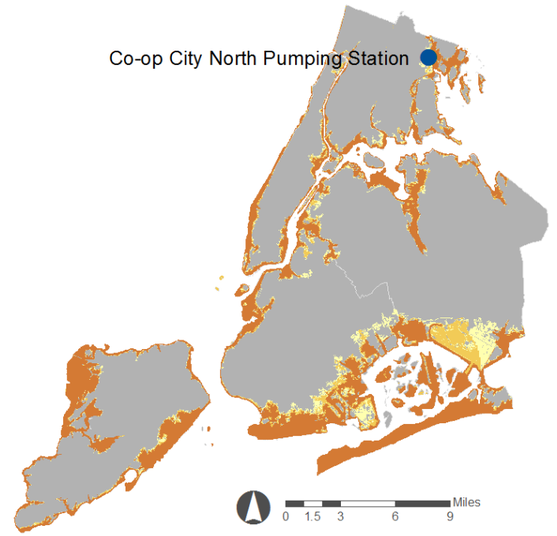
The critical flood elevation would be 2 feet above local grade. Electrical controls are below grade within the structure, and the doorway threshold into the structure is about 1 foot above grade, which is 1 foot below the critical flood elevation. Flood waters could enter the structure and damage the electrical controls. The submersible pumps should withstand flooding. The Co-op City North pumping station has the ability to receive flow from another pumping station. Therefore, loss of function at Co-op City North increases the vulnerability of an additional pumping station, tributary area, and population.

ADAPTATION STRATEGIES

The Co-op City North pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a significant existing structure, the recommended strategy at Co-op City North is to seal the building. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

FEMA Flood Zones

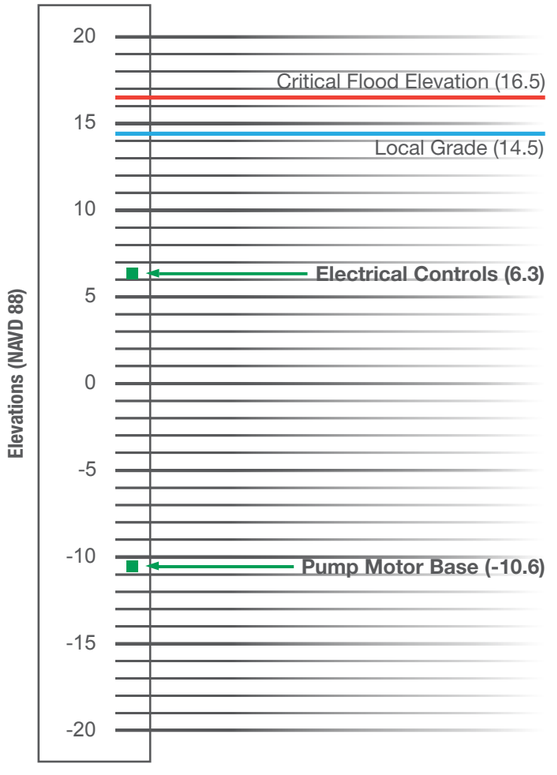




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	16.1
	Affected Area (Acres)	210
Risk	Population in Affected Area	27,285
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	Y
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$350,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,700,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$3,262,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Below grade pumping station between residential neighborhood and wetlands

Recommended Adaptation Strategy:
Elevate Electrical in New Building

Adaptation Cost:
$7,389,000

Douglaston Bay Pumping Station

STATION CHARACTERISTICS

The Douglaston Bay sanitary pumping station is located near the corner of 41st Avenue and 233rd Street in Queens. It is situated in a paved area between the roadway and wetlands that run along the southeastern shore of Little Neck Bay. The Douglaston Bay pumping station is entirely below grade and is accessible through hatches in the pavement.

The Pumping Station Summary table lists the general characteristics of the Douglaston Bay pumping station, the potential effect of its failure, and the recommended adaptation strategy. The Douglaston Bay pumping station is located in a residential area. Failure of the station would affect an area of approximately 27 acres and a population of more than 600. There is one critical facility in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Douglaston Bay pumping station was flooded during Hurricane Sandy, though there is no history of flooding outside of this event.

RISK ASSESSMENT

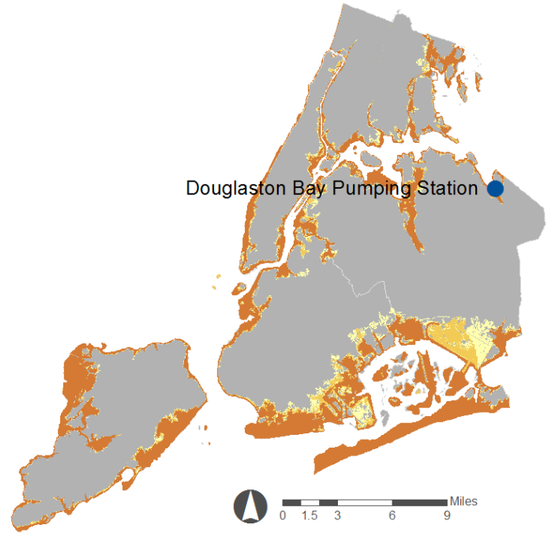
The risk of the Doug Bay pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

Collection Systems staff provided further details on the station's flooding history and vulnerability. The critical flood elevation would be more than 8 feet above local grade, completely inundating the entire station. The electrical controls, which are below grade, would be flooded and damaged. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The Doug Bay pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the 8-foot depth of the critical flood and the lack of an existing structure, the recommended strategy at Doug Bay is to elevate electrical controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

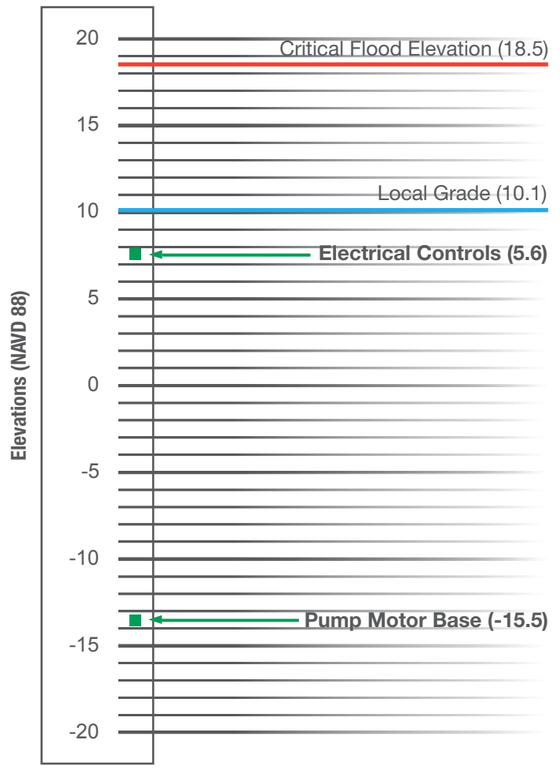
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	1.0
	Affected Area (Acres)	27
Risk	Population in Affected Area	613
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$7,389,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,799,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$9,256,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Large structure within Fresh Kills Landfill

Recommended Adaptation Strategy:
Seal Building

Adaptation Cost:
$588,000

Eltingville Pumping Station

STATION CHARACTERISTICS

The Eltingville sanitary pumping station is located within the Fresh Kills landfill on Staten Island, along a service road that runs into the landfill. The entrance to the service road is on Arthur Kill Road across from Brookfield Avenue. The station is in a large stucco structure completely surrounded by a driveway. Two entrances to the wet well are located in back of the structure.

The Pumping Station Summary table lists the general characteristics of the Eltingville pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a landfill surrounded by residential neighborhoods. Failure of the station would affect an area of approximately 417 acres. There are 3 critical facilities within that area that could be affected if the station failed, and there is a nearby bathing beach that could be affected.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Eltingville pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

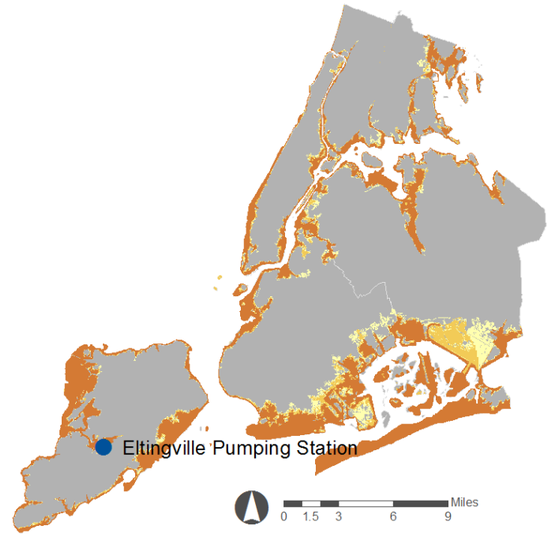
RISK ASSESSMENT

The risk of the Eltingville pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings. The critical flood elevation would be just under 1 foot above local grade. Because electrical controls and non-submersible pumps are located below grade and below the flood elevation, they could be damaged if water enters the structure.

ADAPTATION STRATEGIES

The Eltingville pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a significant existing structure, the recommended strategy at Eltingville is to seal the building so that flood waters cannot enter; this is a less expensive option than those that involve moving electrical controls or motors. While this strategy will provide resilient protection, there is the potential for leaks, inflows to the wells, or unidentified flow paths. DEP will consider replacing the non-submersible pumps with submersibles as normal replacement is needed as part of regular maintenance. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

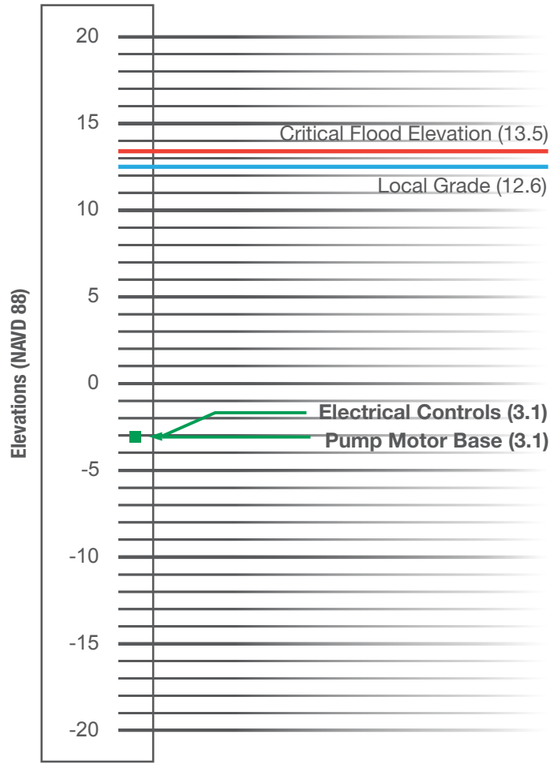
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	17.3
	Affected Area (Acres)	417
Risk	Population in Affected Area	9,363
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	3
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$588,000
	Damage Cost for Critical Flood without Protection[1, 2]	$9,508,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$5,438,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Brick structure in residential commercial area

Recommended Adaptation Strategy:
Seal Building

Adaptation Cost:
$470,000

Ely Avenue Pumping Station

STATION CHARACTERISTICS

The Ely Avenue sanitary pumping station is located at the corner of Ely Avenue and Waring Avenue in the Bronx, adjacent to a Home Depot parking lot. The station has a brick structure with entrances and the main floor situated approximately 2 feet above grade.

The Pumping Station Summary table lists the general characteristics of the Ely Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The Ely Avenue pumping station is located in a mixed residential and commercial area. Failure of the station would affect an area of approximately 300 acres and a population of nearly 1,500. There are five critical facilities in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Ely Avenue pumping station was affected by Hurricane Sandy but there is no history of flooding at this location.

RISK ASSESSMENT

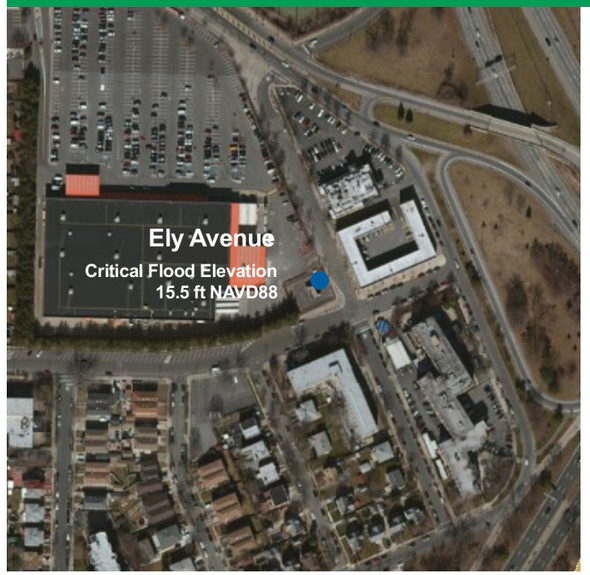
The risk of the Ely Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

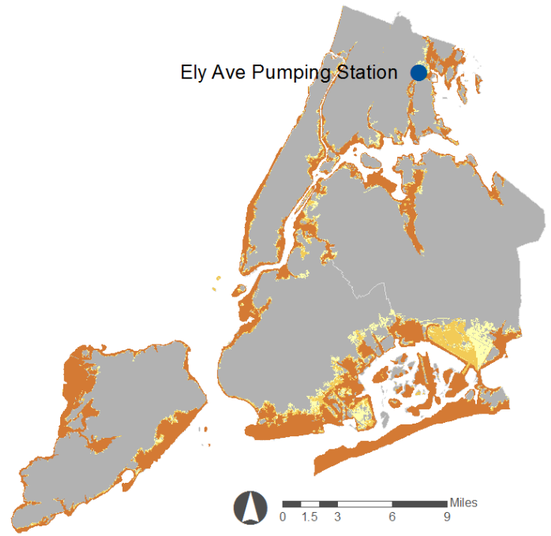
The critical flood elevation would be 2 feet above local grade, which is equal to the elevation of the main floor of the structure where electrical controls are housed. This could cause damage to the electrical controls; submersible pumps should be unaffected.

ADAPTATION STRATEGIES

The Ely Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a substantial existing structure with entrances above the critical flood elevation, the recommended strategy at Ely Avenue is to seal the building. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

FEMA Flood Zones

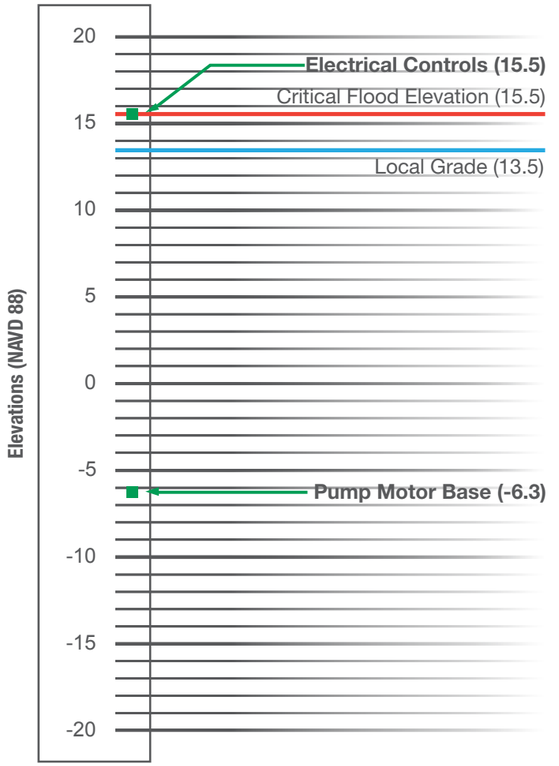




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	1.6
	Affected Area (Acres)	300
Risk	Population in Affected Area	1,460
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	5
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$470,000
	Damage Cost for Critical Flood without Protection[1, 2]	$2,015,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$3,584,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Construct Barrier

Adaptation Cost:
$1,256,000

Structure beneath Flushing Bridge in driveway of concrete company

Flushing Bridge Pumping Station

STATION CHARACTERISTICS

The Flushing Bridge sanitary pumping station is located within the parking lot and driveway of Best Concrete Mix Corp. at 3510 College Point Boulevard in Queens. The station's small brick structure is located directly underneath the roadway of the Flushing Bridge. Hatch entryways to the wells are located in the concrete directly behind the structure.

The Pumping Station Summary table lists the general characteristics of the Flushing Bridge pumping station, the potential effect of its failure, and the recommended adaptation strategy. The Flushing Bridge pumping station is located in an industrial and commercial area. Failure of the station would affect an area of approximately 25 acres. There are no critical facilities in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Flushing Bridge pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

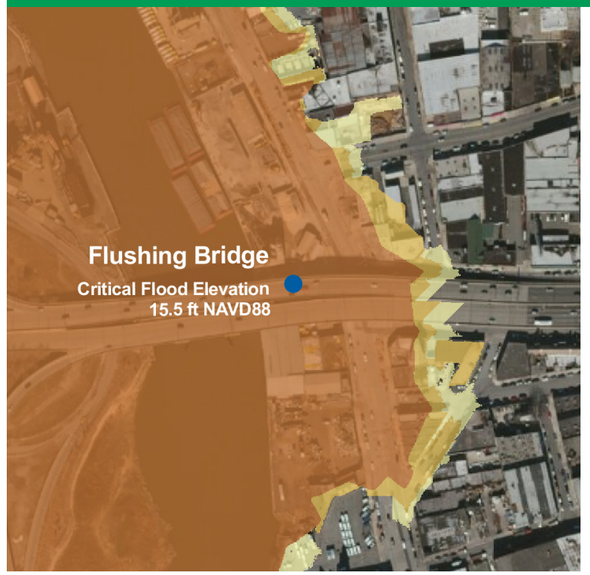
The risk of the Flushing Bridge pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

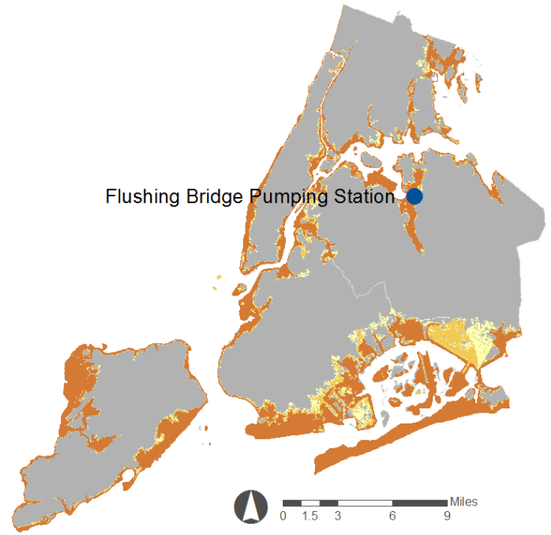
The critical flood elevation would be more than 7 feet above local grade. Water would likely enter the building, flooding and damaging the electrical controls. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The Flushing Bridge pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is an existing structure, but there are numerous potential flood entryways, the recommended strategy at Flushing Bridge is to seal the main door and construct a barrier around the vents on the rear pad of the station. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the seal could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

FEMA Flood Zones

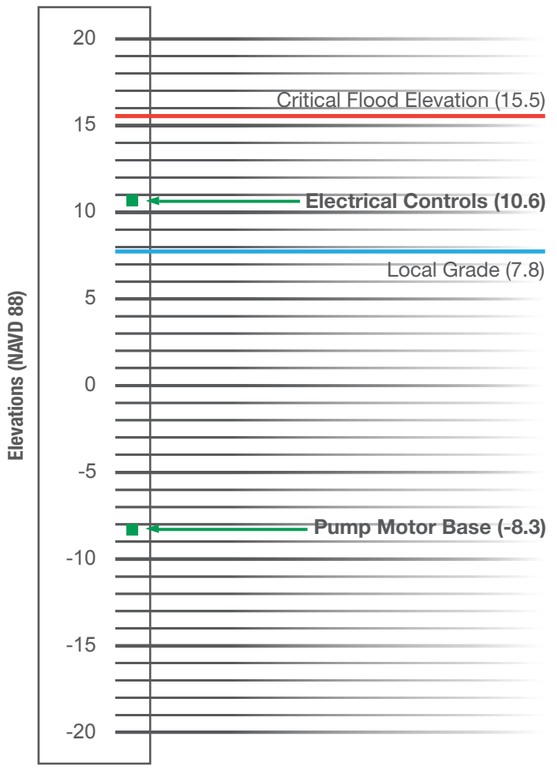




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	1.2
	Affected Area (Acres)	25
Risk	Population in Affected Area	3
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Construct Barrier
	Cost of Protective Measures[1]	$1,256,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,742,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$8,514,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical on a Platform/Pad**

Adaptation Cost: **$895,000**

Pumping station in residential neighborhood between dead-end street and open water

Gildersleeve Avenue Pumping Station

STATION CHARACTERISTICS

The Gildersleeve Avenue sanitary pumping station is located at the dead end of Gildersleeve Avenue near the intersection with Betts Avenue in the Bronx. It is less than 20 feet from an inlet that connects to Long Island Sound. The motor control center (MCC) and electric meters sit on the sidewalk in stainless-steel enclosures. There are hatch entryways to the wells in the sidewalk.

The Pumping Station Summary table lists the general characteristics of the Gildersleeve Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 15 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Gildersleeve Avenue pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

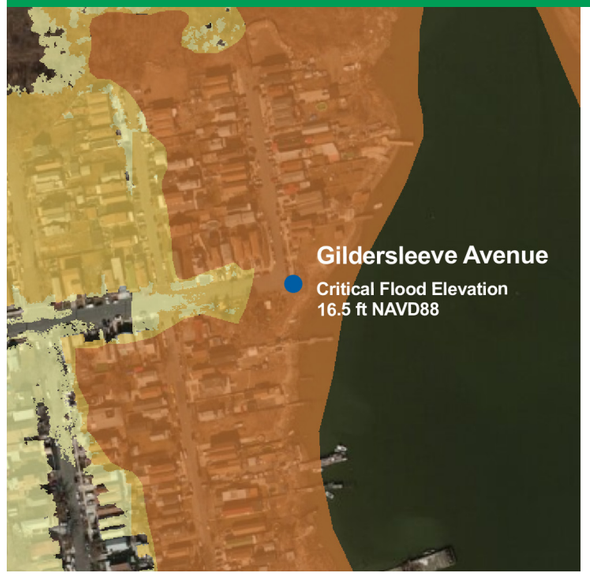
The risk of the Gildersleeve Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior revealed that the MCC and other electrical controls, which are not clearly shown in drawings, are located above grade on the sidewalk.

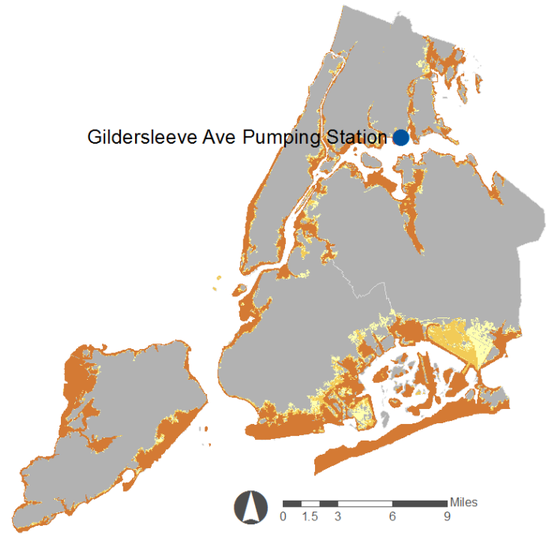
The critical flood elevation would be 3 feet above local grade. Electrical controls sit only a few inches above grade on the sidewalk, and they would be damaged. The submersible pumps should withstand flooding.

ADAPTATION STRATEGIES

The Gildersleeve Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the flood depth and the fact that exposed above grade components are acceptable in this location, the recommended strategy at Gildersleeve Avenue is to elevate electrical controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

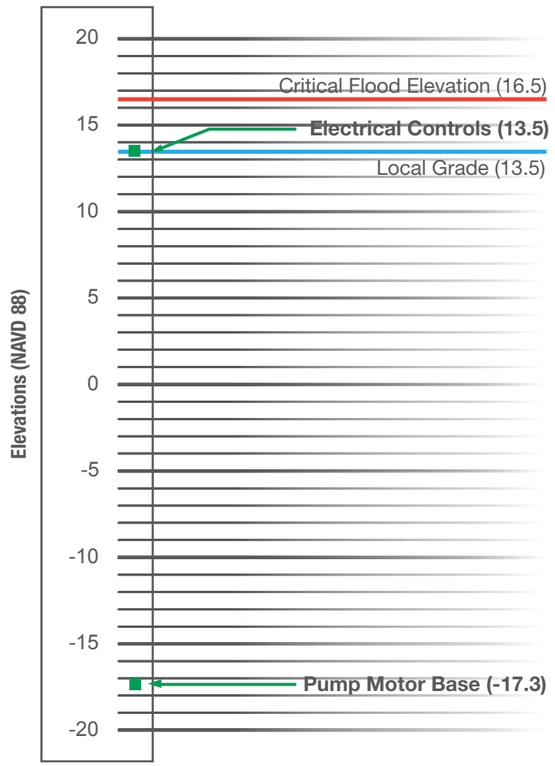




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	<1MGD
	Affected Area (Acres)	15
Risk	Population in Affected Area	363
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$895,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,142,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$3,971,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Elevate Electrical in New Building & Submersible Pump Motors

Adaptation Cost:
$1,372,000

Hannah Street Pumping Station

STATION CHARACTERISTICS

The Hannah Street combined pumping station is located near the intersection of Hannah Street and Murray Hulbert Avenue in Staten Island. The site is approximately 300 feet from the open water of the Narrows. The station consists of large above- and below grade structures. The motor control center and non-submersible pumps are housed below grade within the structure.

The Pumping Station Summary table lists the general characteristics of the Hannah Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 2,166 acres and a population of more than 50,000. There are 44 critical facilities in the area that could be affected if the station fails. Additionally, failure of this pumping station could affect a nearby bathing beach.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, the Hannah Street pumping station lost power but did not experience any flooding. Nearby areas experienced flooding that was 4 feet above grade. The Hannah Street station does have a history of flooding outside of Hurricane Sandy.

RISK ASSESSMENT

The risk of the Hannah Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room and dry well.

The critical flood elevation would be approximately 4.5 feet above local grade. This would likely enter the building, flooding and damaging the electrical controls as well as the non-submersible pumps, all of which are located below the critical flood elevation. The Hannah Street pumping station receives flow from another pumping station. Therefore, loss of function at Hannah Street increases the vulnerability of an additional pumping station, tributary area, and population.

ADAPTATION STRATEGIES

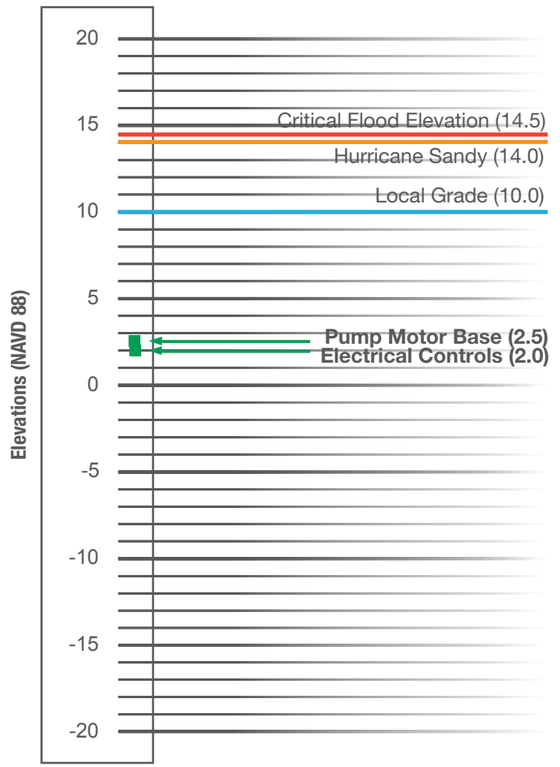
The Hannah Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. The Hannah Street pumping station is currently in design to be rebuilt. To add resiliency, the new plans should include elevating electrical controls and installing submersible pumps. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Non-submersible
	Operating Capacity (MGD)	37.5
	Affected Area (Acres)	2,166
Risk	Population in Affected Area	50,193
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	44
	Historic Flooding	Y
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building & Submersible Pump Motors
	Cost of Protective Measures[1]	$1,372,000
	Damage Cost for Critical Flood without Protection[1, 2]	$12,796,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$63,238,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical in New Building**

Adaptation Cost: **$2,484,000**

Below grade pumping station with above grade entrance adjacent to Eastchester Creek

Hollers Avenue Pumping Station

STATION CHARACTERISTICS

The Hollers Avenue sanitary pumping station is located at the corner of Hollers Avenue and Eastchester Place in the Bronx; it is situated between the roadway and Eastchester Creek. The below grade control room is accessible by a stairwell that has an enclosed doorway entrance above grade, and wells are accessible through hatches. There is an adjacent substation that can be used as backup when the primary station must be taken offline.

The Pumping Station Summary table lists the general characteristics of the Hollers Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 642 acres and a population of more than 800. There are no critical facilities in that area.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Hollers Avenue pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

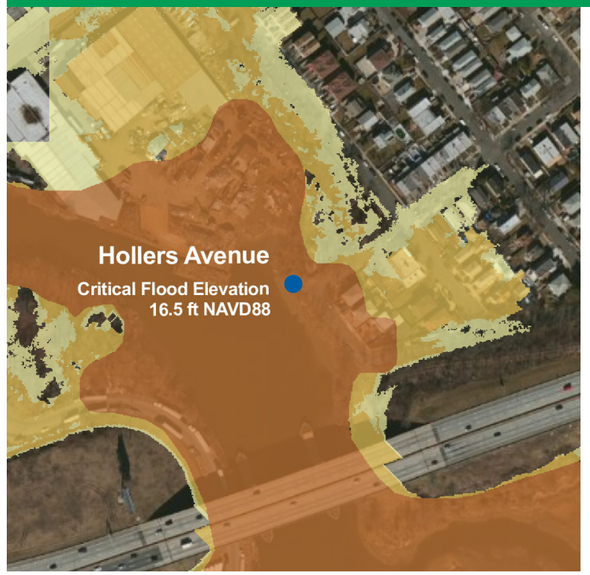
The risk of the Hollers Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

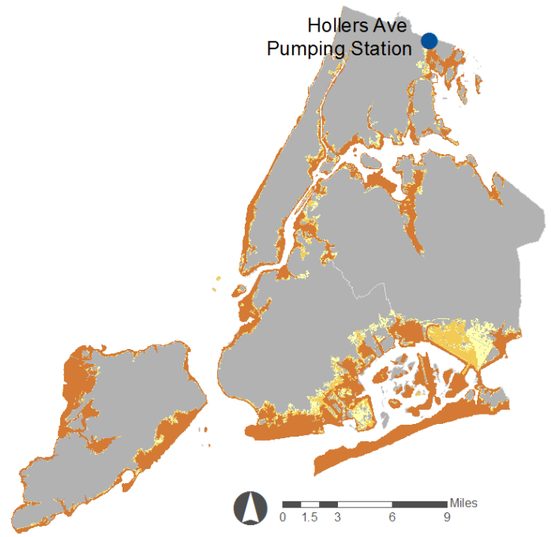
The predicted critical flood elevation would be 7 feet above local grade. This would damage the below grade electrical controls. The submersible pumps should be unaffected.

ADAPTATION STRATEGIES

The Hollers Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the significant depth of the critical flood, the lack of an existing structure, and the available space, the recommended strategy at Hollers Avenue is to elevate electrical controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

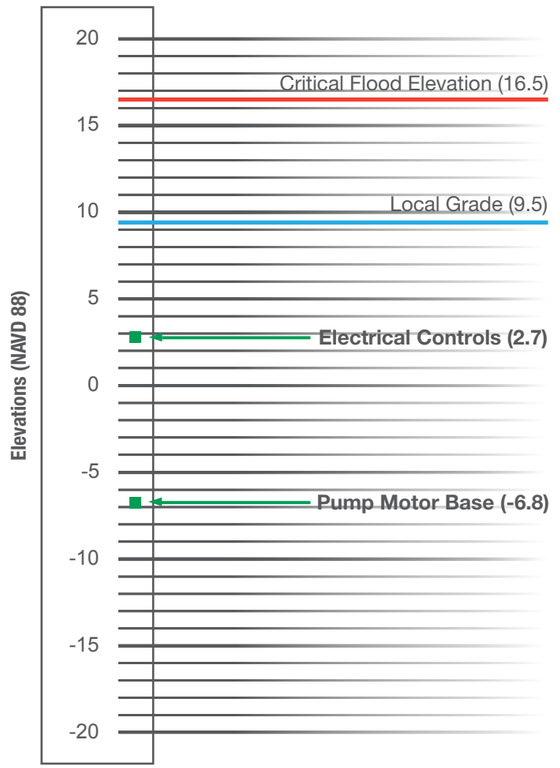




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	1.4
	Affected Area (Acres)	642
Risk	Population in Affected Area	808
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$2,484,000
	Damage Cost for Critical Flood without Protection[1, 2]	$2,824,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$14,531,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Construct Barrier

Adaptation Cost:
$8,165,000

Howard Beach Pumping Station

STATION CHARACTERISTICS

The Howard Beach combined pumping station is located near the corner of 155th Avenue and 100th Street in Queens. The station is below grade, but the entrances to it are elevated about 2 feet above grade on a concrete slab.

The Pumping Station Summary table lists the general characteristics of the Howard Beach pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 3,188 acres and a population of more than 85,000. There are 25 critical facilities, including four hospitals, in the area that could be affected if the station fails.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, the surrounding area did not experience flooding but the station experienced minor impacts due to the storm. There is not history of flooding at this station.

RISK ASSESSMENT

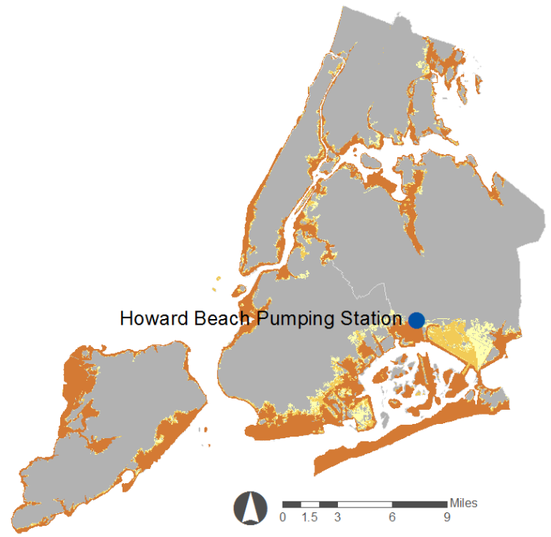
The risk of the Howard Beach pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be about 7 inches above local grade. While entrances are elevated above the flood height, the structure is not flood-proof, and the below grade electrical controls and non-submersible pumps could be flooded and damaged.

ADAPTATION STRATEGIES

The Howard Beach pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because of the shallow depth of the critical flood and the location of most entrances above the flood elevation, the recommended strategy at Howard Beach is to add watertight doors in the existing wall at pedestrian and vehicle entry points. Sandbagging is also a potential option but water tight access doors provide a permanent and more resilient solution. The installation of emergency generators is also recommended. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

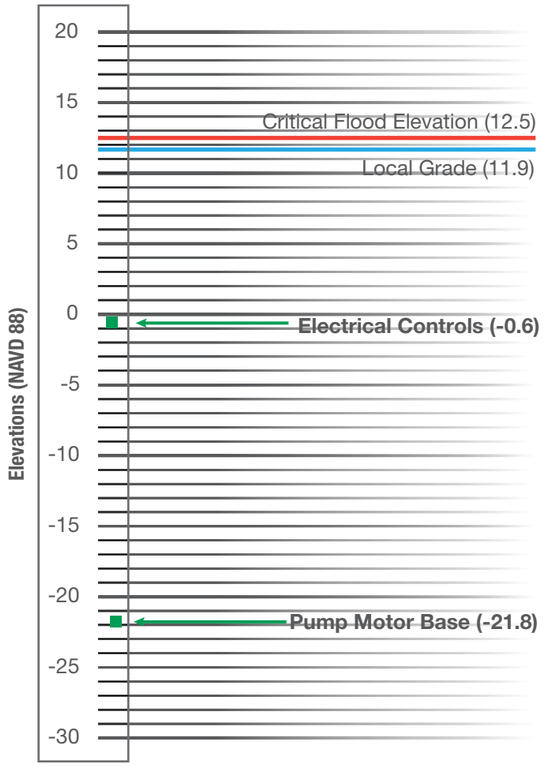
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Non-submersible
	Operating Capacity (MGD)	57.6
	Affected Area (Acres)	3,188
Risk	Population in Affected Area	85,540
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	25
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Construct Barrier
	Cost of Protective Measures[1]	$8,165,000
	Damage Cost for Critical Flood without Protection[1, 2]	$17,438,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$20,649,000
	Resiliency Level	Moderate-Low

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Hunts Point Market Pumping Station

STATION CHARACTERISTICS

The Hunts Point Market sanitary pumping station is located on Farragut Street near its corner with Food Center Drive in the Bronx. The motor control center is located above grade in a small brick enclosure, and the rest of the station is below grade.

The Pumping Station Summary table lists the general characteristics of the Hunts Point Market pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial area. It services an area of approximately 126 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Hunts Point Market pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

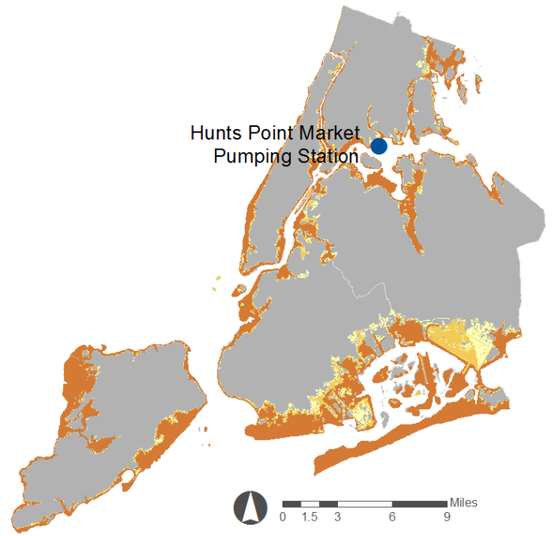
The risk of the Hunts Point Market pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be 2 feet above local grade. The bottom of the motor control center is only 1 foot above grade, so flood waters could enter the surrounding structure and damage the controls. The submersible pumps should be unaffected.

ADAPTATION STRATEGIES

The Hunts Point Market pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the vulnerability of electrical controls in their current location and the presence of vents and hatches near grade level, the recommended strategy at Hunts Point Market is to elevate electrical controls on a platform and place sandbags around the remaining potential water entry points prior to a flooding event.

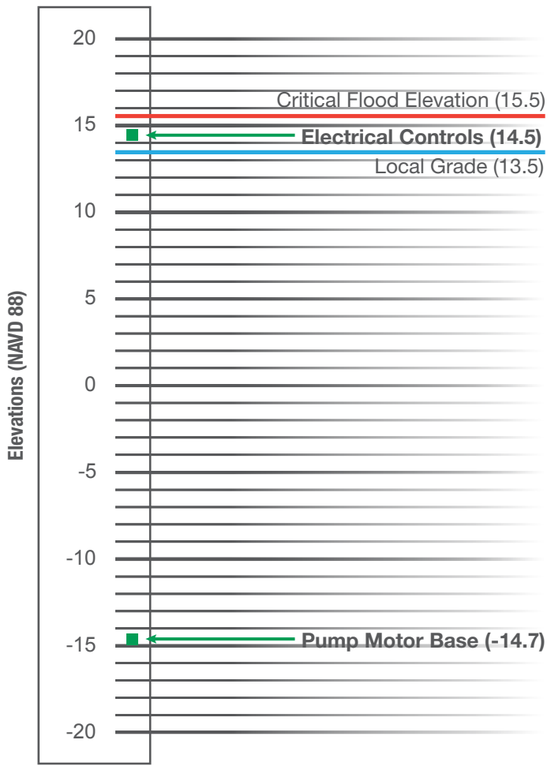
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

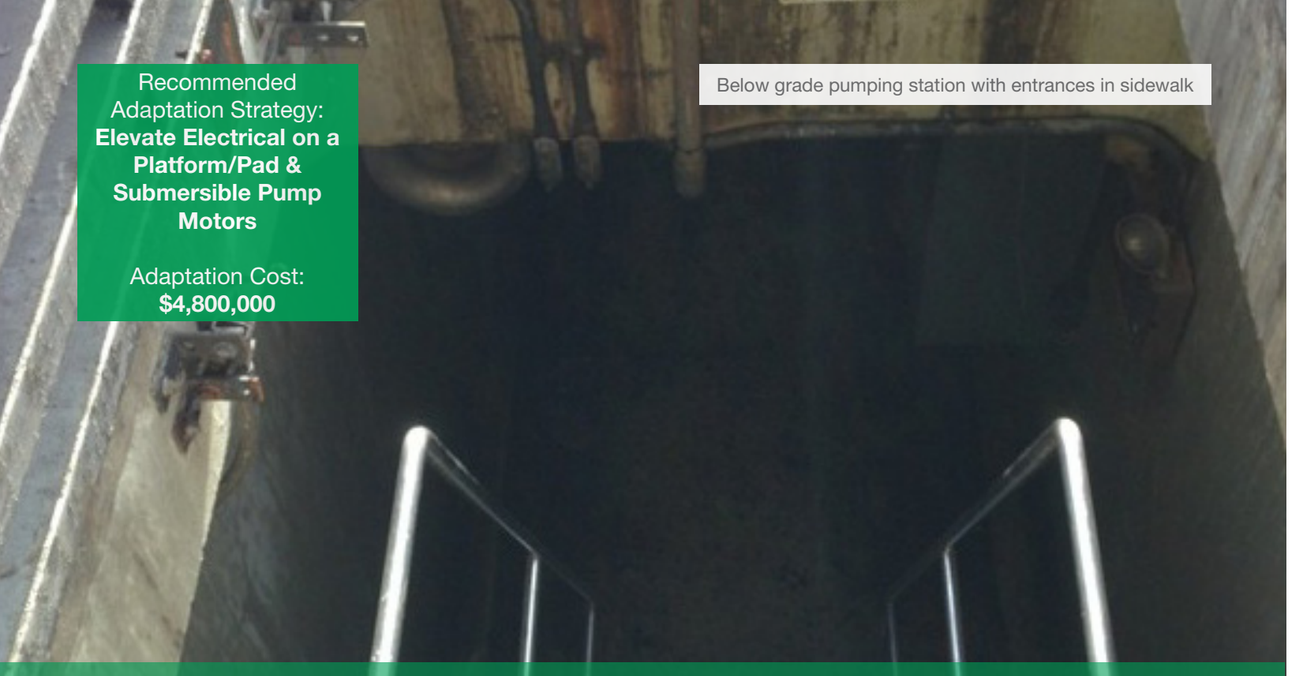
Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	5.8
	Affected Area (Acres)	126
Risk	Population in Affected Area	0
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad & Sandbagging
	Cost of Protective Measures[1]	$730,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,859,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$5,654,000
	Resiliency Level	Moderate-Low

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.



Recommended Adaptation Strategy:
Elevate Electrical on a Platform/Pad & Submersible Pump Motors

Adaptation Cost:
$4,800,000

Below grade pumping station with entrances in sidewalk

Kane Street Pumping Station

STATION CHARACTERISTICS

The Kane Street stormwater pumping station is located on the northwest corner of the intersection of Kane Street and Hicks Street in Brooklyn. The station is located completely below grade, under a sidewalk between residential buildings and the southbound lanes of Hicks Street.

The Pumping Station Summary table lists the general characteristics of the Kane Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a high-density residential area. Failure of the station would affect an area of approximately 51 acres with a population of approximately 5,700. There are three critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Kane Street pumping station has not experienced flooding in the past, including during Hurricane Sandy. Its location adjacent to the Brooklyn–Queens Expressway means that flooding of the pumping station would coincide with flooding of the roadway.

RISK ASSESSMENT

The risk of the Kane Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The predicted critical flood elevation would be more than 2 feet above local grade. This would damage the electrical controls and the non-submersible pumps, all of which are located below grade.

ADAPTATION STRATEGIES

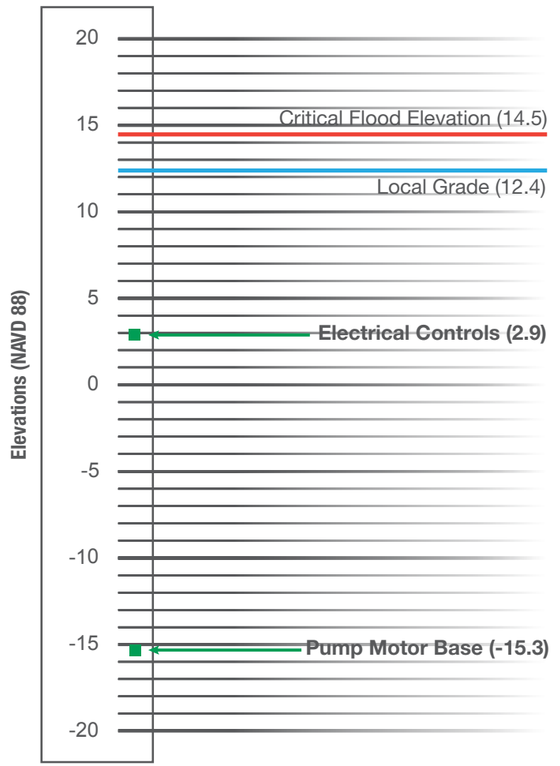
The Kane Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to space limitations, the lack of an existing structure, and the current vulnerability of the pumping station, the recommended strategy at Kane Street is to elevate electrical controls on an aboveground platform and install submersible pumps. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Stormwater
	Pump Type	Non-submersible
	Operating Capacity (MGD)	7.2
	Affected Area (Acres)	51
Risk	Population in Affected Area	5,725
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	3
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on Platform/Pad & Submersible Pump Motors
	Cost of Protective Measures[1]	$4,800,000
	Damage Cost for Critical Flood without Protection[1, 2]	$6,230,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$11,926,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Linden Place Pumping Station

STATION CHARACTERISTICS

The Linden Place combined pumping station is located near the northeast corner of Linden Place and 31st Road in Queens. The pumping station is below grade with grating and hatch entryways in the sidewalk in front of a school.

The Pumping Station Summary table lists the general characteristics of the Linden Place pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a mixed residential and commercial area. Failure of the station would affect an area of approximately 274 acres and a population of more than 13,500. There are six critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Linden Place pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

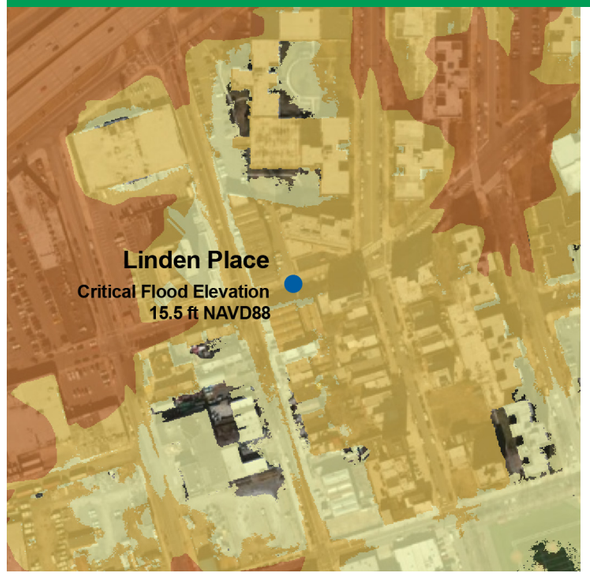
The risk of the Linden Place pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be more than 2 feet above local grade, completely inundating this below grade station. Water would damage the electrical controls, but the submersible pumps should be unaffected.

ADAPTATION STRATEGIES

The Linden Place pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the need to move electrical controls out of the reach of flood waters and limited available space, the recommended strategy at Linden Place is to elevate electrical controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

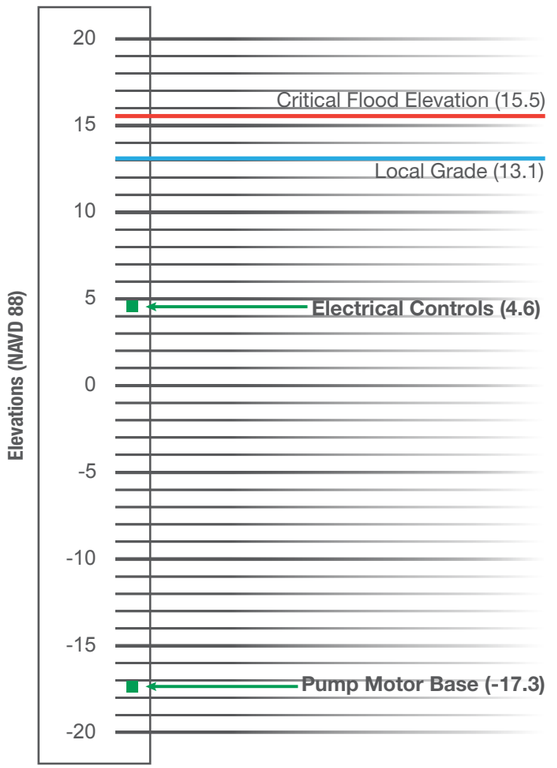
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

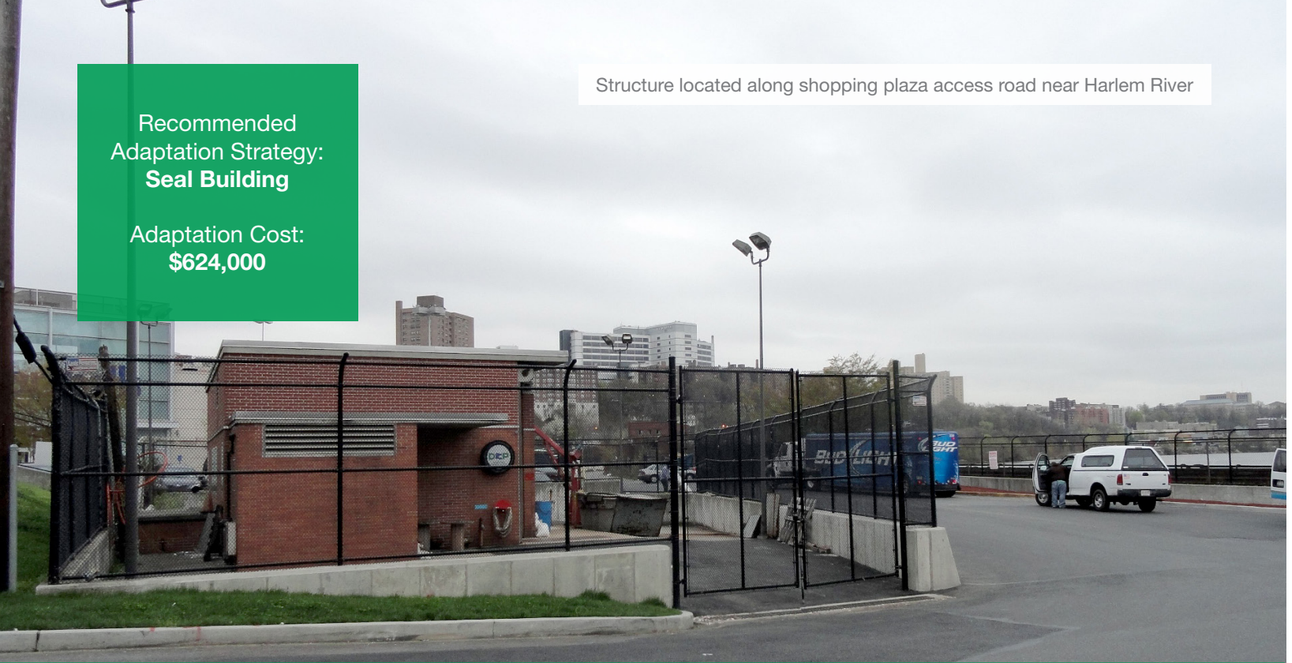
Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	5.0
	Affected Area (Acres)	274
Risk	Population in Affected Area	13,665
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	6
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$1,153,000
	Damage Cost for Critical Flood without Protection[1, 2]	$4,025,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$4,405,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.



Recommended Adaptation Strategy: **Seal Building**

Adaptation Cost: **$624,000**

Structure located along shopping plaza access road near Harlem River

Marble Hill Pumping Station

STATION CHARACTERISTICS

The Marble Hill combined pumping station is located near 58 West 225th Street in the Bronx. It is situated along a shopping plaza entrance road on the south side of 225th Street between Planet Fitness and Target. The Harlem River is about 100 feet away from the station. The station has a brick structure surrounded by a paved lot.

The Pumping Station Summary table lists the general characteristics of the Marble Hill pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial and residential area. Failure of the station would affect an area of approximately 841 acres and a population of nearly 47,000. There are 23 critical facilities within that area that could be affected if the station failed. Additionally, failure of this pumping station could affect a nearby bathing beach.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy nearby areas flooded to a depth of about 6 inches and the station experienced minor impacts. There is no history of flooding at this location beyond flooding caused by Hurricane Sandy.

RISK ASSESSMENT

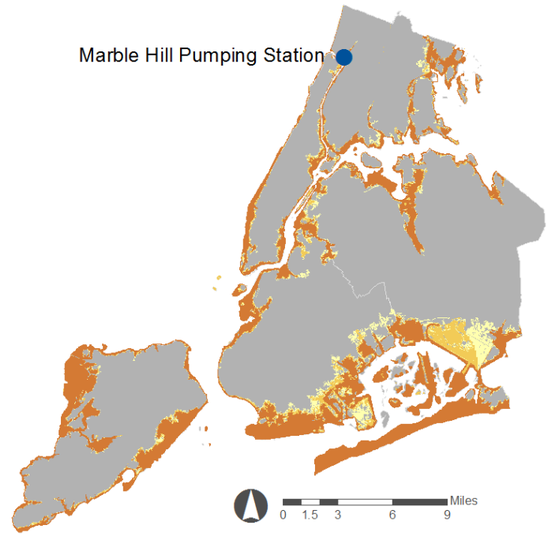
The risk of the Marble Hill pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the March 2013 FEMA Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be nearly 6 feet above local grade. Water would likely enter the building, flooding and damaging the electrical controls, which are located below the flood elevation. The submersible pumps should withstand flooding. The Marble Hill pumping station receives flow from three pumping stations. Therefore, loss of function at Marble Hill increases the vulnerability of additional pumping stations, tributary areas, and populations.

ADAPTATION STRATEGIES

The Marble Hill pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a significant existing structure, the recommended strategy at Marble Hill is to seal the building so that flood waters cannot enter. This is a less expensive option than those that involve moving electrical controls or motors. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

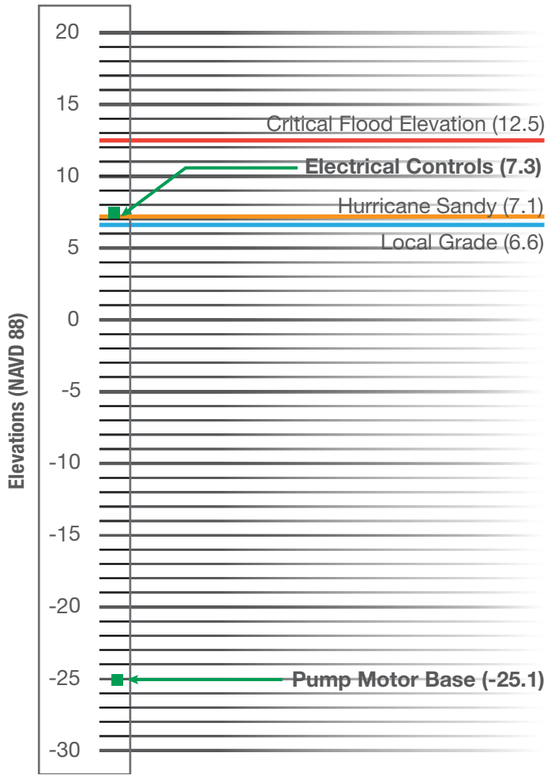
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	15.0
	Affected Area (Acres)	841
Risk	Population in Affected Area	46,958
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	23
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$624,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,383,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$15,670,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Brick structure in residential neighborhood adjacent to wetland

Recommended Adaptation Strategy:
Seal Building

Adaptation Cost:
$549,000

Mason Avenue Pumping Station

STATION CHARACTERISTICS

The Mason Avenue sanitary pumping station is on the east side of Mason Avenue, south of Slater Boulevard, on Staten Island. It is in a residential neighborhood adjacent to tidal wetlands. The station has a brick structure whose main floor is about 4 feet above grade; a fence surrounds the lot.

The Pumping Station Summary table lists the general characteristics of the Mason Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is in a residential area. Failure of the station would affect an area of approximately 362 acres and a population of more than 8,200. There are no critical facilities within the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, the surrounding area flooded to a depth of more than 5 feet above grade. A resident across the street described Sandy's flood waters as coming in through the wetlands and into the neighborhood "like a wave." DEP Collections System staff on site at the time of the visit indicated that the station flooded and suffered significant damage during the storm. Electrical components on the main floor were damaged, and the station went offline due to power loss, damage to electrical equipment, and loss of telemetry. The damaged electrical equipment has since been replaced. DEP indicated there is also a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

The risk of the Mason Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be more than 7 feet above local grade. Water would enter the building, flooding and damaging the electrical controls and the non-submersible pumps, all of which are located below the critical flood elevation.

ADAPTATION STRATEGIES

The Mason Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a significant existing structure, the recommended strategy at Mason Avenue is to seal the building so that flood waters cannot enter; this is a less expensive option than those that involve moving existing electrical controls and pump motors. While this strategy will provide resilient protection, there is the potential for leaks, inflows to the wells, or unidentified flow paths. DEP will consider replacing the non-submersible pumps with submersibles as normal replacement is needed as part of regular maintenance.

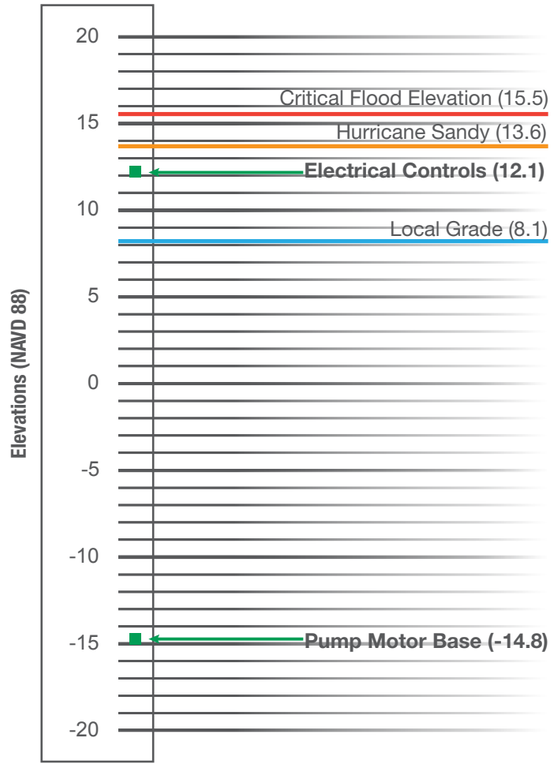
Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures. Failure of seals could result in damage to controls and the pump motors.

FEMA Flood Zones

Source: FEMA; CUNY Institute for Sustainable Cities

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	2.7
	Affected Area (Acres)	362
Risk	Population in Affected Area	8,293
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$549,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,369,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$15,601,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Mayflower Avenue Pumping Station

STATION CHARACTERISTICS

The Mayflower Avenue sanitary pumping station is located near the intersection of Arthur Kill Road and Huguenot Avenue in Staten Island. The pumping station includes a large superstructure located on a gated lot. The station is equipped with a permanent backup diesel generator on the main floor of the superstructure. Electrical controls are also located on the main floor, and non-submersible pumps are located below grade. The main floor and doorway thresholds are 3 feet above local grade.

The Pumping Station Summary table lists the general characteristics of the Mayflower Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 1,099 acres with a population of nearly 18,000. There are four critical facilities in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Mayflower Avenue pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

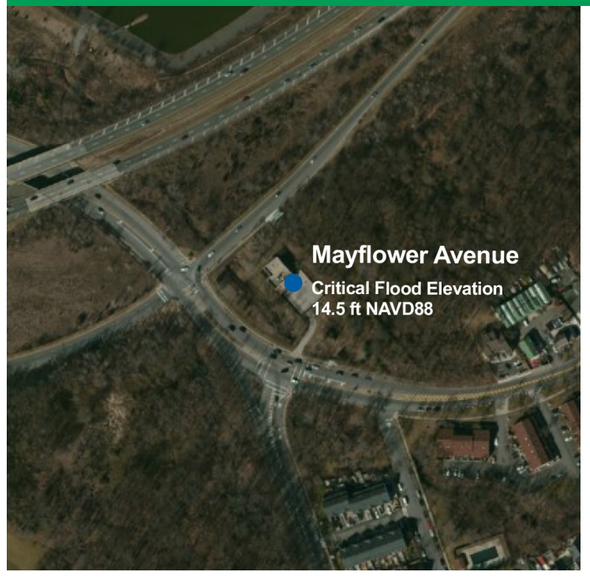
The risk of the Mayflower Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room and dry well.

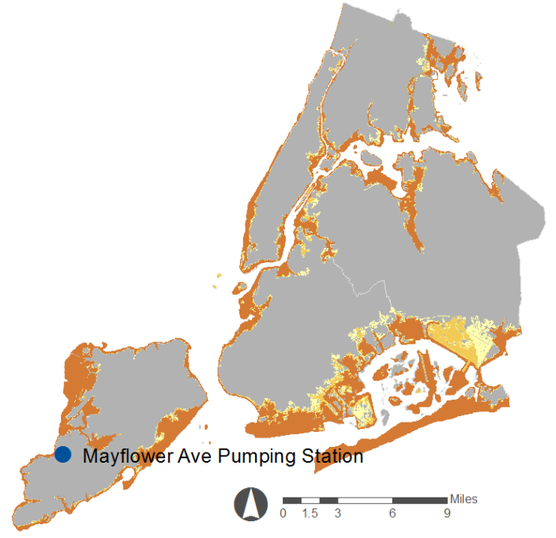
The critical flood elevation would inundate the area surrounding the facility with over 3 feet of water. If flood waters were able to find a pathway into the pumping station, electrical controls and motors could be damaged.

ADAPTATION STRATEGIES

The Mayflower Avenue pumping station requires minor adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a substantial existing structure and most entryways are elevated, the recommended strategy at Mayflower Avenue is to sandbag potential flood entry points. Residual risk is related to a greater depth of flooding from larger storms, more extreme climate change, failure of the sandbag barrier, or leakage through alternative flow pathways.

FEMA Flood Zones

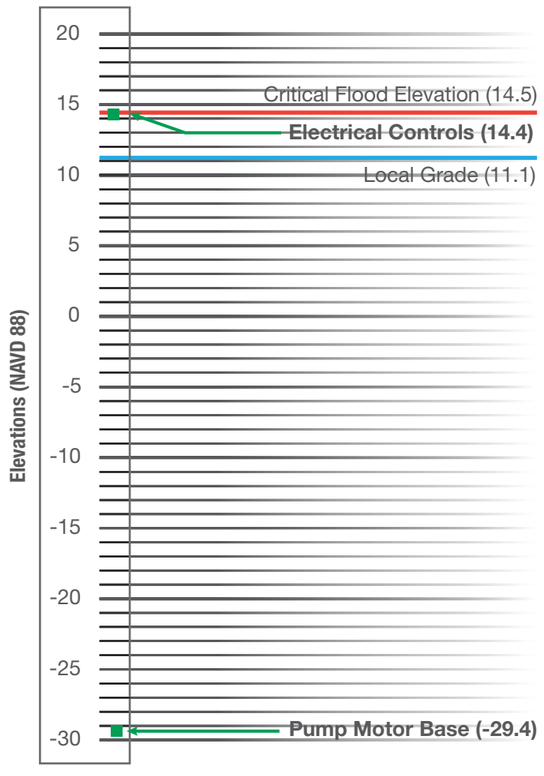




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	13.0
	Affected Area (Acres)	1,099
Risk	Population in Affected Area	17,940
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	4
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Sandbagging
	Cost of Protective Measures[1]	$40,000
	Damage Cost for Critical Flood without Protection[1, 2]	$6,500,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$28,431,000
	Resiliency Level	Moderate-Low

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevated Electrical in New Building & Submersible Pump Motors**

Adaptation Cost: **$2,539,000**

Melvin Avenue Pumping Station

STATION CHARACTERISTICS

The Melvin Avenue sanitary pumping station is located underneath the roadway at the dead end of Melvin Avenue where the road abuts Schmul Park. There is one hatch in the road to access the wet well; the meter and what appear to be controls are mounted in a box on a telephone pole. Power is supplied by overhead lines.

The Pumping Station Summary table lists the general characteristics of the Melvin Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 9 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy nearby areas flooded to a depth of more than 3 feet above grade. The Melvin Avenue pumping station also has a history of flooding due to smaller events.

RISK ASSESSMENT

The risk of the Melvin Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the data available in the plan drawings.

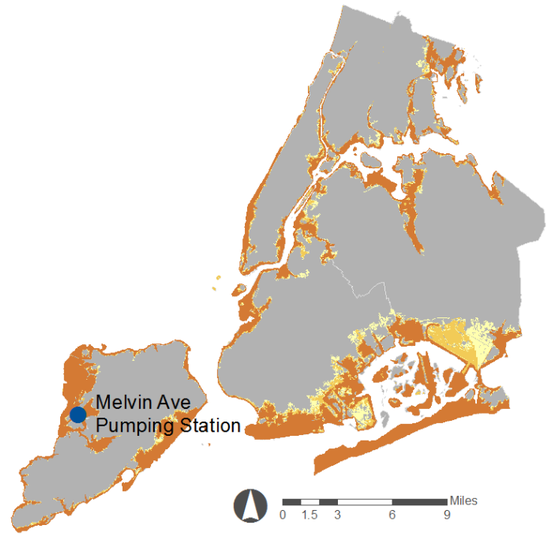
The critical flood elevation would be 8 feet above local grade. This would reach beyond the above grade controls, damaging them, and it would completely inundate the below grade portion of the station, also damaging the non-submersible pumps.

ADAPTATION STRATEGIES

The Melvin Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the station's current vulnerability, the extreme depth of the critical flood, and available space nearby, the recommended strategy at Melvin Avenue is to elevate electrical controls in a new building and install submersible pumps. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

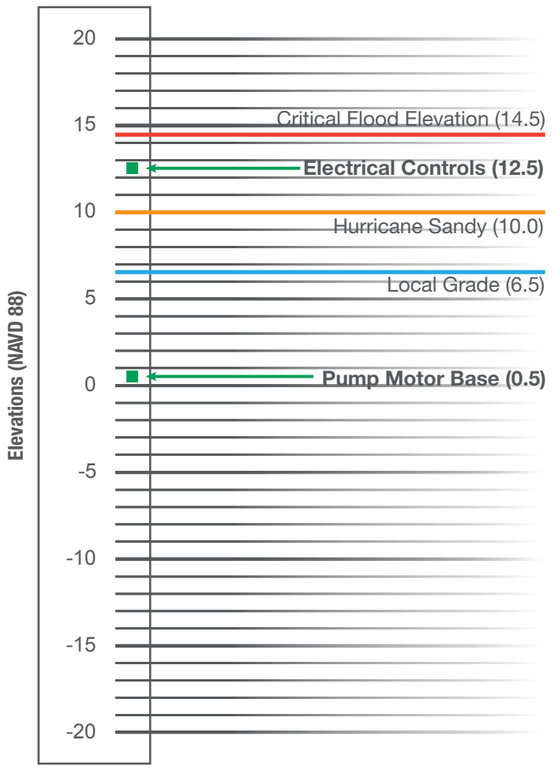
FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	0.3
	Affected Area (Acres)	9
Risk	Population in Affected Area	90
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building & Submersible Pump Motors
	Cost of Protective Measures[1]	$2,539,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,775,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$9,135,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical in New Building**

Adaptation Cost: **$2,420,000**

Generator plug and new pump controls panel loacated above grade

Nautilus Court Pumping Station

STATION CHARACTERISTICS

The Nautilus Court combined pumping station is at the eastern end of Cliff Street near Nautilus Court on Staten Island. The pumping station is almost entirely below grade and located approximately 100 feet from the banks of The Narrows, leaving it vulnerable to flooding. The site consists of a flat asphalt surface with two access points to the pumping station: a hatch to access the electrical control vault and an open grate over the wet well, which houses three submersible pumps.

The Pumping Station Summary table lists the general characteristics of the Nautilus Court pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 374 acres with a population of approximately 8,000. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

Nautilus Court pumping station was completely inundated by the storm surge during Hurricane Sandy, which damaged the electrical controls. DEP indicated there is also a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

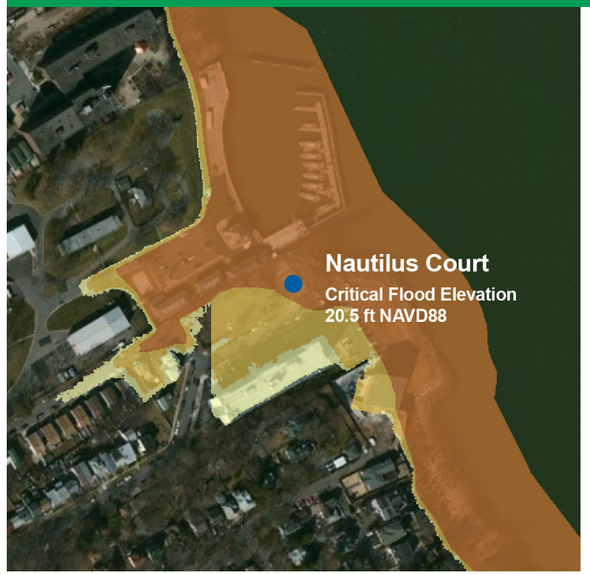
The risk of the Nautilus Court pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the property to view the station's components.

The critical flood elevation would inundate the area surrounding the facility with over 12 feet of water. This would damage electrical controls but would not affect the submersible pumps. The Nautilus Court pumping station is connected to another station; however it discharges to it rather than receiving flow. Therefore, loss of function at Nautilus Court does not increase the vulnerability of an additional pumping station.

ADAPTATION STRATEGIES

The Nautilus Court pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the lack of an existing structure and the extreme depth of the critical flood, the recommended strategy at Nautilus Court is to elevate electrical controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

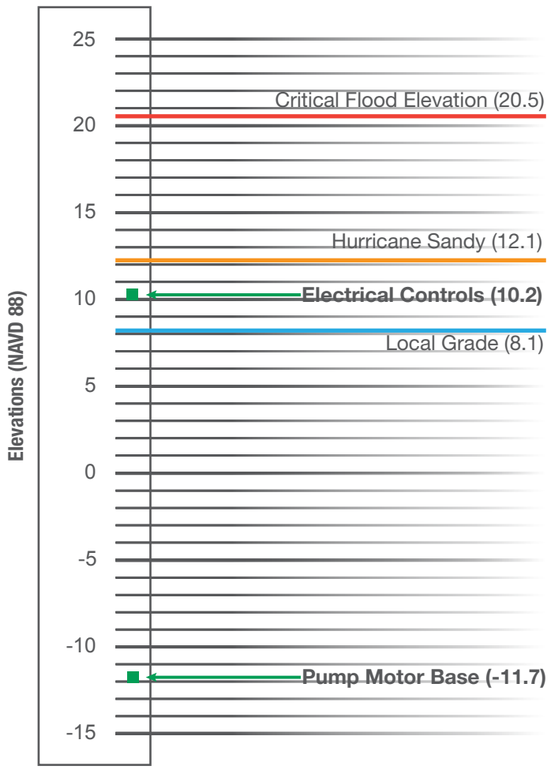
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	0.9
	Affected Area (Acres)	374
Risk	Population in Affected Area	8,053
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$2,420,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,275,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$16,851,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical on Wall**

Adaptation Cost: **$1,091,000**

Pumping station running on bypass due to damage from Hurricane Sandy

Nevins Street Pumping Station

STATION CHARACTERISTICS

The Nevins Street combined pumping station is located on Nevins Street, east of Degraw Street in Brooklyn. It is completely below grade, under the sidewalk on Nevins Street and adjacent to the handball courts at the Thomas Greene playground. Access to the station is provided through hatches in the sidewalk. A 4½ foot high wall runs behind the pumping station, separating the sidewalk from the handball courts.

The Pumping Station Summary table lists the general characteristics of the Nevins Street station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a primarily area. Failure of the station would affect an area of approximately 34 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

Nevins Street pumping station was completely inundated by the storm surge during Hurricane Sandy, which flooded the electrical controls. DEP employees estimated that this station was under 8–10 feet of water during the storm. DEP indicated there is also a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

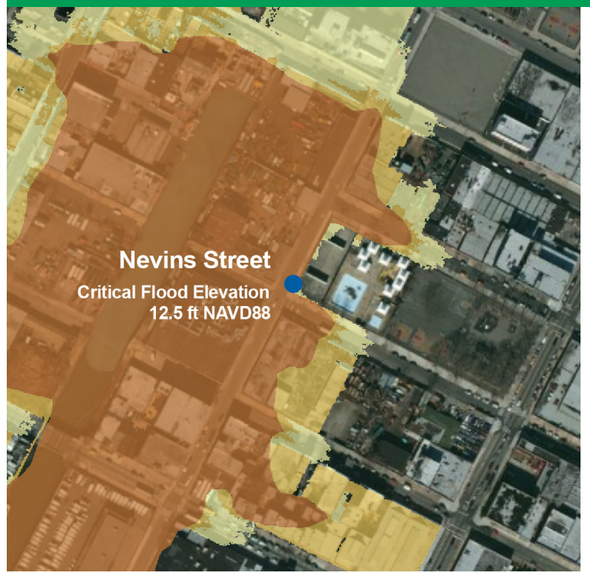
The risk of the Nevins Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the property to view the station's components.

The critical flood elevation would inundate the area surrounding the facility with over 5 feet of water. This would damage electrical controls but would not affect the submersible pumps. The Nevins Street pumping station is connected to another station; however it discharges to it rather than receiving flow. Therefore loss of function at Nevins Street does not increase the vulnerability of an additional pumping station.

ADAPTATION STRATEGIES

The Nevins Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to limited available space and the extreme depth of the critical flood, the recommended strategy at Nevins Street is to elevate electrical controls onto the nearby wall. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

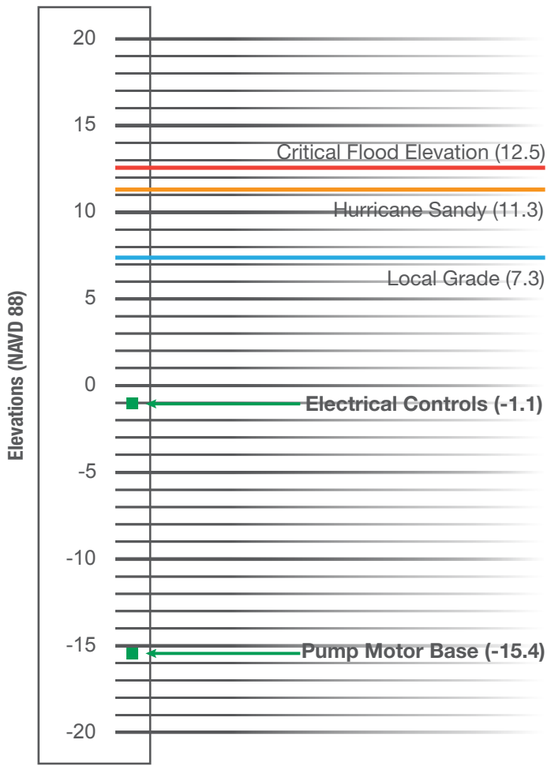
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	2.2
	Affected Area (Acres)	34
Risk	Population in Affected Area	645
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical on Wall
	Cost of Protective Measures[1]	$1,091,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,311,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$6,747,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

New York Times Pumping Station

STATION CHARACTERISTICS

The New York Times sanitary pumping station is located near the corner the Whitestone Expressway service road and Linden Place in Queens, adjacent to the property surrounding the New York Times building. It is an entirely below grade station with access hatches in concrete slabs.

The Pumping Station Summary table lists the general characteristics of the New York Times pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in an industrial and commercial area. Failure of the station would affect an area of approximately 59 acres. There are no critical facilities within that area.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The New York Times pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

The risk of the New York Times pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be 6 feet above local grade, completely inundating the entire station. The electrical controls, which are below grade, would be flooded and damaged. The submersible pumps should withstand flooding.

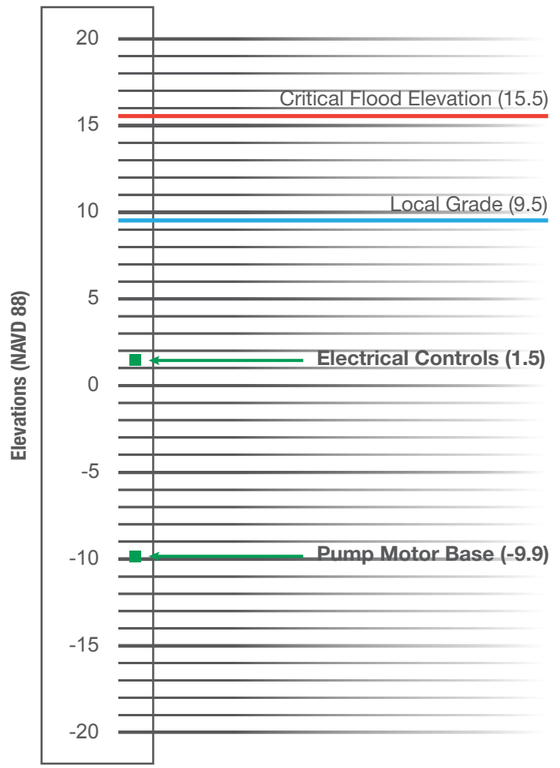
ADAPTATION STRATEGIES

The New York Times pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because of the significant depth of the critical flood, the recommended strategy at New York Times is to elevate electrical controls on a platform. The installation of backup generators is also recommended. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	0.6
	Affected Area (Acres)	59
Risk	Population in Affected Area	0
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$5,562,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,988,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$10,230,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical on a Platform/Pad**

Adaptation Cost: **$738,000**

Primary below grade pumping station adjacent to tidal wetlands

Old Douglaston Pumping Station

STATION CHARACTERISTICS

The Old Douglaston sanitary pumping station is located on park land, along the south side of Northern Blvd. and west of the intersection with 234th Street in Queens. The pumping station site is adjacent to wetlands. The station, rebuilt in 2010, is almost completely below grade.

The Pumping Station Summary table lists the general characteristics of the Old Douglaston pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial area surrounded by residentially zoned land. Failure of the station would affect an area of approximately 2,566 acres. There are 21 critical facilities within the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Old Douglaston pumping station was not inundated by the storm surge during Hurricane Sandy and does not have a history of flooding.

RISK ASSESSMENT

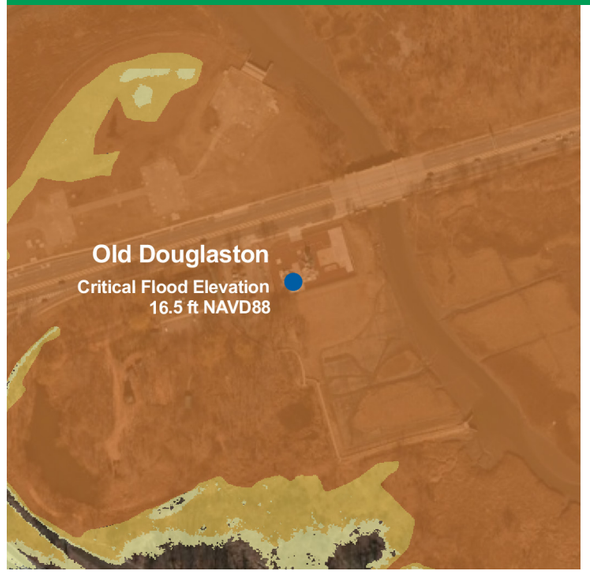
The risk of the Old Douglaston pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room, valve room, and dry well.

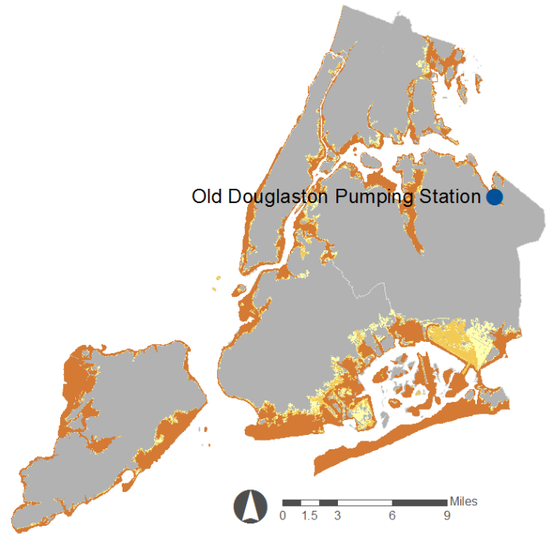
The critical flood elevation would inundate the area surrounding the facility with nearly 5 feet of water. This would damage electrical controls but would not affect the submersible pumps.

ADAPTATION STRATEGIES

The Old Douglaston pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. To achieve resiliency while respecting park structure limitations, the recommended strategy at Old Douglaston is to elevate electrical controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

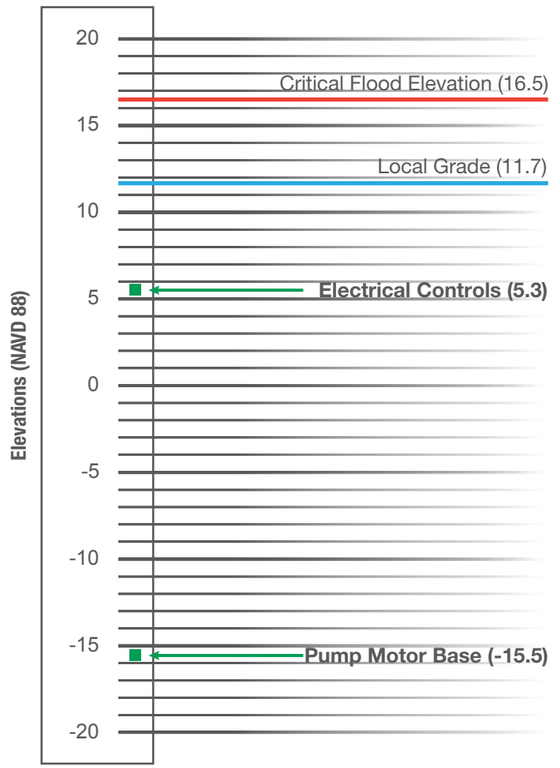




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	8.5
	Affected Area (Acres)	2,566
Risk	Population in Affected Area	58,400
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	21
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$738,000
	Damage Cost for Critical Flood without Protection[1, 2]	$4,071,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$20,951,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Orchard Beach Pumping Station

STATION CHARACTERISTICS

The station is located in Pelham Bay Park near Orchard Beach in the Bronx. The Orchard Beach pumping station is a new station that was still under construction during the development of this report. The station consists of a wet well below grade and electrical components, including control panels and a high-voltage transformer, mounted above grade on a concrete and gravel structure.

The Pumping Station Summary table lists the general characteristics of the Orchard Beach pumping station, the potential effect of its failure, and the recommended adaptation strategy. Failure of the station would affect an area of approximately 81 acres. There are no critical facilities in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Orchard Beach pumping station experienced minor impacts from Hurricane Sandy but there is no other history of flooding at this location.

RISK ASSESSMENT

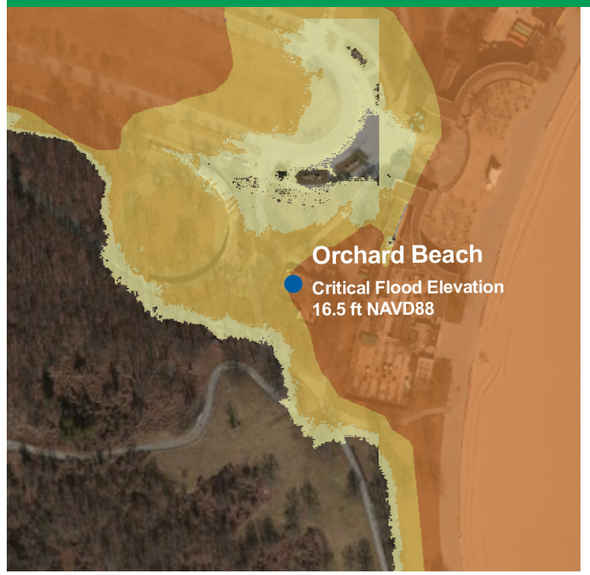
The risk of the Orchard Beach pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

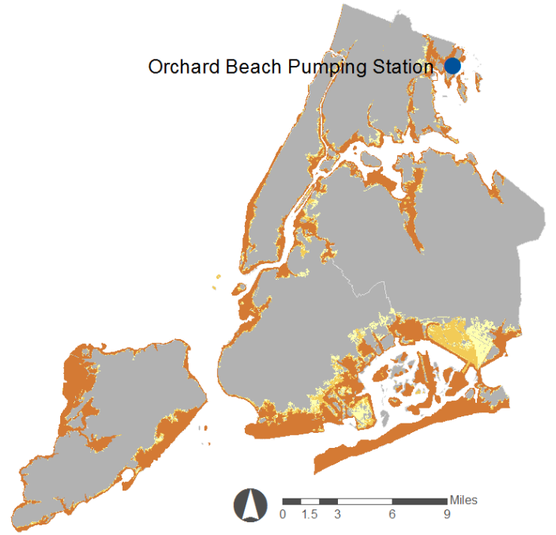
The critical flood elevation would inundate the area surrounding the facility with over 3 feet of water. This flood elevation would be just below electrical controls, but it would inundate the transformer. The submersible pumps would not be affected by a flood. There is a high wall between the beach and the pumping station that could reduce or slow inundation.

ADAPTATION STRATEGIES

The Orchard Beach pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because controls are currently exposed, the addition of a surrounding building does not appear to be necessary, but electrical equipment must be moved above the flood elevation. Therefore, the recommended strategy at Orchard Beach is to elevate electrical controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

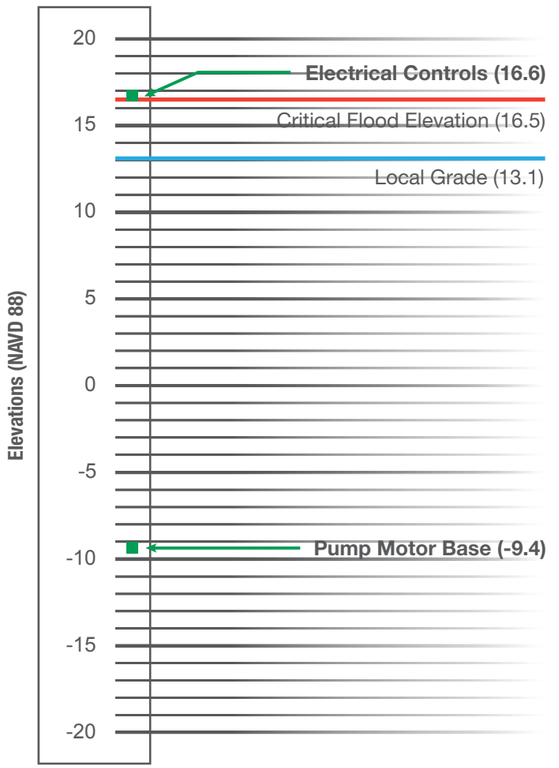




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	0.9
	Affected Area (Acres)	81
Risk	Population in Affected Area	0
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$662,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,147,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$3,053,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Pumping station located in large brick structure

Recommended Adaptation Strategy: **Construct Barrier**

Adaptation Cost: **$16,960,000**

Paerdegat Pumping Station

STATION CHARACTERISTICS

The Paerdegat combined pumping station is located at 6016 Flatlands Avenue in Brooklyn. The pumping station has a large brick structure that sits between the roadway and the Paerdegat Basin.

The Pumping Station Summary table lists the general characteristics of the Paerdegat pumping station, the potential effect of its failure, and the recommended adaptation strategy. Failure of the station would affect an area of approximately 2,200 acres and a population of nearly 130,000. There are 83 critical facilities within that area and a nearby bathing beach would also be affected.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Paerdegat pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

The risk of the Paerdegat pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be approximately 2.5 feet above local grade. Electrical controls are located on the main floor of the structure, above grade but a few inches below the flood elevation. Non-submersible pumps are located below grade. The Paerdegat pumping station receives flow from another station. Therefore, loss of function at Paerdegat increases the vulnerability of an additional pumping station, tributary area, and population.

ADAPTATION STRATEGIES

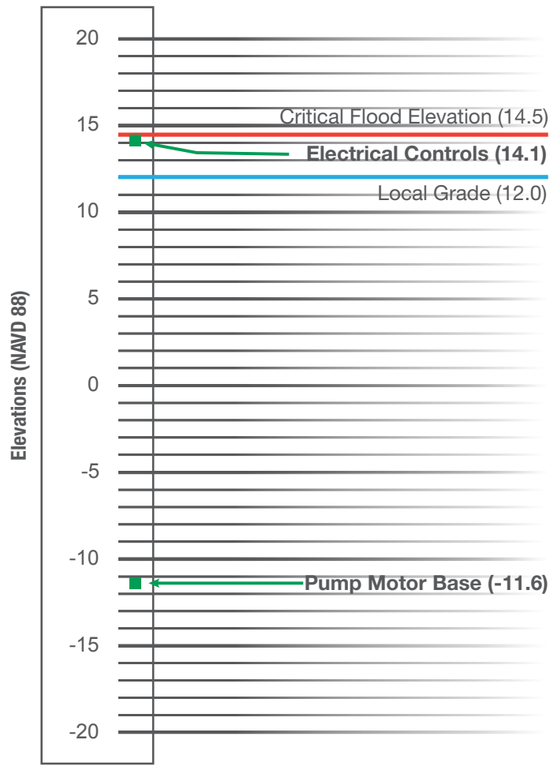
The Paerdegat pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because the extensive controls would be difficult to relocate, the recommended strategy at Paerdegat is to construct a barrier around the station. The installation of backup generators is also recommended. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change, or alternative pathways for floodwaters.

FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Non-submersible
	Operating Capacity (MGD)	57.0
	Affected Area (Acres)	2,226
Risk	Population in Affected Area	128,903
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	83
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Construct Barrier
	Cost of Protective Measures[1]	$16,960,000
	Damage Cost for Critical Flood without Protection[1, 2]	$15,409,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$19,205,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Sandbagging**

Adaptation Cost: **$11,000**

Richmond Hill Road Pumping Station

STATION CHARACTERISTICS

The Richmond Hill Road sanitary pumping station is located at the dead end of Richmond Hill Road near the intersection with Richmond Avenue on Staten Island. The property borders the tidal wetlands of the William T. Davis Wildlife Refuge. The pumping station's substantial structure is located atop a small mound of land. Transformers and a generator fuel tank sit outside the station within its fenced-in lot.

The Pumping Station Summary table lists the general characteristics of the Richmond Hill Road pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial area adjacent to open wetlands. Failure of the station would affect an area of approximately 894 acres and a population of more than 23,000. There are six critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Richmond Hill Road pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

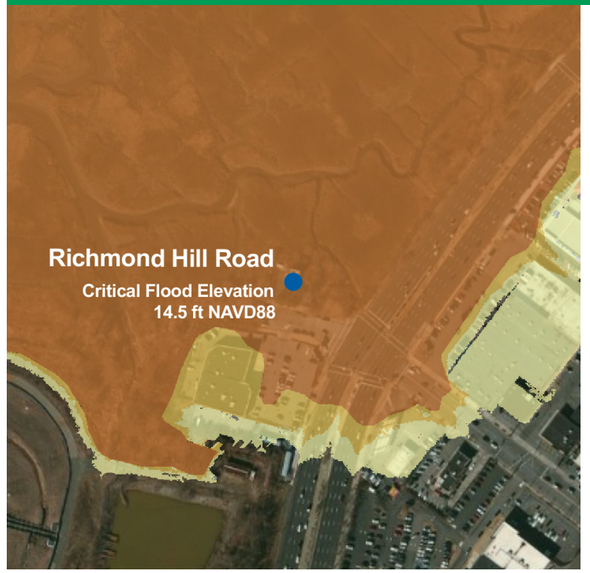
The risk of the Richmond Hill Road pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be about an inch above local grade. Because the electrical controls and non-submersible pumps are located below grade, infiltration along piping and through well walls could potentially enter the building and damage those components.

ADAPTATION STRATEGIES

The Richmond Hill Road pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the shallow depth of the critical flood and the substantial existing structure, the recommended strategy at Richmond Hill Road is to place sandbags around potential water entry points prior to flooding events. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change, or from sandbags being stacked improperly or disturbed by residents. Because the property is fenced in, sandbags are unlikely to be disturbed.

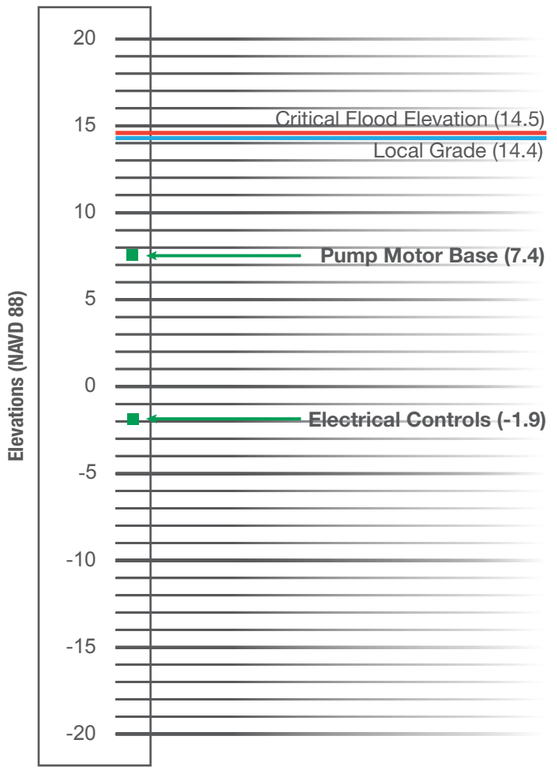
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

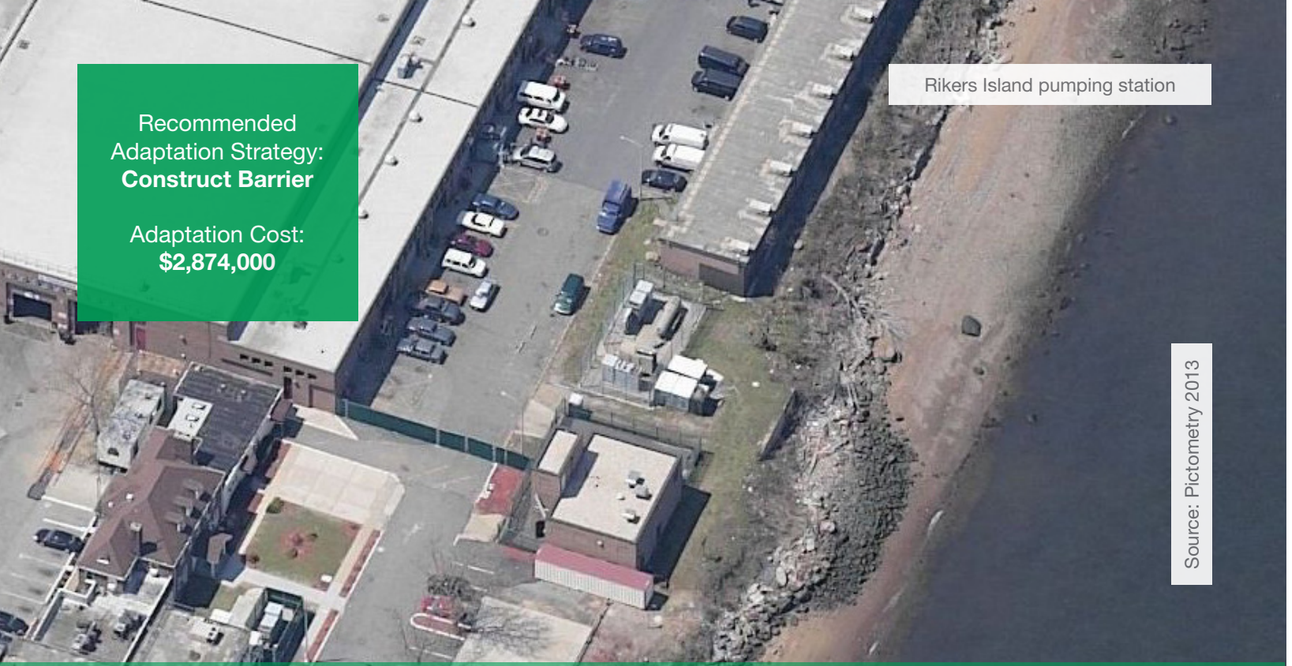
Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	6.1
	Affected Area (Acres)	894
Risk	Population in Affected Area	23,188
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	6
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Sandbagging
	Cost of Protective Measures[1]	$11,000
	Damage Cost for Critical Flood without Protection[1, 2]	$5,490,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$1,201,000
	Resiliency Level	Moderate-Low

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.



Rikers Island pumping station

Source: Pictometry 2013

Recommended Adaptation Strategy: **Construct Barrier**

Adaptation Cost: **$2,874,000**

Rikers Island North Pumping Station

STATION CHARACTERISTICS

The Rikers Island North pumping station is located on Rikers Island. It is just north of the warden's building and is nearly adjacent to the East River. The station has a structure above grade that houses electrical controls; the wells are beneath the structure. Due to its location, this site was not visited, and no pictures are currently available.

The Pumping Station Summary table lists the general characteristics of the Rikers Island North pumping station, the potential effect of its failure, and the recommended adaptation strategy. Failure of the station would affect an area of approximately 124 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Rikers Island pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

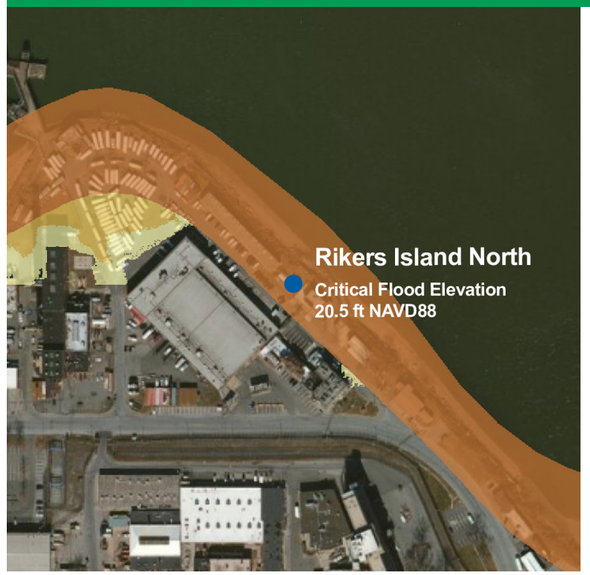
The risk of the Rikers Island North pumping station was assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation).

The critical flood elevation would be more than 3 feet above local grade. If water entered the building, the control room could be flooded to a depth of about 3 feet as well. This would damage the electrical controls. The submersible pumps should withstand flooding. The Rikers Island North pumping station is connected to another station; however it discharges to it rather than receiving flow. Therefore loss of function at Rikers Island North does not increase the vulnerability of an additional pumping station.

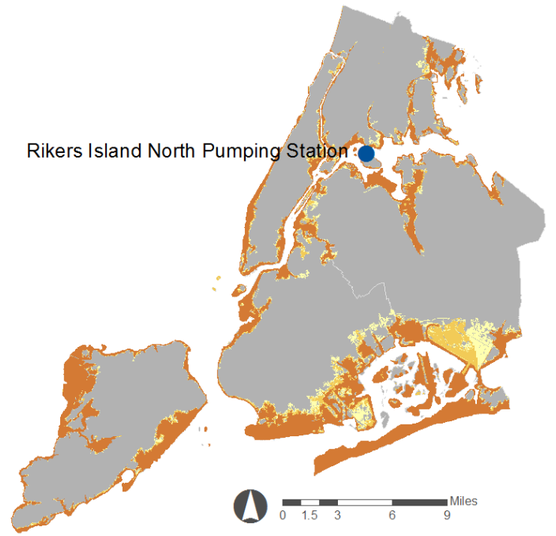
ADAPTATION STRATEGIES

The Rikers Island North pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. The recommended strategy at Rikers Island North is to construct a barrier to keep flood waters from reaching the station. The condition of the submersible pumps is not known. Onsite generators may also be required. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

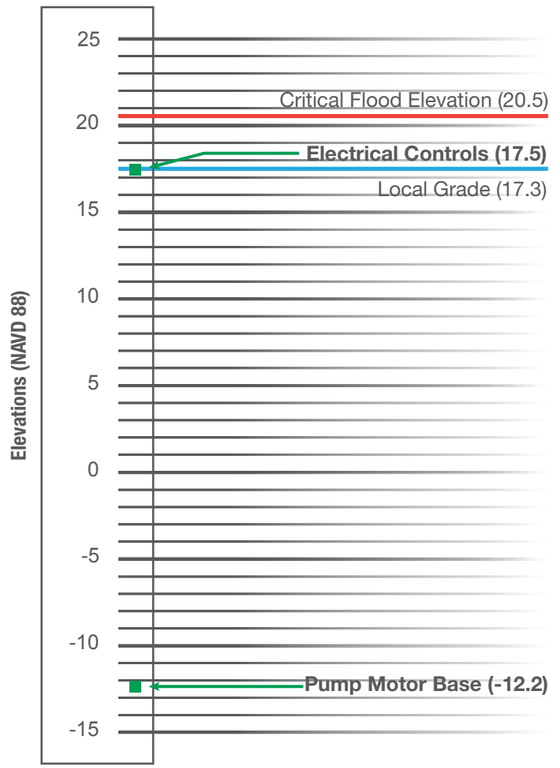


2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	4.6
	Affected Area (Acres)	124
Risk	Population in Affected Area	0
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	Y
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Construct Barrier
	Cost of Protective Measures[1]	$2,874,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,140,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$6,354,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Seal Building**

Adaptation Cost: **$266,000**

Structure with grade level entrances

Roosevelt Island Main Pumping Station

STATION CHARACTERISTICS

The Roosevelt Island Main sanitary pumping station is located within the Department of Sanitation facility off of Main Street on Roosevelt Island. The large superstructure has an electrical control room at grade where the main controls are housed. Submersible pumps and additional electrical controls are located below grade.

The Pumping Station Summary table lists the general characteristics of the Roosevelt Island Main pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located a commercial area surrounded by residential land use. Failure of the station would affect an area of approximately 20 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

There is no history of flooding at this station and the effects of Hurricane Sandy were limited to power outages.

RISK ASSESSMENT

The risk of the Roosevelt Island Main pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room.

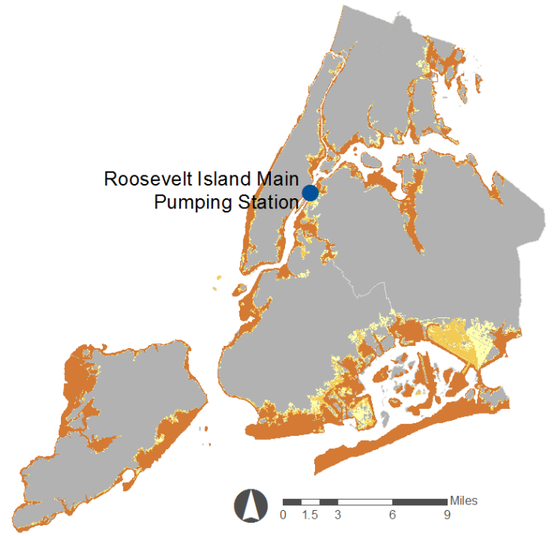
The critical flood elevation would inundate the area surrounding the facility with about 1.6 feet of water. This flood elevation could damage the electrical controls housed in the above grade structure as well as any electrical components below grade. The submersible pumps would not be affected by a flood. The Roosevelt Island Main pumping station receives flow from two additional stations. Therefore loss of function at Roosevelt Island Main increases the vulnerability of additional pumping stations, tributary areas, and populations.

ADAPTATION STRATEGIES

The Roosevelt Island Main pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a substantial existing structure, the recommended strategy at Roosevelt Island Main is to seal the building. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to the potential for water pressure to exceed the rating of the sealing measures.

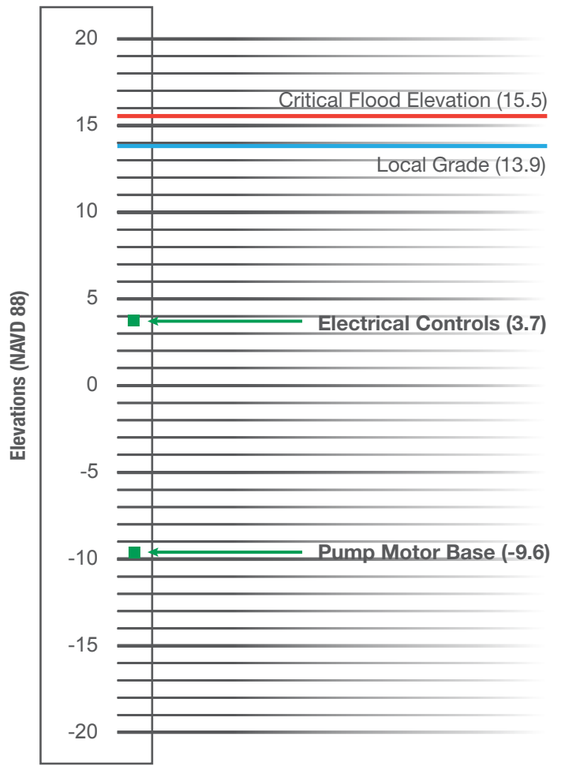
FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	10.8
	Affected Area (Acres)	20
Risk	Population in Affected Area	5,239
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$266,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,015,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$698,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Elevate Electrical in New Building**

Adaptation Cost: **$2,539,000**

Small Structure for controls and hatch entryways to wells; East River in background

Roosevelt Island North Pumping Station

STATION CHARACTERISTICS

The Roosevelt Island North sanitary pumping station is located at the southeast corner of the Coler Hospital property along East Road on Roosevelt Island. An above grade concrete structure houses the motor control center; the wells are accessible through grade-level hatches.

The Pumping Station Summary table lists the general characteristics of the Roosevelt Island North pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 26 acres and a population of over 22,000. There are seven critical facilities within the area.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Roosevelt Island North pumping station experienced minor impacts during Hurricane Sandy but there is no other history of flooding at this location.

RISK ASSESSMENT

The risk of the Roosevelt Island North pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

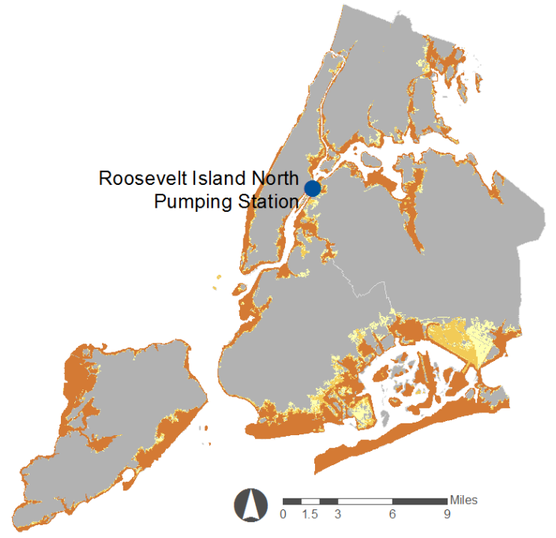
The critical flood elevation would be more than 6 feet above local grade, completely inundating the wells and the above grade control panels. This would damage the electrical controls, but the submersible pumps should be unaffected. The Roosevelt Island North pumping station is connected to another station; however it discharges to it rather than receiving flow. Therefore loss of function at Roosevelt Island North does not increase the vulnerability of an additional pumping station.

ADAPTATION STRATEGIES

The Roosevelt Island North pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the significant depth of the critical flood and the small size of the existing structure, the recommended strategy at Roosevelt Island North is to elevate electrical controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

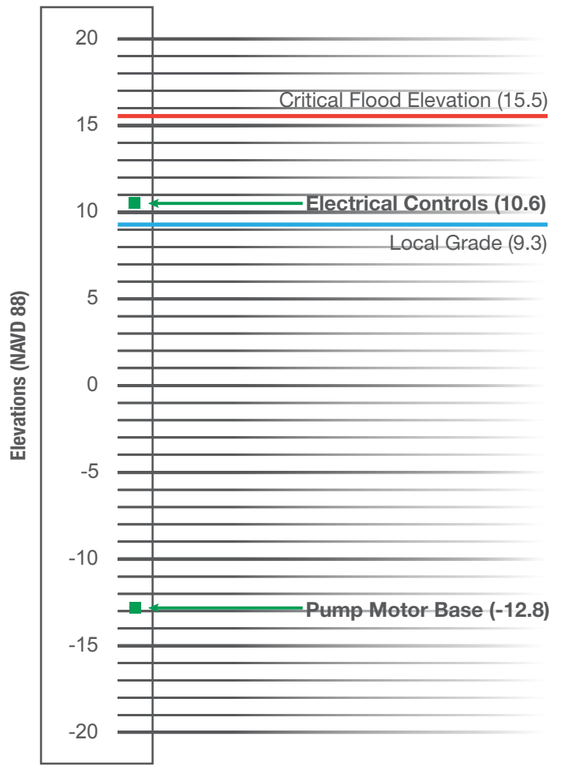
FEMA Flood Zones

2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	2.3
	Affected Area (Acres)	26
Risk	Population in Affected Area	22,045
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$2,539,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,663,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$8,560,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Seal Building**

Adaptation Cost: **$658,000**

Roosevelt Island South Pumping Station

STATION CHARACTERISTICS

The Roosevelt Island South sanitary pumping station is located at the corner of East Road and Road 3 behind the Goldwater Hospital on Roosevelt Island. The site is less than 100 feet from the open water of the East River. The electrical controls are housed above grade in a small brick superstructure, and there are hatch entryways to the wells.

The Pumping Station Summary table lists the general characteristics of the Roosevelt Island South pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 85 acres. There are seven critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, the door to the electrical control room was sandbagged, which prevented the shallow floodwaters from reaching critical electrical equipment. Though the station lost power, no damage occurred. There is no history of flooding due to smaller events.

RISK ASSESSMENT

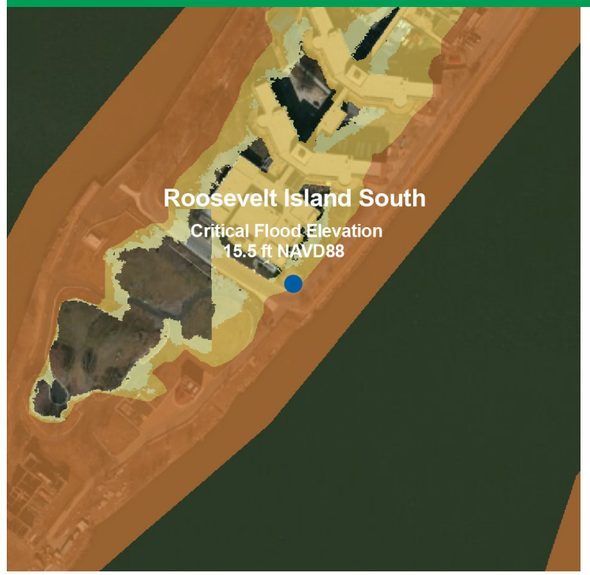
The risk of the Roosevelt Island South pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room.

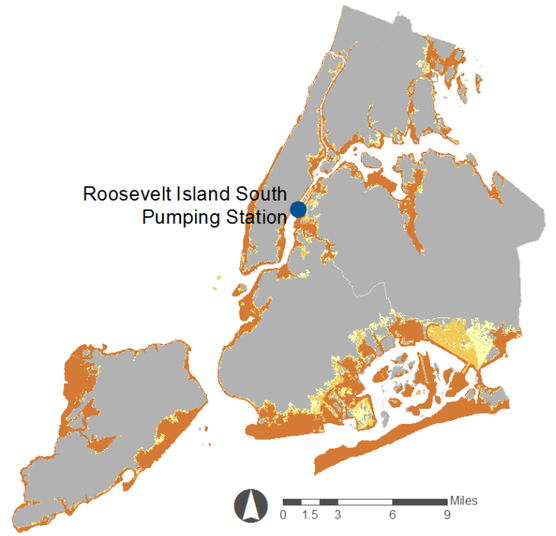
The critical flood elevation would inundate the area surrounding the facility with about 2.4 feet of water. This would damage the electrical controls house in the above grade structure as well as any electrical components below grade. The submersible pumps would not be affected by a flood. The Roosevelt Island South pumping station is connected to another station; however it discharges to it rather than receiving flow. Therefore loss of function at Roosevelt Island South does not increase the vulnerability of an additional pumping station.

ADAPTATION STRATEGIES

The Roosevelt Island South pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the shallow depth of the critical flood and the presence of an existing building to house controls, the recommended strategy at Roosevelt Island South is to seal the building. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to the potential for water pressure to exceed the rating of the sealing measures.

FEMA Flood Zones

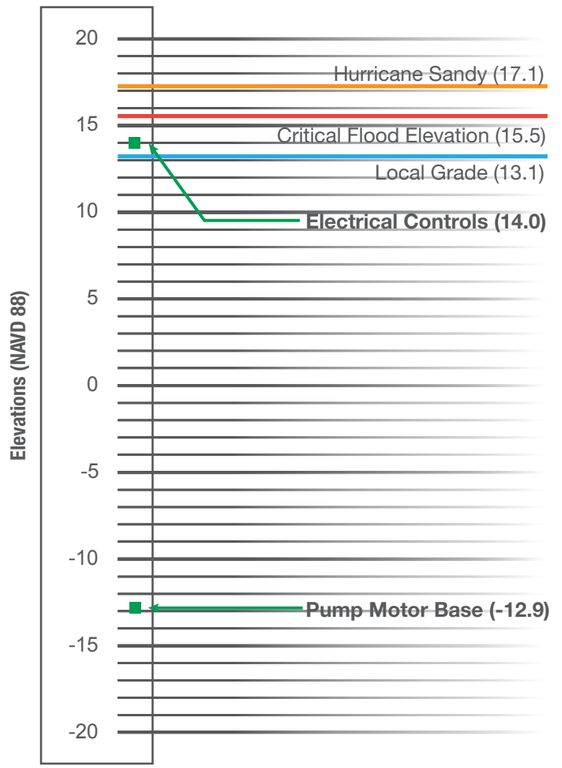




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	2.5
	Affected Area (Acres)	85
Risk	Population in Affected Area	22,631
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	7
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Seal Building
	Cost of Protective Measures[1]	$658,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,663,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$513,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Rosedale Pumping Station

STATION CHARACTERISTICS

The Rosedale sanitary pumping station is located near the intersection of 147th Avenue and 235th Street in Queens, on a flat parcel of land adjacent to Brookville Park. The edge of Conselyeas Pond, in the park, and the creek into which it drains, are just over 100 feet from the pumping station. Rosedale pumping station is completely below grade, with the exception of some ventilation equipment housed in an onsite brick structure. Damage from Hurricane Sandy prompted reconstruction, including replacing pump controls, sump pumps, ventilation and heating equipment, and compressors.

The Pumping Station Summary table lists the general characteristics of the Rosedale pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 990 acres. There are four critical facilities in the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

Rosedale pumping station was completely inundated by the storm surge during Hurricane Sandy, which damaged the electrical controls and non-submersible pump motors. DEP staff indicated there is also a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

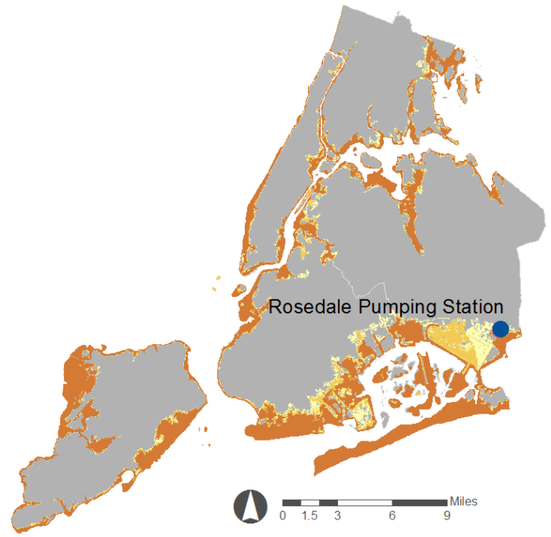
The risk of the Rosedale pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room.

The critical flood elevation would inundate the area surrounding the facility with over 4 feet of water. This would damage electrical controls and the non-submersible pump motors. The Rosedale pumping station receives flow from another pumping station. Therefore loss of function at Rosedale increases the vulnerability of an additional pumping station.

ADAPTATION STRATEGIES

The Rosedale pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the depth of the critical flood, the lack of an existing structure, and concerns about vandalism in the area, the recommended strategy at Rosedale is to elevate electrical controls and pump motors in a new building. Elevating pump motors and replacing existing motors with submersibles are both acceptable solutions, however elevating pump motors may be a more cost-effective adaptation for this pumping station. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

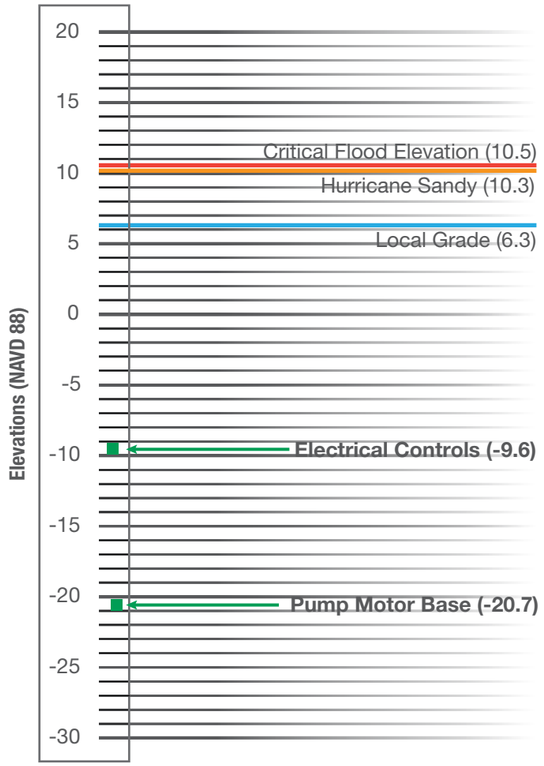
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	5.8
	Affected Area (Acres)	990
Risk	Population in Affected Area	17,683
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	4
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building & Elevate Pump Motors
	Cost of Protective Measures[1]	$9,943,000
	Damage Cost for Critical Flood without Protection[1, 2]	$5,216,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$26,842,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Sapphire Street Pumping Station

STATION CHARACTERISTICS

The Sapphire Street stormwater pumping station is located on Sapphire Street between Linden Boulevard and Dumont Avenue in Brooklyn, along the side of a minor street and adjacent to an empty lot. Sapphire Street is a small and simply designed station with two submersible pumps in a wet well surrounded by a fence. Electrical controls are elevated on a pole.

The Pumping Station Summary table lists the general characteristics of the Sapphire Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential/industrial area. Failure of the station would affect an area of approximately 1 acre. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

Though this station was not damaged during Hurricane Sandy, DEP staff indicated that overland flooding from stormwater runoff, predominantly from the vacant lot to the west, has been an issue at this station in the past. Evidence of this was found in the electrical control panel. The controls themselves have not been damaged, but flood waters have reached the bottom of the control panel housing and deposited debris there. The station's operation has not been affected by flooding and is therefore not considered to have a problem with historic flooding, but access to the station may be affected by localized flooding issues.

RISK ASSESSMENT

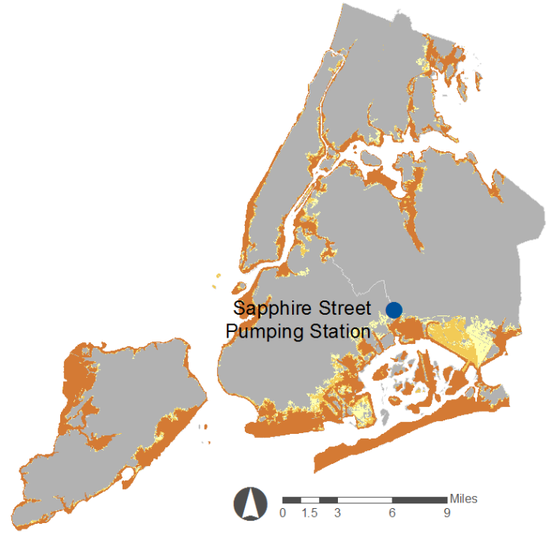
The risk of the Sapphire Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the property to view the station's components.

The critical flood elevation would inundate the area surrounding the facility with over 8 feet of water. This would damage electrical controls. Submersible pump motors would not be affected.

ADAPTATION STRATEGIES

The Sapphire Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because components are currently exposed above grade but need to be moved out of reach of potential flood waters, the recommended strategy at Sapphire Street is to elevate electrical controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

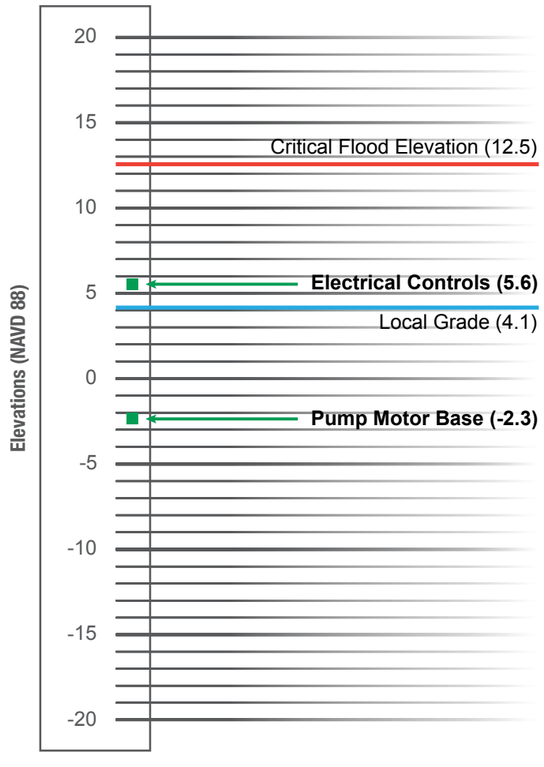
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

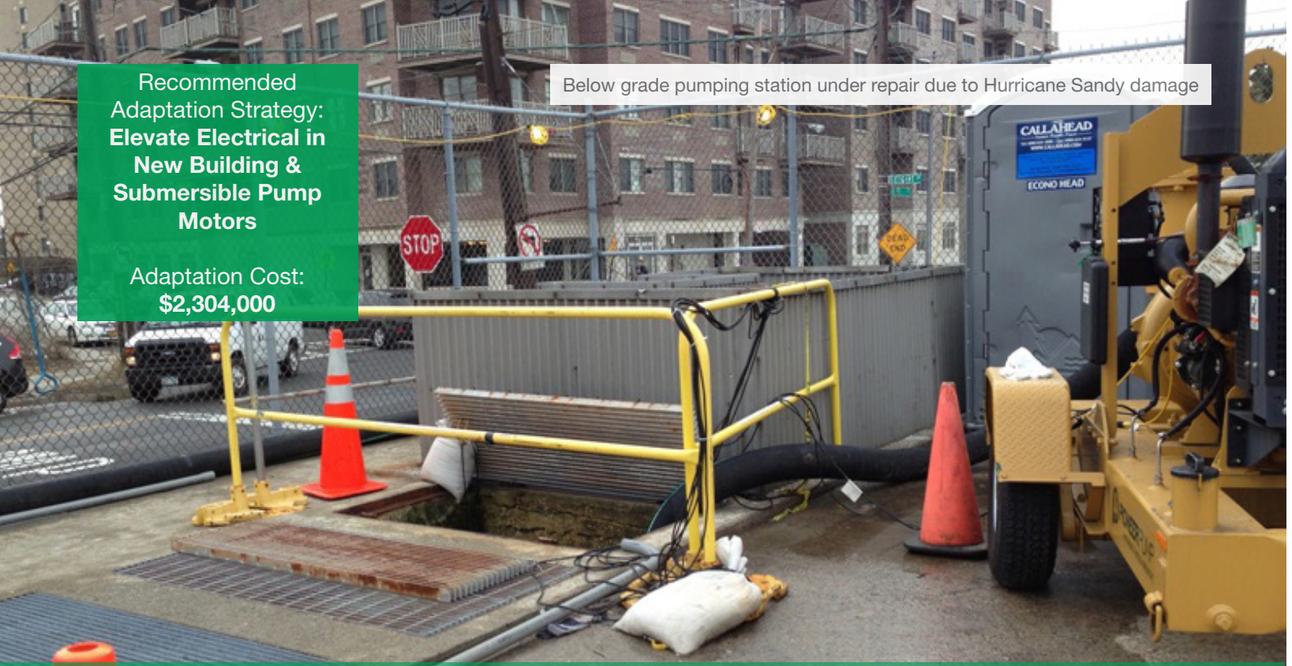
Critical Elevations



Pumping Station Summary

Background	Station Type	Stormwater
	Pump Type	Submersible
	Operating Capacity (MGD)	<1MGD
	Affected Area (Acres)	1
Risk	Population in Affected Area	5
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on Platform/Pad
	Cost of Protective Measures[1]	$800,000
	Damage Cost for Critical Flood without Protection[1, 2]	$3,700,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$19,040,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.



Below grade pumping station under repair due to Hurricane Sandy damage

Recommended Adaptation Strategy: **Elevate Electrical in New Building & Submersible Pump Motors**

Adaptation Cost: **$2,304,000**

Seagirt Avenue Pumping Station

STATION CHARACTERISTICS

The Seagirt Avenue sanitary pumping station is located on the southwest corner of the intersection of Seagirt Avenue and Beach 9th Street, about 500 feet from the open water of Reynolds Channel. All critical electrical components and non-submersible motors are located on the below grade main floor of the onsite concrete superstructure. The pumping station may be accessed through a stairwell that runs from the top of the concrete structure into the station, as well as through hatches and vents on top of the structure.

The Pumping Station Summary table lists the general characteristics of the Seagirt Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 244 acres. There are seven critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Seagirt Avenue pumping station was not inundated by the storm surge during Hurricane Sandy, but loss of power caused the wet well to flood the station, damaging motors and the electrical controls in the process. There is no history of flooding due to smaller storms at this location.

RISK ASSESSMENT

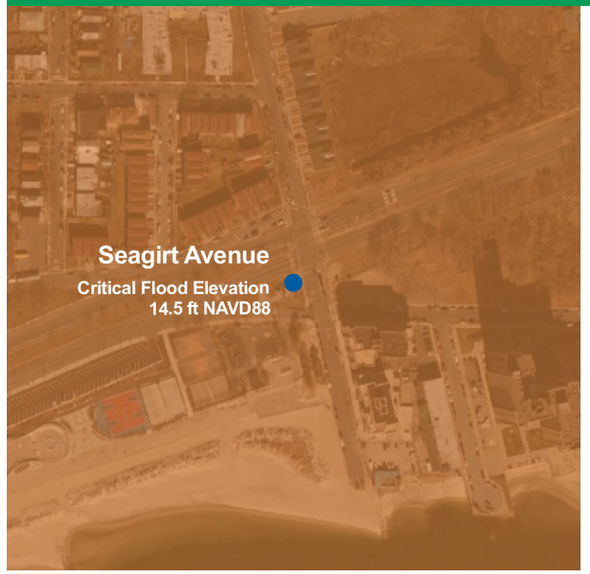
The risk of the Seagirt Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room.

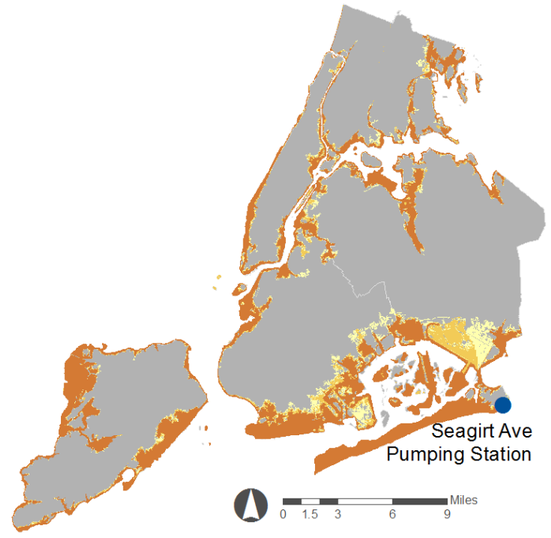
The critical flood elevation would inundate the area surrounding the facility with over 6 feet of water. This would damage electrical controls and pump motors.

ADAPTATION STRATEGIES

The Seagirt Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the significant depth of the critical flood, the recommended strategy at Seagirt Avenue is to elevate electrical controls in a new building. When pumps need to be replaced as part of regular maintenance, submersible pumps should be installed. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

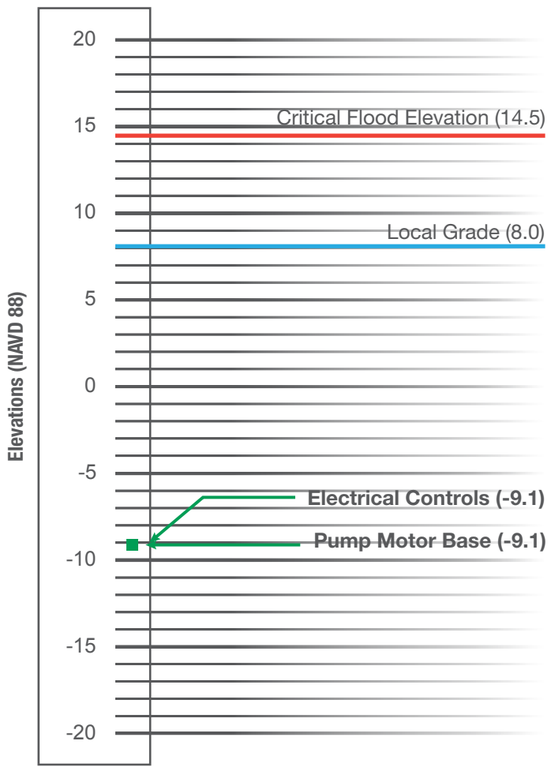




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	6.5
	Affected Area (Acres)	244
Risk	Population in Affected Area	7,725
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	7
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building & Install Submersible Pump Motors
	Cost of Protective Measures[1]	$2,304,000
	Damage Cost for Critical Flood without Protection[1, 2]	$4,226,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$21,749,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Hurricane Sandy high-water mark visible on panels within structure

Recommended Adaptation Strategy: **Seal Building & Submersible Pump Motors**

Adaptation Cost: **$286,000**

South Beach Pumping Station

STATION CHARACTERISTICS

The South Beach sanitary pumping station is located at 300 Father Capodanno Blvd. in Staten Island about 650 feet from the open water of the Lower Bay. The pumping station consists of an aboveground structure, where critical electrical components are located; non-submersible pump motors are located below grade.

The Pumping Station Summary table lists the general characteristics of the South Beach pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 69 acres. There is one critical facility within the area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The South Beach pumping station was inundated by the storm surge during Hurricane Sandy, which damaged motors and the electrical controls. DEP staff indicated there is a history of flooding due to smaller storms at this location.

RISK ASSESSMENT

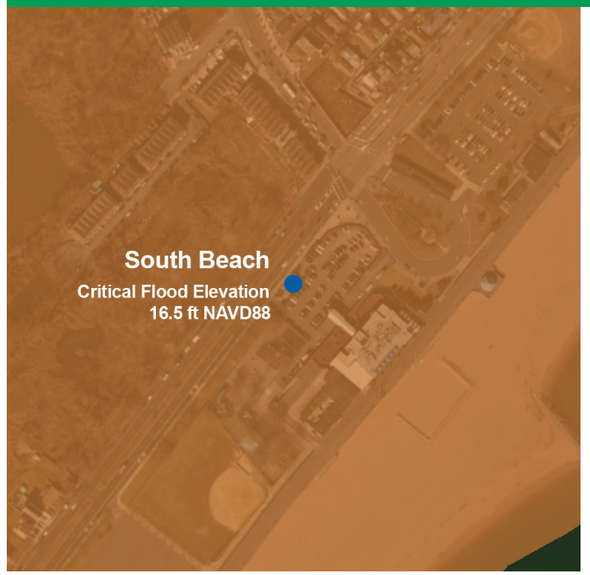
The risk of the South Beach pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room.

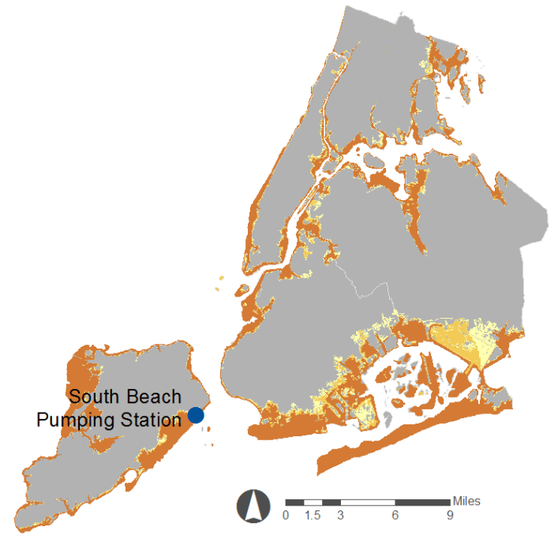
The critical flood elevation would inundate the area surrounding the facility with almost 9 feet of water. This would damage electrical controls and pump motors in the process.

ADAPTATION STRATEGIES

The South Beach pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because there is a substantial existing structure, the recommended strategy at South Beach is to seal the existing building. When pumps need to be replaced as part of regular maintenance, submersible pumps should be installed. Because water tight cases, doors, and building sealants are only rated up to a certain pressure, if flood depth is greater than expected the water pressure could exceed the rating and the building sealing could fail. Therefore, residual risk is related to a greater depth of flooding from larger storms or more extreme climate change and the potential for water pressure to exceed the rating of the sealing measures.

FEMA Flood Zones

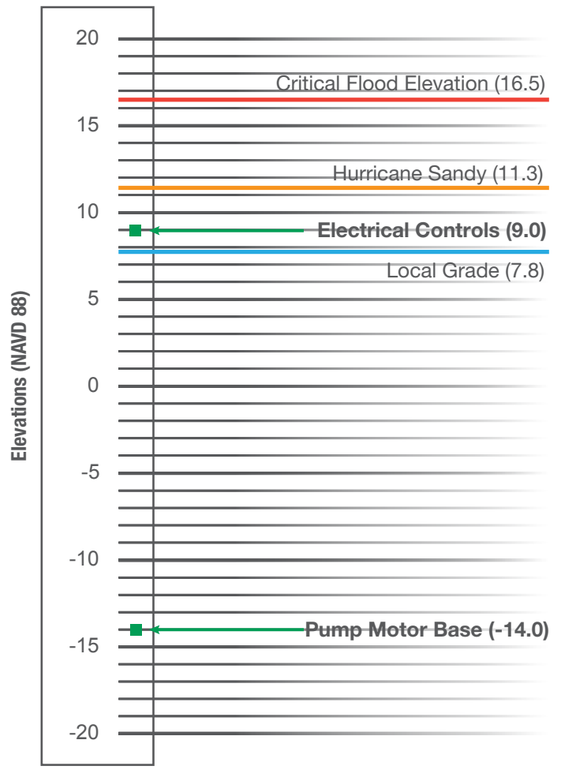




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Non-submersible
	Operating Capacity (MGD)	1.5
	Affected Area (Acres)	69
Risk	Population in Affected Area	2,165
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Seal Building & Install Submersible Pump Motors
	Cost of Protective Measures[1]	$286,000
	Damage Cost for Critical Flood without Protection[1, 2]	$2,359,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$10,925,000
	Resiliency Level	Moderate

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy: **Construct Barrier**

Adaptation Cost: **$5,920,000**

Structure surrounded by driveway and concrete perimeter wall

Throgs Neck Pumping Station

STATION CHARACTERISTICS

The Throgs Neck combined pumping station is located at the intersection of Lafayette Avenue and Zerega Avenue in the Bronx, behind the Department of Sanitation building. Controls and pumps are located on and below the below grade main floor of the structure onsite.

The Pumping Station Summary table lists the general characteristics of the Throgs Neck pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial/industrial area. Failure of the station would affect an area of approximately 2,639 acres and a population of over 67,000. There are 33 critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The station has experienced significant flooding, particularly during Hurricane Sandy. Flood water from Hurricane Sandy did not rise above the door threshold or windows, but the flood did submerge below grade Con Edison transformers, cutting power to the station and halting operation during the storm.

RISK ASSESSMENT

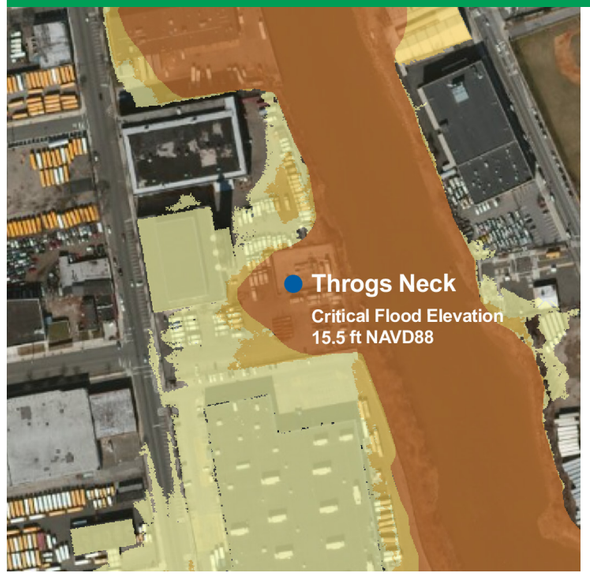
The risk of the Throgs Neck pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the control room and wells. Submersible pumps were confirmed but the condition of the pumps and the resiliency of supporting equipment is not known.

The critical flood elevation would completely inundate the station, and the surrounding flood would be 5 feet above local grade. This would damage electrical controls but would not affect the submersible pumps.

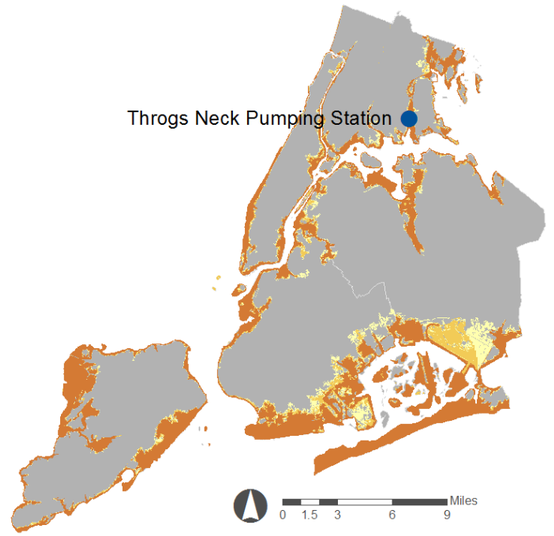
ADAPTATION STRATEGIES

The Throgs Neck pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because the extensive electrical controls would be difficult and expensive to move, the recommended strategy at Throgs Neck is to construct a barrier around the station. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

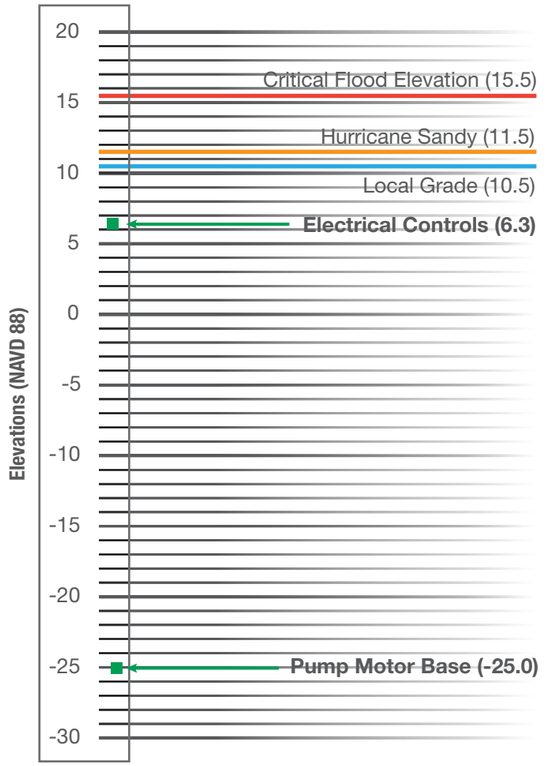


2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain



Source: FEMA; CUNY Institute for Sustainable Cities

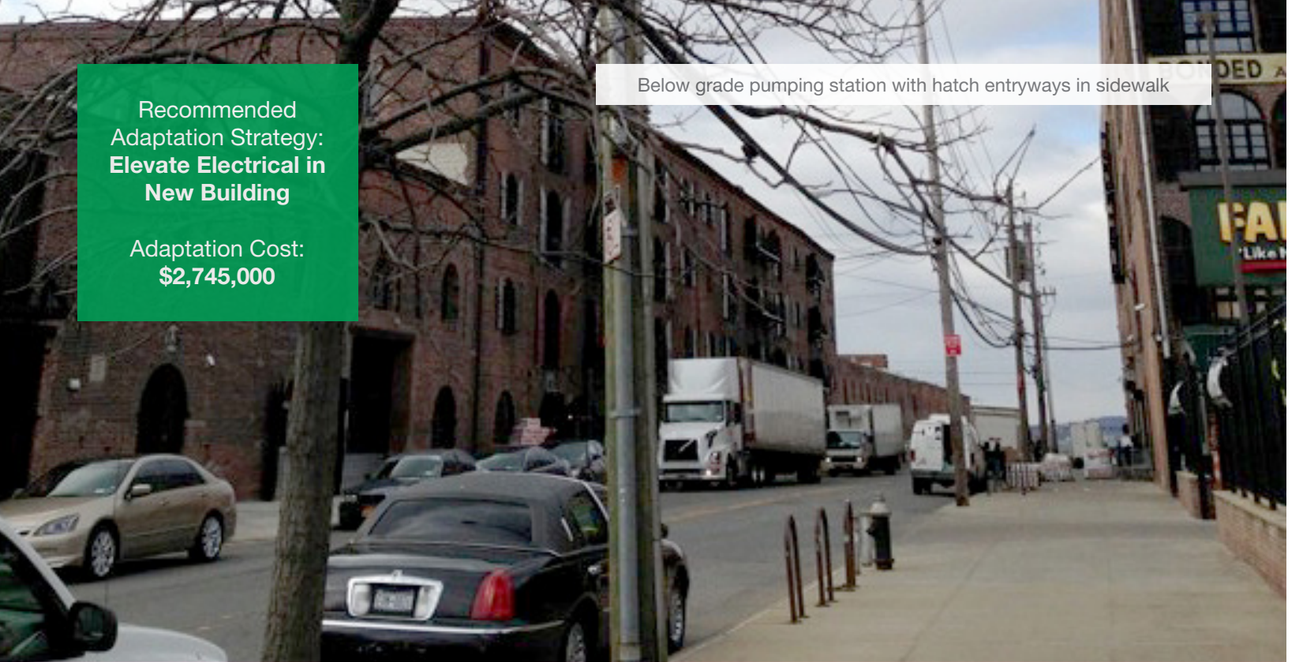
Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	36.7
	Affected Area (Acres)	2,639
Risk	Population in Affected Area	67,498
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	33
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Construct Barrier
	Cost of Protective Measures[1]	$5,920,000
	Damage Cost for Critical Flood without Protection[1, 2]	$10,672,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$53,001,000
	Resiliency Level	High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.



Recommended Adaptation Strategy: **Elevate Electrical in New Building**

Adaptation Cost: **$2,745,000**

Below grade pumping station with hatch entryways in sidewalk

Van Brunt Street Pumping Station

STATION CHARACTERISTICS

The Van Brunt combined pumping station is located in Brooklyn at the intersection of Van Brunt Street and Reed Street, less than 500 feet from the open water of the Upper Bay. The station is located entirely below grade, with the exception of telemetry equipment. Hatch entryways are located in the sidewalk.

The Pumping Station Summary table lists the general characteristics of the Van Brunt Street pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a commercial/industrial area. Failure of the station would affect an area of approximately 19 acres. There is one critical facility within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, the Van Brunt pumping station was completely inundated. All electrical equipment had to be replaced following the storm and new telemetry equipment was relocated above grade. DEP indicated there is a history of flooding at this location due to smaller storms.

RISK ASSESSMENT

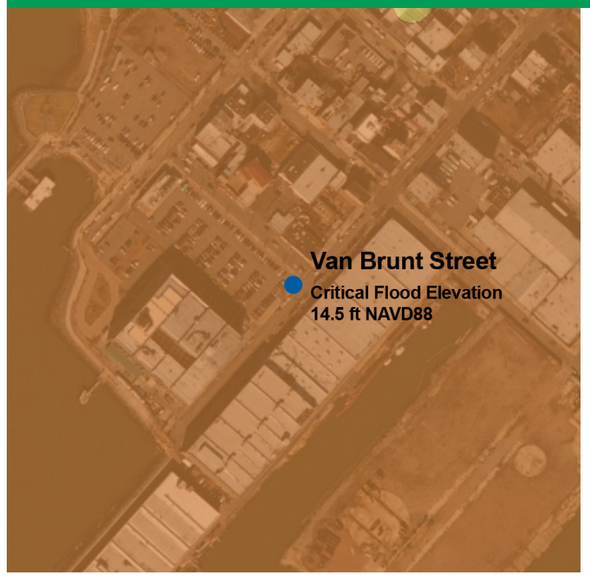
The risk of the Van Brunt Street pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included viewing the electrical components and dry well.

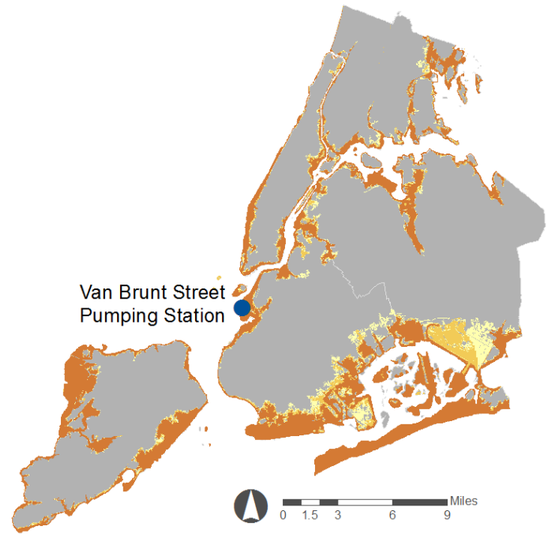
The critical flood elevation would completely inundate the station, and the surrounding flood would be nearly 9 feet above local grade. This would damage electrical controls but would not affect the submersible pumps.

ADAPTATION STRATEGIES

The Van Brunt Street pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Due to the extreme depth of the critical flood and the lack of an existing structure, the recommended strategy at Van Brunt Street is to elevate electrical controls in a new building. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

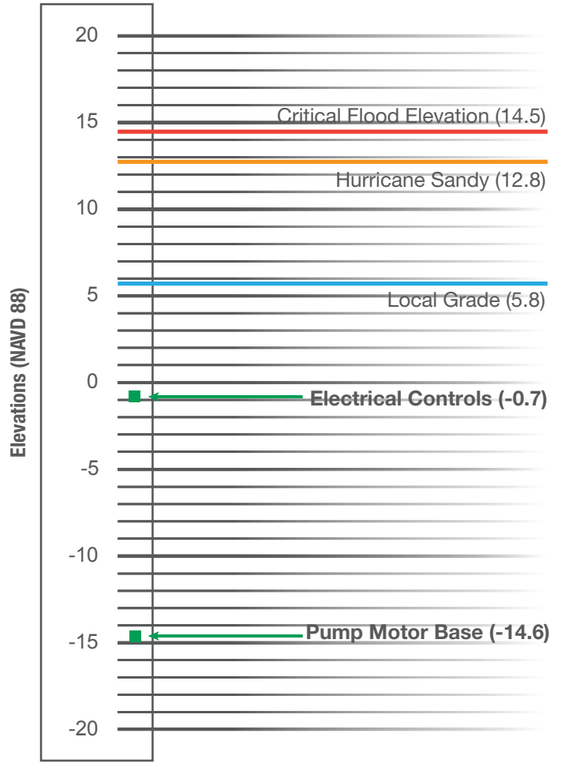




2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Combined
	Pump Type	Submersible
	Operating Capacity (MGD)	1.4
	Affected Area (Acres)	19
Risk	Population in Affected Area	388
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	Y
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	Y
Adaptation	Recommended Protective Measure	Elevate Electrical in New Building
	Cost of Protective Measures[1]	$2,745,000
	Damage Cost for Critical Flood without Protection[1, 2]	$931,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$4,790,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Victory Boulevard Pumping Station

STATION CHARACTERISTICS

The Victory Boulevard sanitary pumping station is located at the southwestern dead end of Victory Blvd. on Staten Island. It is adjacent to the property surrounding a Con Edison plant and is only a few hundred feet from the tidally influenced Arthur Kill. The station is primarily below grade underneath a concrete slab with control panels and meters mounted above the slab.

The Pumping Station Summary table lists the general characteristics of the Victory Boulevard pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a sparse industrial area. Failure of the station would affect an area of approximately 117 acres and a population of nearly 1,000. There is one critical facility within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Victory Boulevard pumping station was not affected by Hurricane Sandy and there is no history of flooding at this location.

RISK ASSESSMENT

The risk of the Victory Boulevard pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100-year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior revealed that electrical controls, which were shown below grade in the drawings, had been moved above grade. Otherwise, the station appeared consistent with the drawings.

The critical flood elevation would be nearly 4 feet above local grade. This may not reach the pump controls, which are mounted about 1 foot above the flood elevation but could reach other electrical equipment. Flood waters would enter the wells, but the submersible pumps should be unaffected. The Victory Boulevard pumping station is connected to another station, receiving flow from one pumping station and discharging to another. Loss of function at Victory Boulevard does not increase the vulnerability of the pumping station to which it discharges, but would increase the vulnerability of the pumping station from which it receives flow.

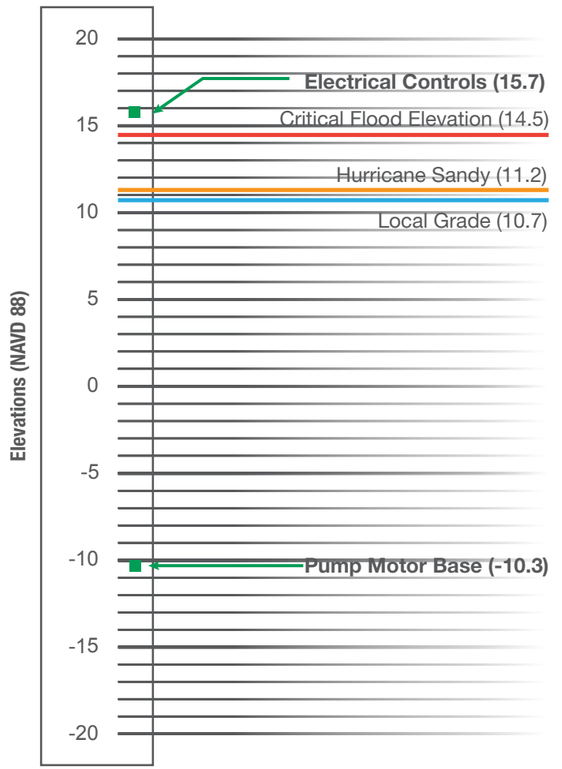
ADAPTATION STRATEGIES

The Victory Boulevard pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because controls are located above the critical flood elevation, but only by a small margin, the recommended strategy at Victory Boulevard is to elevate controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

FEMA Flood Zones

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	4.3
	Affected Area (Acres)	117
Risk	Population in Affected Area	970
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	1
	Historic Flooding	N
	Affected by Hurricane Sandy	N
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$876,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,849,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$9,517,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Recommended Adaptation Strategy:
Elevate Electrical on Platform/Pad

Adaptation Cost:
$880,000

Warnerville Pumping Station

STATION CHARACTERISTICS

The Warnerville sanitary pumping station is located near the intersection of Brookville Boulevard and Rockaway Boulevard in Queens. All critical electrical components are located above grade either outdoors on a concrete pad or within the onsite superstructure. The Warnerville pumping station includes four submersible sewage pumps and grinders located below grade and accessible by hatches.

The Pumping Station Summary table lists the general characteristics of the Warnerville pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a manufacturing area. Failure of the station would affect an area of approximately 24 acres. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

During Hurricane Sandy, the station lost power. The power outage caused the wet well to flood the dry well; however, no equipment was damaged during the flooding. There is no additional history of flooding due to smaller storms at this location.

RISK ASSESSMENT

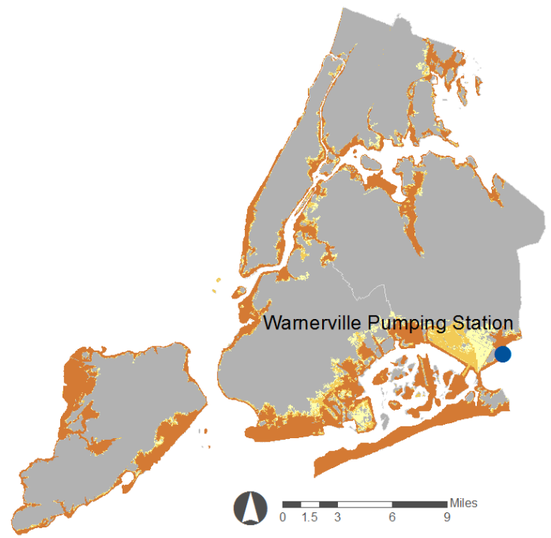
The risk of the Warnerville pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). These elevations and other notable characteristics were confirmed during a thorough station visit that included entering the structure and viewing the electrical components.

The critical flood elevation would inundate the area surrounding the facility with over 4 feet of water. This would damage electrical controls but would not affect the submersible pumps. The Warnerville pumping station is connected to another station; however it discharges to it rather than receiving flow. Therefore loss of function at Warnerville does not increase the vulnerability of an additional pumping station.

ADAPTATION STRATEGIES

The Warnerville pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because electrical controls are currently mounted outdoors but need to be moved out of the reach of flood waters, the recommended strategy at Warnerville is to elevate electrical controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

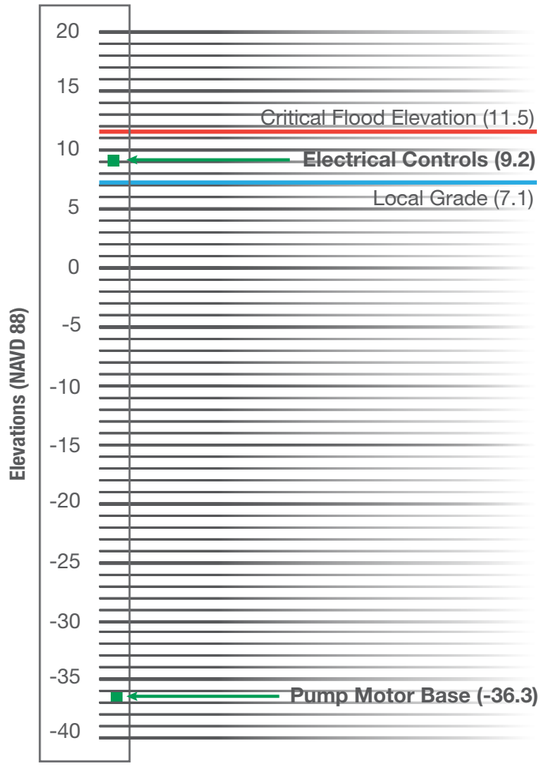
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	<1MGD
	Affected Area (Acres)	24
Risk	Population in Affected Area	170
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	N
	Connected to Other Stations	Y
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$880,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,142,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$5,875,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

Zerega Avenue Pumping Station

STATION CHARACTERISTICS

The Zerega Avenue sanitary pumping station is located at the southern dead end of Zerega Avenue near the corner of Castle Hill Avenue. It is across the street from a YMCA and is less than 500 feet from the East River. The pumping station is mostly below grade; the wells are accessible through hatches in the sidewalk, and electrical controls are located in a stainless-steel box on the sidewalk.

The Pumping Station Summary table lists the general characteristics of the Zerega Avenue pumping station, the potential effect of its failure, and the recommended adaptation strategy. The station is located in a residential area. Failure of the station would affect an area of approximately 7 acres and a population of approximately 200. There are no critical facilities within that area that could be affected if the station failed.

HURRICANE SANDY IMPACTS AND OTHER FLOODING HISTORY

The Zerega Avenue pumping station experienced minor impacts during Hurricane Sandy but there is no additional history of flooding at this location.

RISK ASSESSMENT

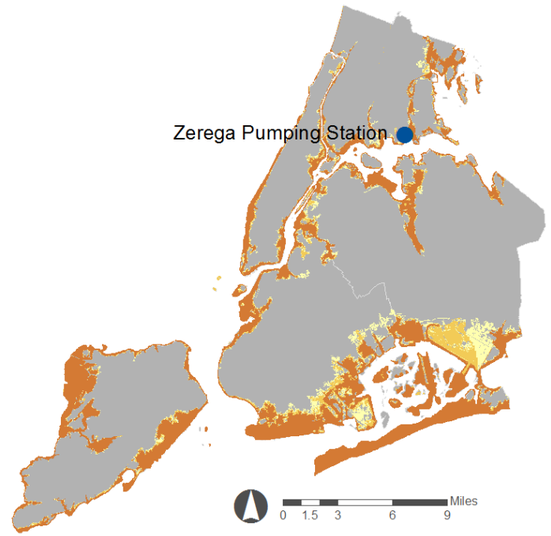
The risk of the Zerega Avenue pumping station was first assessed based on a review of the station's plan drawings, comparing the elevation of the critical components to that of the FEMA March 2013 Advisory Base Flood Elevation (ABFE) 100- year flood plus 30 inches of sea level rise (critical flood elevation). A visit to the pumping station to view its exterior revealed that electrical controls, which were shown below grade in the drawings, had been moved above grade. Otherwise, the station appeared consistent with the drawings.

The critical flood elevation would be almost 6 feet above local grade, completely inundating the wells and the above grade control panels. This would damage the electrical controls, but the submersible pumps should be unaffected.

ADAPTATION STRATEGIES

The Zerega Avenue pumping station requires adaptive measures to withstand the critical flood elevation. Potential strategies were evaluated against such factors as flood depth, equipment location, and space. Viable strategies were reviewed to identify the most cost-effective, resilient option. Because controls are currently exposed, space is limited, and controls need to be moved above the flood elevation, the recommended strategy at Zerega Avenue is to elevate electrical controls on a platform. Residual risk is related to a greater depth of flooding from larger storms or more extreme climate change.

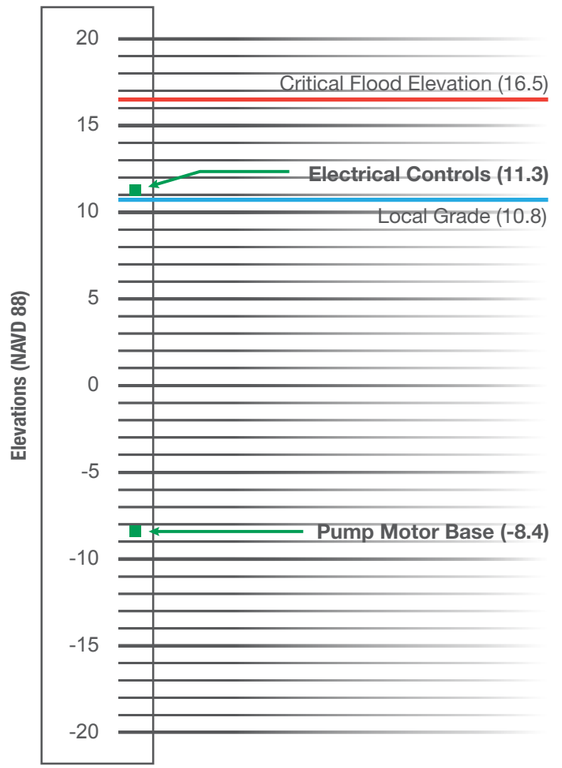
FEMA Flood Zones



2013 Advisory 100-Year Floodplain
Projected 2020s 100-Year Floodplain
Projected 2050s 100-Year Floodplain

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations



Pumping Station Summary

Background	Station Type	Sanitary
	Pump Type	Submersible
	Operating Capacity (MGD)	<1MGD
	Affected Area (Acres)	7
Risk	Population in Affected Area	195
	Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area	0
	Historic Flooding	N
	Affected by Hurricane Sandy	Y
	Historic Loss of Power	Y
	Connected to Other Stations	N
	Beach Affected	N
Adaptation	Recommended Protective Measure	Elevate Electrical on a Platform/Pad
	Cost of Protective Measures[1]	$662,000
	Damage Cost for Critical Flood without Protection[1, 2]	$1,283,000
	Cumulative Risk Avoided Over 50 Years[1, 3]	$6,603,000
	Resiliency Level	Very High

1) All cost estimates are presented in 2013 US Dollars.
2) One-time replacement cost of at-risk equipment if no protective measures are in place and critical flood scenario occurs (i.e., current 100-year flood plus 30 inches). This estimate does not consider the probability of storm occurrence.
3) Repair/replacement costs that would be avoided over 50 years if protective measures are in place for storm surges up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

SOUTH RICHMOND BMP, STATEN ISLAND, NY

CHAPTER 4: PRECIPITATION, WATERSHED, AND TIDE GATE ANALYSIS

Staten Island Bluebelt

Introduction

In order to effectively plan for the future, DEP has studied how climate change coupled with population growth could affect its wastewater collection systems and wastewater treatment infrastructure. Rising sea level, higher flows due to increasing population, more intense storms, and elevated surface temperatures are all factors that DEP has considered which could potentially affect the city's drainage infrastructure, wastewater collection system, and treatment operations. Table 1 summarizes the potential impacts associated with climate change on drainage infrastructure.

Table 1: Potential Impacts on Watersheds

Sea Level Rise	Air Temperature Variations	Precipitation Variations
• Physical inundation • Changed hydraulics • Changed influent wastewater characteristics • Change in energy use or pumping requirements • Saltwater intrusion • Impact on storm surge elevations • Increased operation and maintenance requirements • Shifting of inundation zones • Flooding of pump stations (especially if not watertight)	• Change in energy use • Increased operation and maintenance requirements • Increased occurrence of days greater than 90°F and impact on energy use • Increased probability of electrical grid failure	• Changes in the frequency of street flooding • Change in combined sewer overflow quantities, frequency, and water quality • Changes in stormwater discharge quantities, frequency, and water quality • Material strain • Increased operation and maintenance requirements • Increased frequency of emergency management actions

Excerpted from New York City Panel on Climate Change (NPCC) report entitled *Climate Risk Information*, issued February 2009. The NPCC issued a report in 2013 updating the projections used for its 2009 report. The changes to the projections would not alter the recommendations of this study.

The present study assesses the potential risks and impacts associated with changing precipitation patterns and sea level rise. It also evaluates adaptation strategies to improve resiliency in the face of climate change. The study was conducted in three phases:

Phase 1: Precipitation Analysis

The first phase of the study had two objectives. The first objective was to assess whether the rainfall intensity-duration-frequency (IDF) relationships used for sewer design have changed significantly since their original development during the first half of the 20th century. Sixty years of rainfall data have been collected since the development of the rainfall statistics currently used in sewer design. Analysis of this longer, more complete data set would inform the City's existing operations and assist in planning for the future. The second objective was to evaluate whether the typical rainfall year used for combined sewer overflow (CSO) Long-Term Control Plan (LTCP) development is representative of the 'average annual baseline' or if it should be revised in light of new rainfall data. The complete rainfall records from gauges throughout the New York City region through 2012 were examined to complete this phase of the study.

Phase 2: Watershed Analysis

The second phase of the study used hydrologic and hydraulic computer modeling to simulate how potential future rainfall and tides may affect drainage characteristics and the frequency and volume of CSOs. For this phase of the study, the projected future precipitation and tide data were applied using computer simulation modeling to a selected planning area, the Flushing Bay watershed, to compare CSO volume and frequency under current and future climate conditions. In addition, an analysis of potential changes in flood frequency and volume was conducted. Finally, the models were modified to simulate simplified adaptation strategies in order to assess their relative potential for mitigating the negative effects of climate change. The Flushing Bay watershed was chosen as a sample case study because it is representative of the city as a whole in a number of critical ways, and therefore feasible adaptation strategies developed for this watershed may be applicable citywide.

Phase 3: Tide Gate Analysis

The final phase of the study assessed the effectiveness, cost, and benefits of installing tide gates at stormwater outfalls to prevent storm surge inundation in adjacent communities. A preliminary, static analysis was performed to determine the viability and impacts of tide gate installations at 211 DEP-owned stormwater outfalls in New York City. The screening analysis looked at the local topography of the community upstream of each associated outfall and compared it to the elevations of typical tidal events to see whether the installation of a tide gate would provide flood protection.

Right-of-Way Bioswale

Phase I: Precipitation Analysis

Precipitation is the driving factor for peak flows in the sewer system; the system is designed and built to collect and convey runoff generated by a specific rainfall intensity called the design storm event. While the sewers themselves consistently function as designed, the weather is not always cooperative. Real temporal and spatial rainfall patterns can vary significantly from the design storm, resulting in sewer backups, surface flooding, and combined sewer overflows (CSO). Thorough analysis of precipitation data is therefore critical to assessing system functionality and planning for the future.

A fresh examination of regional rainfall data was conducted to determine if drainage and CSO Long Term Control Planning (LTCP) should be based on revised statistics, to identify a new typical rainfall year to be used for CSO LTCP modeling efforts, and to develop a means of modeling projected future precipitation conditions in the city's urban watershed. The analysis found that current drainage planning tools remain suitable for design, but that future modeling efforts should employ a different year of rainfall data based on recent historical data and projected changes in precipitation.

Rainfall Data Collection

Rainfall data were obtained from the Northeast Regional Climate Center at Cornell University. All data were subject to quality checks prior to delivery. Data were requested for the ten stations shown in Figure 1 and described in Table 2, which are the stations in and around New York City with the longest records. The longest available record comprises daily rainfall data at Central Park where data records commence in 1876, and only 3 years contain missing data. Newark also has a long daily record, commencing in 1897; however, daily data at stations other than Central Park were not used in the study as hourly data provides the most comprehensive record for short durations. Hourly observations began in 1948, and four stations also provided 15-minute data beginning in 1972.

Figure 1: Rainfall Stations with Long Records of Hourly Data Around New York City

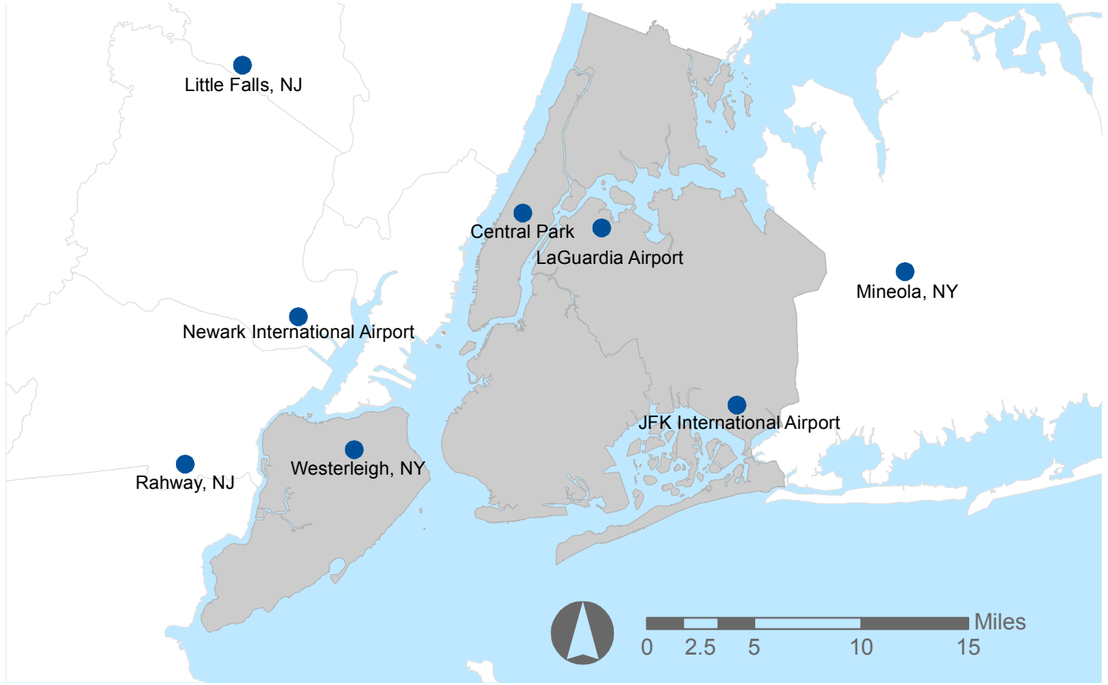


Table 2: Available Rainfall Records

Type of data	Station name	Record length	15 -minute data availability
Daily	Central Park, NY	1876-2011	None
Hourly	Ave V, Brooklyn, NY	1948-1976	None
Hourly	Westerleigh, NY	1948-1992	None
Hourly	White Plains, NY	1948-1992	1982-1992
Hourly	Rahway, NJ	1948-2003	1984-2000
Hourly	Central Park, NY	1948-2011	None
Hourly	Newark Airport, NJ	1948-2011	None
Hourly	Mineola, NY	1948-2011	1972-2010
Hourly	Little Falls, NY	1948-2011	1984-2000
Hourly	LaGuardia Airport, NY	1948-2011	None
Hourly	JFK Airport, NY	1949-2011	None

Spatio-temporal Trend Analyses of New York City Rainfall Data

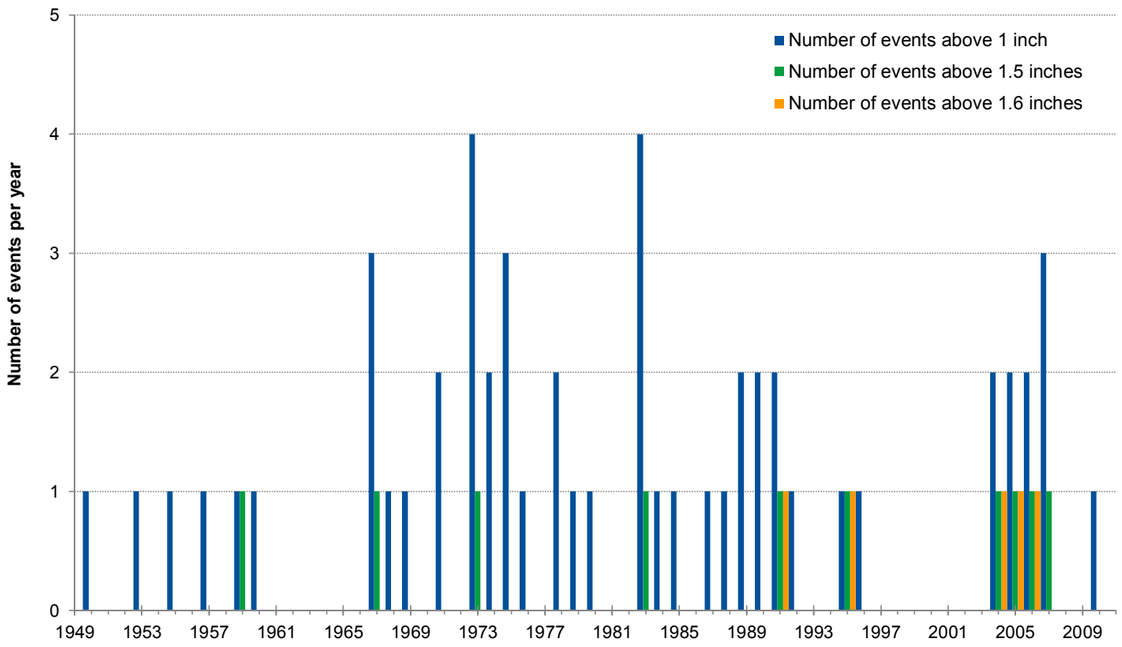
No single station can necessarily be considered representative of the entire city; rainfall within the city shows a strong spatial variation as storms tend to be localized. Locations in the southwest part of the city tend to receive higher rainfall; however, none of the stations in the southwest part of the city have sufficiently complete data, and using data from the gauges at Central Park and the three airports (JFK, Newark, and LaGuardia) for the period 1969-2010 provides the most complete spatial and temporal coverage (at the time of the analysis, data for 2011 and 2012 were not yet available). The period 1969-2010 is the longest period for which near complete datasets are available across these stations. This period is long enough to reliably estimate events of 10-year return periods or greater frequency, and includes the most recent cluster of recent extreme rainfall events to hit New York City in the 1990s and 2000s (Figure 2).

Since 1990, all of the following have occurred:

- three of the five largest precipitation events to occur at JFK;
- four of the five largest precipitation events to occur at LaGuardia and Newark; and
- all five of the largest precipitation events to occur at Central Park.

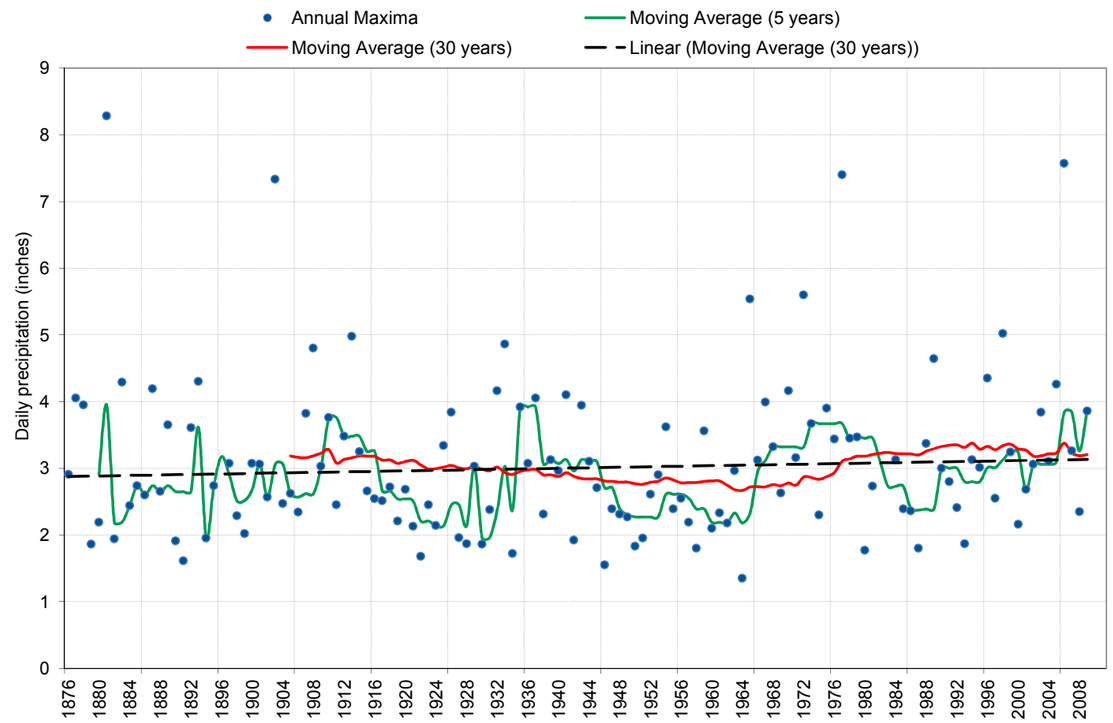
While these statistics would seem to suggest a dramatic shift in the rainfall climate towards more extreme rainfall events, it is difficult to draw very definitive conclusions. Analysis of the rainfall data shows that historically there have been similar clusters of large events, such as in the late 1880s and 1970s. The strong peak in the 5-year moving average illustrates the cluster of large storms in the 1970s (Figure 3). Similarly, the 30-year moving average (period recommended for climatological standard normals) shows a cyclic nature, with a decrease in daily precipitation from the beginning of the record to 1970,

Figure 2: Number of Large Rainfall Events Each Year since 1948



Number of large rainfall events occurring in each year since 1948, based on hourly data at Central Park. Data provided by the Northeast Regional Climate Center.

Figure 3: Trend Analysis of Daily Data from Central Park Rain Gauge



Annual maxima from hourly precipitation data at Central Park. Data provided by the Northeast Regional Climate Center.

and then an increase, reflecting the clusters of large events in the 1970s and the last two decades. Overall, the data show a gradual trend towards increased rainfall which is consistent with the recent observations of large precipitation events. It is difficult to predict rainfall trends and although global and regional climate models suggest increased precipitation, they do not provided clarity particularly regarding rainfall intensities used to size smaller sewer systems. Sewer systems are conservatively designed to capture large volumes of water very quickly to minimize street flooding in the interest of public safety. With future rain data collected in the coming years, it will be much clearer whether this increasing trend is real and statistically significant.

Intensity Duration Frequency Curves

With long records of rainfall, statistical methods can be applied to estimate the probability of a storm event with a specific intensity and duration occurring in a given year; this is referred to as the storm's return frequency. The rainfall intensity over a spectrum of durations from 5 minutes to 24 hours for storms with varying return frequencies are compiled into useful charts referred to as intensity-duration-frequency (IDF) curves.

IDF curves are one of the most common and useful tools for sewer design. The standard sewer design criterion in New York City is to use the intensity-duration values for a storm with a 5-year return frequency (i.e., a 20 percent chance of occurrence in any given year) to calculate how large the sewer pipes need to be sized to appropriately manage stormwater. The peak sewer design flow for a drainage area can be estimated using a runoff coefficient based on land use and imperviousness, the rainfall intensity value taken from the IDF curves, and the size of the contributing drainage area. The design of combined sewers also accounts for sanitary flows.

The city's current 5–year sewer design standard is fairly robust and conservative when compared to standards for other municipalities. Nevertheless, it is necessary to track rainfall patterns over time to see if the characteristics of a 5-year storm have changed.

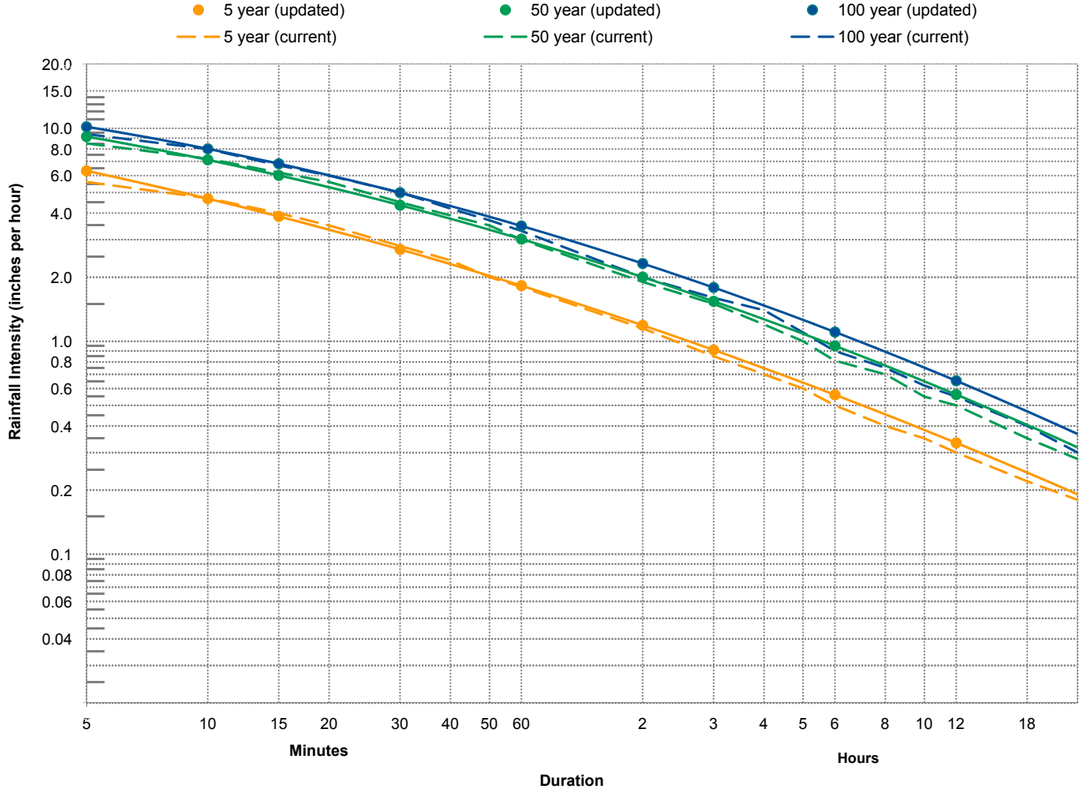
The current sewer design standard is based on IDF curves derived from rainfall data from the period 1903

to 1951. To accurately estimate the peak design flow for sewers, it is important to analyze whether rainfall patterns, and the derived IDF curves, show a shift over time when the analysis includes additional data that have been collected over the past 60 years. The original IDF curves were also based on data from a single rain gauge (believed to be Central Park) but are applied to drainage systems throughout the five boroughs.

A single IDF curve is necessary for ease of use and consistency for sewer design, yet the IDF curve needs to be representative of conditions across the entire city. A full set of IDF curves was developed for each of the four stations using the 1969-2010 data. As the source data are hourly, intensities for durations less than one hour were derived using published scaling factors and validated through analysis of the 15-minute data at Mineola. The highest point from the IDF curve generated for each of the four stations was then used to generate a single curve. This conservative approach recognizes that the data used does not include stations in the southwest of the city where rainfall is highest; adopting the higher values acknowledges and compensates for this omission.

For the majority of the city's sewer network, depending on the size of the collection area, it takes up to 100 minutes for stormwater to reach an outfall. As shown in the IDF curve (Figure 4), the intensities for a storm with a 5-year return period are not significantly different between the current and updated curves for durations (or travel time) between 5 and 100 minutes. In other words, for durations relevant to sewer design (up to 100 minutes), the expanded, more recent data record revealed no discernible trend toward more intense rainfall, and the current IDF curves can remain the basis of drainage design for now. However, for the longer durations, (2 hours and greater), the computed rainfall intensities are larger based on the updated curve, reflecting the more recent trends in increased rainfall intensity. In order to more definitively recognize emerging trends in precipitation intensity due to future climate change, DEP will periodically review rainfall trends and assess implications for stormwater infrastructure, as appropriate.

Figure 4: Comparison of Current and Updated Intensity-Duration-Frequency (IDF) Curves



Typical Rainfall Year

Based on the revised statistics developed for the IDF, historical data was assessed to develop a "typical year" to represent average annual conditions for LTCP modeling. These models provide information about how stormwater runoff and sanitary wastewater move and consequently discharge into waterbodies, and are used as quantitative tools to understand impacts on water quality. For each year and station, five rainfall parameters were calculated: annual rainfall depth, July rainfall depth, November rainfall depth, number of very wet days, and average peak storm intensity. The number of very wet days was chosen to be the number of days with more than two inches of rainfall.

The statistics were examined to find the year and station which is closest to the mean of all four stations for all five climate parameters, both for current conditions and future conditions considering climate change. Based on current climate statistics (1969-2010) the 2008 record from JFK airport was found to be the most representative year overall.

The future most typical years were then identified by shifting the mean of the distribution by change factors based on climate projections from the New York City Panel on Climate Change (NPCC) *Climate Risk Information* report (2009)[1]. Both central and precautionary estimates, which are described in detail below under Phase 2, were used for the development of the change factors, based on the middle and upper ranges of the climate projections, respectively. Changes in rainfall intensity were not available from the NPCC, and therefore research findings from Forsee et al. (2010) were used as a proxy. JFK 2005 was found to be the most typical future year using the central estimate for climate change, while LaGuardia 2006 is the most typical year using the precautionary estimate (Table 3).

As a result of this analysis, data from JFK Airport in 2008 is now the selected as the "typical" rainfall year and will be used for LTCP modeling. Furthermore, to account for more extreme years that may become the norm in the future with climate change, the time series used for LTCP modeling has been expanded to ten years--including 2005 and 2006--to test the robustness of various CSO mitigation approaches under a range of average and extreme conditions.

Table 3: Precipitation Values for Selecting Historical Years Representing Baseline and Future Scenarios[1]

Parameter	Baseline		Future Central		Future Precautionary	
	Aggregate Statistic (1969-2010)	Best Fit Annual Time Series JFK 2008	Target Value (Change Factor)	Best Fit Annual Time Series JFK 2005	Target Value (Change Factor)	Best Fit Annual Time Seres LGA 2006
Annual Depth (in)	45.5	46.3	47.8 (+5%)	48.5	50.1 (+10%)	54
July Depth (in)	4.3	3.3	4.5 (+4.5%)	5.2	4.9 (+14%)	6
November Depth (in)	3.7	3.3	3.8 (+3.5%)	4	4.3 (+17%)	5.8
Number of days >2 in	2.4	3	2.8 (+17%)	3	3.2 (+33%)	4
Average Intensity (in/hr)	0.15	0.15	0.18 (+18%)	0.16	0.2 (+32%)	0.2

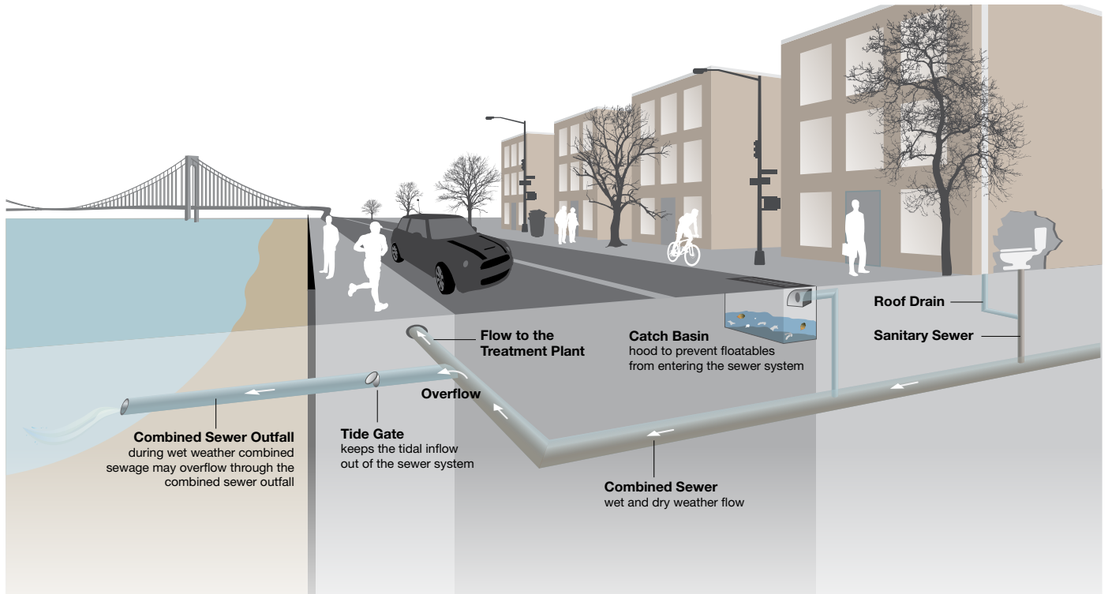
[1] The NPCC issued a report in 2013 updating the projections used for its 2009 report. The changes to the projections would not alter the recommendations of this study.

Phase II: Watershed Analysis

As a highly urbanized area, New York City's watersheds have both natural and engineered features to convey stormwater from the city's streets, sidewalks and properties to nearby waterways or wastewater treatment facilities when it rains. Approximately 60 percent of New York City's sewer system is combined, meaning that it handles sanitary waste from homes and businesses as wells as stormwater from streets and rooftops. Combined sewers (Figure 5) are common to older, more developed US cities and are designed to receive significant amounts of stormwater to prevent local flooding which can also result in combined sewer overflows (CSO) during significant rain events. Watershed analyses are conducted to understand the sensitivity of the wastewater infrastructure to changes in the system; therefore, for this study a representative watershed was evaluated under two possible future climate scenarios.

CSO mitigation is an ongoing process, including the development of Long Term Control Plans (LTCP). LTCP projects typically involve sewer and wastewater treatment plant upgrades, and the implementation of green infrastructure, which work together to increase the capacity of the sewer system and reduce the amount of stormwater flowing into the sewers. The planning areas for which LTCPs are being developed can span the service areas of multiple treatment plants, and can contain numerous pumping stations and several major CSO outfalls. With a sewer system so large, the City uses extensive computer simulation models of the sewer network and historical rainfall records to understand how much CSO is generated annually, and to determine how CSO mitigation projects will reduce CSOs upon implementation.

Figure 5: Combined Sewer System



For this study, DEP sought a representative watershed to demonstrate the impacts of climate change, and the robustness of current and future infrastructure to absorb these changes. The candidate watersheds were based on the planning areas used by DEP's LTCP program (Figure 6). The general considerations for choosing a representative watershed were as follows:

1. Infrastructure: Consideration was given to which wastewater treatment plants were associated with the watershed, and whether there were regional CSO facilities (such as at Paerdegat Basin or Flushing Bay), pump stations, and tide gates in the drainage area.

2. Drainage Area Characteristics: The selection process weighed the benefits of selecting an open water planning area versus a confined tributary, or a large drainage area versus a smaller one. In addition, the amount of combined sewer area, the housing density, and risk of storm surge inundation were considered. The verified sewer backup and street flooding complaint database from a 10-year period were evaluated as evidence of one type of flood risk in the drainage area.

3. Expected Investments and Projected CSO Reductions: DEP's CSO program includes a long list of capital commitments and construction projects, and it was agreed that the planning area selected should include a significant amount of future investment. The green and grey infrastructure investments and associated CSO reductions reported in the NYC Green Infrastructure Plan were considered, as were the presence of "Tier I Outfalls" (essentially the 10-15 largest CSOs citywide).

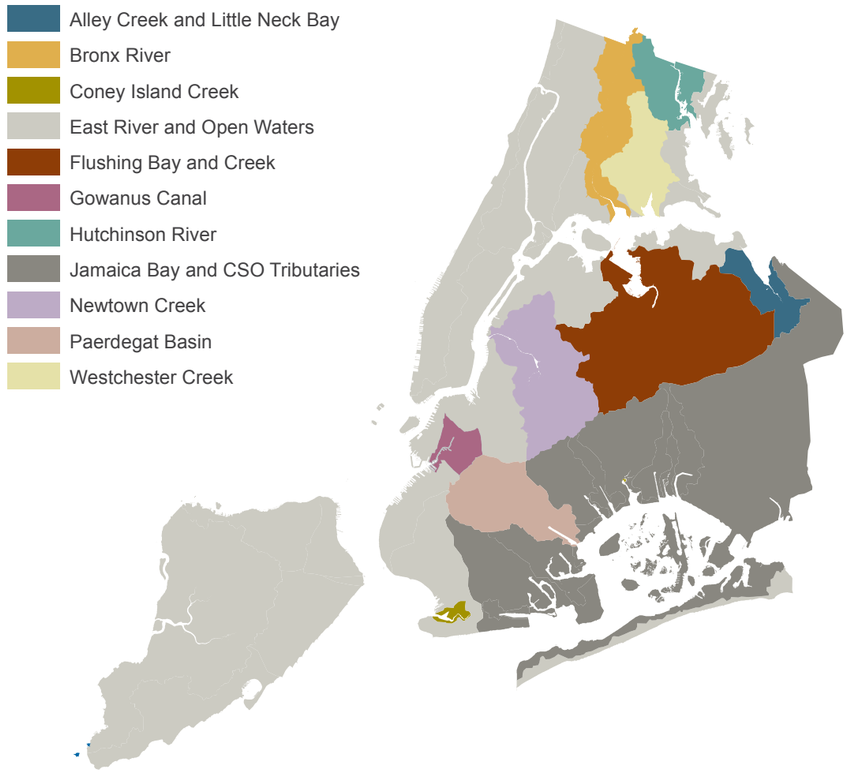
Based on these criteria, the Flushing Bay watershed was selected for further analysis for a conceptual sensitivity test of system response to two future climate scenarios, as it is broadly representative of the city's watersheds. To conduct this sensitivity test, an existing watershed (model InfoWorks CS) for Flushing Bay was used and modified to reflect the project needs for baseline and future population, sea level rise, and precipitation changes.

Two future scenarios, which are representative of projections for the 2050s, were defined. The 2050s represents a timescale of interest to DEP for the planning, design and operation of infrastructure, representing the planned life of much of the City's wastewater infrastructure. Two future scenarios representing two degrees of severity were used, since climate projection are wide-ranging due to uncertainty in future greenhouse gas emission levels and variations between climate models themselves. These future scenarios are coupled with a 'baseline' scenario, representing current conditions, to better understand the potential change in system responses. These scenarios are defined below.

- Current or Baseline: This is the scenario against which future scenarios are compared to quantify change, and it is intended to reflect the climate and operational conditions of the present or recent past.
- Future Central Estimate: This scenario represents the climate conditions near the middle range of 2013 projections published by the New York City Panel on Climate Change (NPCC) for the 2050s and assumes a 5 percent increase in annual precipitation and about 10 inches of additional sea level rise. An increase of 18 percent in precipitation intensity was assumed based on research findings from Forsee et al. (2010).
- Future Precautionary Estimate: This scenario represents a more severe change that could occur by the 2050s and includes a 10 percent increase in annual precipitation and 24 inches of additional sea level rise. It is at the upper end of the middle range of 2013 climate projections published by the NPCC for the 2050s. An increase of 32 percent in precipitation intensity was assumed based on research findings from Forsee et al. (2010).

The analysis showed that CSO discharges and local flooding will likely increase under future climate conditions in response to potential increases in precipitation volume and intensity. Overall annual rainfall volume is the most important driver of increased CSO volume, with the greatest changes at outfalls with large tributary areas because more runoff flows into those parts of the sewer system. Projections show that CSO increases at individual outfalls are consistent under both future scenarios, with increases from baseline between 5 and 47 percent for the future central scenario, and 9 and 46 percent for the future precautionary scenario. A number of the CSO catchments show a decrease in CSO spill between the Future Central and Future Precautionary scenarios. While the difference between the two estimated values is small, it is likely due to the large rise in tidal levels between the two scenarios, leading to 'tide locking' of the outfalls on a more regular basis. The differences between the future scenarios range from -11.9 to 14.8 percent, with no significant outliers. The relative consistency of the observed changes between the CSO catchments can be interpreted to suggest that there are not necessarily any specific elements or infrastructure within the CSO system that is

Figure 6: New York City Watersheds



at greater risk than others; rather, the system is generally susceptible to changes to the conditions for which they were designed, and size of the catchment area will dictate changes in CSO volumes.

In addition to the Future Central and Precautionary scenario analyses, which included future changes to rainfall, sea level, and dry weather flow, the individual impacts of rainfall and sea level projections were also reviewed. The intent of these analyses was to understand the relative contribution of changes in sea level and rainfall in the projected changes in CSO discharges. For each future scenario, two additional modeling runs were performed—one with the projected rainfall for that scenario with baseline tides, and another with baseline rainfall and projected tides. This analysis confirmed that changes in future rainfall have a far greater impact on CSO performance than does sea level rise.

Analysis of surface water drainage focused on a synthetic intense rainfall event for baseline, future central, and future precautionary climate scenarios. This event incorporates the intense rainfall in a 6-minute duration meant to simulate the type of flash flooding event that occurs during summer thunderstorms. The total rainfall volume for the baseline flooding event was increased uniformly in each 6-minute time step by 18 and 32 percent to simulate larger volumes of rainfall under the future central and future precautionary scenarios, respectively.

The incidence of surface flooding under the baseline, future central and future precautionary flooding events were analyzed in terms of surface flooding volumes, the normalized flood volume over each CSO catchment area, and the site-specific flood rates measured as a percentage of the local pipe full capacity. These are all important metrics for the management of surface flooding, although total flood volumes are the key consideration. The normalized volumes help understand the relative distribution of flooding within the watershed, and the pipe full capacity analysis helps identify areas where storm intensity in excess of the design storm would likely cause flooding in the system. It should be noted that the watershed sensitivity analyses considered only the 'combined' system, and did not examine the separate storm sewer network.

It should also be noted that the model selected for this study was not built with sufficient resolution to accurately evaluate site-specific flood extents and depths; however, results showed that there is an increase in flood volumes from baseline to future scenarios at the catchment scale. For example, an 18 percent increase in intensity under the future central scenario could result in doubling of flood volumes compared to baseline, whereas a 32 percent increase in intensity under the future precautionary scenario could result in flood volumes that are three times greater than the baseline. This demonstrates the importance of rainfall intensity to the surface drainage performance of the system. Additionally, the analysis suggests that potential flooding is largely localized, at least within the Flushing Bay watershed. As noted earlier, the city's drainage infrastructure is designed manage the 5-year storm event. For this analysis, when the intensity (and volume) of that design event is increased, it resulted in increased potential surface flooding impacts, which is not surprising due to the fact that the system was not designed to accommodate these larger flows.

In order to address the future projected climate changes, a range of adaptation strategies were investigated. Key findings from the analysis of adaptation strategies showed that 'source control' type options, designed to delay or prevent stormwater entering the sewer system, provide a comprehensive approach to improving system resilience. Source control can be achieved through either temporary retention or infiltration, either of which serves to reduce peak flows and consequently reduce or prevent impacts associated with flooding and CSO spills which, by definition, occur during event peaks. Green infrastructure was considered throughout this evaluation, and demonstrated benefits for both flooding and CSO overflows. It is both logical and evident from the results of this analysis that the more stormwater inflow to the sewers can be reduced, the more the load on the system is reduced, and impacts avoided.

New York City is already committed to implementing green infrastructure to capture the first inch of rainfall on 10 percent of impervious surfaces in combined sewer areas by 2030. This approach will result in reduced CSOs and improved water quality. As the green infrastructure system is built out, it could produce a gradual increase in stormwater system resilience, in parallel to the anticipated gradual increase in rainfall due to climate change. While the construction of green infrastructure is an effective solution to manage rainfall and reduce CSOs, in other areas, where feasible and based on local land use and sewer configuration, local disconnection or separation of the sewer system (conveying stormwater separately from sanitary sewage flows) could be more effective. Accordingly, DEP will augment existing combined sewers with high-level storm sewers in certain areas near the water's edge around the city. The benefit of this approach is similar to source controls in that it reduces stormwater flows into the combined sewer system.

Sewer outfall with tide gate on Shellbank Basin in Howard Beach, Queens

Phase III: Tide Gate Analysis

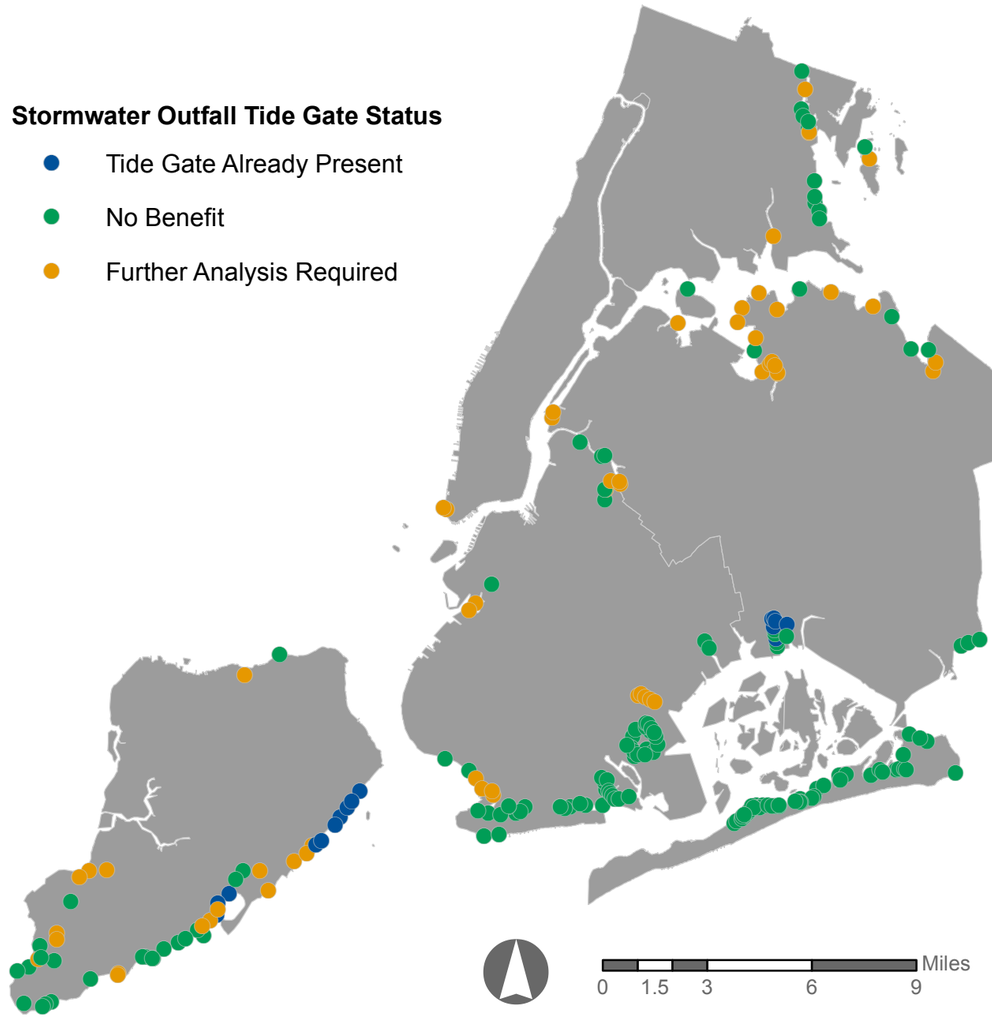
Tide gates prevent salt water from entering the combined sewer system and disrupting operations at wastewater treatment plants. While the combined system is equipped with tide gates, separate stormwater outfalls are not always equipped with tide gates, and therefore DEP sought to determine where additional tide gates might improve the functioning of the system during a storm surge event. A preliminary, static analysis was performed to determine the viability and impacts of tide gate installations at 211 DEP owned stormwater outfalls in New York City.

This analysis looked at the local topography of the community upstream of each associated outfall and compared it to the elevations of typical tidal events to see if the installation of a tide gate would provide flood protection to the communities directly adjacent to the associated shoreline. It should be noted that tide gates are effective in communities and areas where a seawall or similar flood protection measure are installed in tandem with the tide gate.

Of the 211 DEP-owned stormwater outfalls that were analyzed, it was determined that 152 outfalls would have no benefits from tide gate installation, while 59 required further analysis (Figure 7). For Coney Island and the Rockaways, tide gates have no benefit for the community due to the flat and low-lying topography of the surrounding communities. These conditions create a situation where a tide gate would not open during high tide events coinciding with certain rainfall events. Alternatively, for the south shore of Staten Island, the elevation of the communities is so high above the typical high tide that tide gates would also have a minimal impact.

The analysis demonstrated that tide gates must be analyzed on a case-by-case basis at each outfall to examine the hydraulics of the local drainage system, the surrounding topography of the community, and the typical tidal elevation along the associated shoreline. The installation of a seawall or other flood barrier is critical to the ability of a tide gate to benefit the community. The outfalls identified by this study as requiring further analysis necessitate dynamic modeling to determine the effectiveness and functional operation of tide gates during rainfall events. Additionally, each outfall needs to be assessed to determine the size of the area and types of assets that would potentially benefit from tide gate installation. Installing tide gates at every outfall in the city would be neither cost-effective, nor would it provide effective flood mitigation, adding costs for maintenance and replacements, and in some cases, potentially exacerbating flooding conditions.

Figure 7: Stormwater Outfalls Assessed for Tide Gate Analysis



Pennsylvania Avenue Landfill, Brooklyn, NY

Conclusion

New York City's drainage system is robust, and has provided excellent service to its residents for generations; however, projected changes in climate may pose new challenges. More intense precipitation patterns and a rise in sea level can contribute to increased frequency of CSO discharges, and a greater risk of local street flooding. Improving the city's wastewater and sewer systems will enhance the ability of the existing infrastructure to cope with environmental changes. DEP is actively addressing these issues and will continue to implement a number of its programs that are already underway, and where opportunities exist will seek to expand these programs.

This study is an important step in planning for the future because it specifically addressed the question of how global climate change is likely to affect New York City. It provides a basis for continuing existing efforts such as the Green Infrastructure Program, CSO Long-Term Control Plans, Bluebelt drainage program, and building out storm sewers in areas with limited drainage systems. In addition, this study, although focused on watershed-level impacts, produced results that are directly applicable to efforts to protect the DEP's entire wastewater infrastructure.

The analysis of watershed-level impacts on the collection system began with a comprehensive analysis of the complete available record of precipitation, including for the 60-year period since the Department's sewer design guidelines were formulated. The study reached the important conclusion that the current design documents, the IDF curves, need not be changed at this time, but should be revisited periodically in the future. The data analysis also selected the 2008 JFK data record as the typical year to be used for LTCP modeling, replacing the previous model year which was no longer the most representative of current New York City conditions. This analysis was the basis for projecting potential future rainfall conditions, under which the watershed was evaluated.

The representative watershed study of the drainage system indicated that changes to precipitation in New York City would increase the frequency of CSO discharges and the amount of local street flooding, while the increase in sea level would have little effect in the selected study area. Tide gates on stormwater outfalls were another specific element of the drainage infrastructure evaluated. A comprehensive analysis found that they can be an important feature in local flood protection, but only if they are used as part of a total engineering solution.

The study confirms the efficacy of the city's current green infrastructure approach, outlined in *PlaNYC*, especially the target of modifying impervious surfaces of city streets with bioswales, local infiltration or local storage, targeted separation of sewers, and regional Bluebelt-type designs. In fact, a clear result of the analysis was that the careful integration of green and traditional grey-infrastructure modifications will provide the largest benefit with the least cost. Additionally, other DEP initiatives such as adoption of new design standards for wastewater facilities and the recommended strategies for hardening wastewater infrastructure, as discussed in detail in Chapters 2 and 3, will further improve the city's resiliency in the face of future climate change. The data analysis of precipitation, the computer modeling of the sewer system of the Flushing Bay watershed, and the examination of critical pieces of system infrastructure all provide a foundation uppon which DEP can build future efforts to respond to climate change and sea level rise.

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