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
ACKNOWLEDGMENTS

The NYC Wastewater Resiliency Plan was developed by the Department of Environmental Protection in collaboration with a dedicated team of consultants.

Executive Acknowledgments:
Carter H. Strickland, Jr.  Commissioner
Angela Licata    Deputy Commissioner, Sustainability

Development Team:
Pinar Balci    Director, Bureau of Environmental Planning & Analysis
Alan Cohn    Director, Climate & Water Quality
Sydney Mescher    Environmental Analyst, Bureau of Environmental Planning & Analysis
Julie Stein    Former Director, Wet Weather Planning & Water Quality Policies

DEP Contributors:
Gregory Anderson    Kenneth Moriarty
Luis Carrio    James Mueller
Kevin Donnelly    Patrick O’Connor
Anthony Fiore    John Pettito
Ryan Fleming    James Roberts
Caroline Forger    Vincent Sapienza
Jason Galea    John Sexton
Kathryn Garcia    Prakash Shah
Oscar Gonzalez    Arthur Spangel
Paul Kiskorna    Dennis Stanford
Robert LaGrotta    Hortense Taylor
Pedick Lai    Candice Tsai
Chris Laudando    Constance Vavilis
Anthony Maracic    Jerry Volgende

Consultant Team:
Hazen and Sawyer:
Laura Bendernagel    Klaus Albertin
Rebecca Carmine    Adam Hosking
Tim Groninger    Kate Marney
Anni Luck    Gary Ostroff
Sanddeep Mehrotra    Vin Rubino
Karen Norgren    Emma Smith
Arnie Weitzman    Peter Sokolow

CH2M:
CH2M:

We would also like to thank Radley Horton (Columbia University), Steve Moddemeyer (CollinsWoerman), Richard Palmer (University of Massachusetts Amherst), and Diego Rosso (University of California Irvine) for their expert feedback.
# TABLE OF CONTENTS

## Executive Summary 1

## Chapter 1: Citywide Framework

### Chapter 2: Wastewater Treatment Plants 31

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

## Chapter 3: Pumping Stations

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

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

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

<table>
<thead>
<tr>
<th>Page</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>239</td>
<td>Introduction</td>
</tr>
<tr>
<td>241</td>
<td>Phase I: Precipitation Analysis</td>
</tr>
<tr>
<td>247</td>
<td>Phase II: Watershed Analysis</td>
</tr>
<tr>
<td>251</td>
<td>Phase III: Tide Gate Analysis</td>
</tr>
<tr>
<td>253</td>
<td>Conclusion</td>
</tr>
<tr>
<td>254</td>
<td>References</td>
</tr>
</tbody>
</table>
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 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.

The study produced a number of key results: 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.

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?**

<table>
<thead>
<tr>
<th>Wastewater Facilities At-Risk of Storm Surge Inundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>☢️ 14 Wastewater Treatment Plants</td>
</tr>
<tr>
<td>☢️ 58 Pumping Stations</td>
</tr>
<tr>
<td>☢️ 2013 Advisory 100-Year Floodplain</td>
</tr>
<tr>
<td>☢️ Projected 2020s 100-Year Floodplain</td>
</tr>
<tr>
<td>☢️ Projected 2050s 100-Year Floodplain</td>
</tr>
</tbody>
</table>

**How should it be mitigated?**

<table>
<thead>
<tr>
<th>Adaptation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevate Equipment</td>
</tr>
<tr>
<td>Flood-Proof Equipment</td>
</tr>
<tr>
<td>Seal Building</td>
</tr>
<tr>
<td>Construct Barrier</td>
</tr>
<tr>
<td>Sandbag Temporarily</td>
</tr>
<tr>
<td>Install Backup Power</td>
</tr>
</tbody>
</table>

**What is the cost?**

<table>
<thead>
<tr>
<th>Summary of Estimated Costs for Wastewater Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>📊</td>
</tr>
<tr>
<td>$2.0 B</td>
</tr>
<tr>
<td>$1.5 B</td>
</tr>
<tr>
<td>$1.0 B</td>
</tr>
<tr>
<td>$0.5 B</td>
</tr>
<tr>
<td>$0.0 B</td>
</tr>
<tr>
<td>$-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost of Protective Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>$315 M</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Damage Cost for Critical Flood without Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.1 B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cumulative Risk Avoided Over 50 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2.5 B</td>
</tr>
</tbody>
</table>

Source: FEMA; CUNY Institute for Sustainable Cities

Note: All facilities are already equipped with backup generator power.
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.

Lessons Learned from Hurricane Sandy

- 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.

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 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.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 26</td>
<td>DEP begins implementing Storm Preparedness Plan</td>
</tr>
<tr>
<td>Oct 27-28</td>
<td>Sandy makes landfall in NYC</td>
</tr>
<tr>
<td>Oct 29</td>
<td>North River Wastewater Treatment Plant loses power 11PM-Oct 29-11PM-Oct 30</td>
</tr>
<tr>
<td>Oct 30</td>
<td>Coney Island Wastewater Treatment Plant loses power 11PM-Oct 29-6AM-Oct 30</td>
</tr>
<tr>
<td>Nov 2-10</td>
<td>DEP starts transfer of wastewater and stormwater</td>
</tr>
<tr>
<td>Nov 11</td>
<td>Manhattan Pumping Station loses power 11PM-Oct 29-11PM-Oct 30</td>
</tr>
</tbody>
</table>

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

- **Climate Analysis**: Gather local climate data and existing conditions and base flood elevations. Establish a critical flood elevation (ex. 100-year floodplain with 30 inches of sea level rise).

- **Facility Risk Analysis**: Identify flood pathways and elevations of facilities. Identify facilities where flood pathway elevations are below the critical flood elevation. Determine if at-risk facilities contain critical, non-submersible infrastructure that resides below the critical flood elevation. Estimate cost of damage to at-risk locations and infrastructure.

- **Adaptation Analysis**: Review literature of adaptation strategies considered worldwide. Identify strategies applicable to NYC. Evaluate feasibility of using strategies at a facility and estimate cost of implementation. Provided strategy recommendations per facility based on feasibility, strategy cost, and resiliency level.

- **Next Steps**: Implement more robust design standards. Harden pumping stations through capital projects. Harden wastewater treatment plants through capital projects.

---

NYC WASTEWATER RESILIENCY PLAN
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.

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.

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.

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.
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.

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

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.
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 for 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. 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.

Notes: Avenue V and Govanous 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) Repairs/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 Stations At-Risk of Storm Surge Inundation

<table>
<thead>
<tr>
<th>Pumping Stations</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>122nd Street</td>
<td>$0.28</td>
<td>$1.85</td>
<td>$0.62</td>
</tr>
<tr>
<td>15th Avenue</td>
<td>$2.66</td>
<td>$3.51</td>
<td>$1.00</td>
</tr>
<tr>
<td>15th Street</td>
<td>$0.30</td>
<td>$3.66</td>
<td>$1.43</td>
</tr>
<tr>
<td>24th Avenue</td>
<td>$1.48</td>
<td>$5.03</td>
<td>$15.75</td>
</tr>
<tr>
<td>2nd Avenue</td>
<td>$1.91</td>
<td>$1.32</td>
<td>$6.78</td>
</tr>
<tr>
<td>37th Avenue</td>
<td>$0.96</td>
<td>$3.51</td>
<td>$3.85</td>
</tr>
<tr>
<td>40th Road</td>
<td>$0.51</td>
<td>$1.77</td>
<td>$8.32</td>
</tr>
<tr>
<td>40th Street</td>
<td>$2.87</td>
<td>$2.12</td>
<td>$10.91</td>
</tr>
<tr>
<td>6th Road</td>
<td>$2.87</td>
<td>$1.37</td>
<td>$6.77</td>
</tr>
<tr>
<td>Avenue M</td>
<td>$1.07</td>
<td>$3.84</td>
<td>$19.75</td>
</tr>
<tr>
<td>Avenue U</td>
<td>$2.60</td>
<td>$3.70</td>
<td>$19.04</td>
</tr>
<tr>
<td>Bayswater Avenue</td>
<td>$0.17</td>
<td>$1.14</td>
<td>$5.29</td>
</tr>
<tr>
<td>Borden Avenue</td>
<td>$1.94</td>
<td>$1.24</td>
<td>$15.22</td>
</tr>
<tr>
<td>Broad Channel</td>
<td>$2.40</td>
<td>$2.34</td>
<td>$12.03</td>
</tr>
<tr>
<td>Bush Terminal</td>
<td>$0.59</td>
<td>$3.47</td>
<td>$17.84</td>
</tr>
<tr>
<td>Canal Street</td>
<td>$2.42</td>
<td>$2.71</td>
<td>$13.33</td>
</tr>
<tr>
<td>Cannon Avenue</td>
<td>$1.43</td>
<td>$4.39</td>
<td>$20.46</td>
</tr>
<tr>
<td>Clearview</td>
<td>$4.71</td>
<td>$7.82</td>
<td>$16.80</td>
</tr>
<tr>
<td>Commerce Avenue</td>
<td>$0.63</td>
<td>$1.04</td>
<td>$5.34</td>
</tr>
<tr>
<td>Conner Street</td>
<td>$5.46</td>
<td>$6.67</td>
<td>$32.13</td>
</tr>
<tr>
<td>Co-op City North</td>
<td>$0.35</td>
<td>$3.26</td>
<td>$3.62</td>
</tr>
<tr>
<td>Douglas Bay</td>
<td>$7.39</td>
<td>$1.80</td>
<td>$9.26</td>
</tr>
<tr>
<td>Eltingville</td>
<td>$3.89</td>
<td>$9.51</td>
<td>$5.44</td>
</tr>
<tr>
<td>Elly Avenue</td>
<td>$0.47</td>
<td>$2.02</td>
<td>$3.58</td>
</tr>
<tr>
<td>Flushing Bridge</td>
<td>$1.26</td>
<td>$1.74</td>
<td>$5.51</td>
</tr>
<tr>
<td>Gildersleeve Avenue</td>
<td>$0.89</td>
<td>$1.14</td>
<td>$3.97</td>
</tr>
<tr>
<td>Hannah Street</td>
<td>$1.37</td>
<td>$12.80</td>
<td>$63.24</td>
</tr>
<tr>
<td>Hollers Avenue</td>
<td>$2.48</td>
<td>$2.82</td>
<td>$14.53</td>
</tr>
<tr>
<td>Howard Beach</td>
<td>$8.16</td>
<td>$17.44</td>
<td>$20.65</td>
</tr>
<tr>
<td>Hunts Point Market</td>
<td>$0.73</td>
<td>$1.86</td>
<td>$5.65</td>
</tr>
<tr>
<td>Kean Street</td>
<td>$4.80</td>
<td>$6.23</td>
<td>$11.93</td>
</tr>
<tr>
<td>Linden Place</td>
<td>$1.15</td>
<td>$4.03</td>
<td>$4.41</td>
</tr>
<tr>
<td>Marble Hill</td>
<td>$0.62</td>
<td>$3.38</td>
<td>$15.67</td>
</tr>
<tr>
<td>Mason Avenue</td>
<td>$0.55</td>
<td>$3.37</td>
<td>$15.60</td>
</tr>
<tr>
<td>Mayflower Avenue</td>
<td>$0.04</td>
<td>$6.50</td>
<td>$28.43</td>
</tr>
<tr>
<td>Melville Avenue</td>
<td>$2.84</td>
<td>$1.78</td>
<td>$9.14</td>
</tr>
<tr>
<td>Nautilus Court</td>
<td>$2.42</td>
<td>$3.28</td>
<td>$16.85</td>
</tr>
<tr>
<td>Nevins Street</td>
<td>$1.09</td>
<td>$3.11</td>
<td>$6.75</td>
</tr>
<tr>
<td>New York Times</td>
<td>$5.96</td>
<td>$10.23</td>
<td>$30.96</td>
</tr>
<tr>
<td>Old Douglastown</td>
<td>$0.74</td>
<td>$4.07</td>
<td>$20.96</td>
</tr>
<tr>
<td>Orchard Beach</td>
<td>$0.66</td>
<td>$1.15</td>
<td>$3.06</td>
</tr>
<tr>
<td>Paerdegan</td>
<td>$16.85</td>
<td>$15.41</td>
<td>$102.13</td>
</tr>
<tr>
<td>Richmond Hill Road</td>
<td>$0.61</td>
<td>$5.49</td>
<td>$1.20</td>
</tr>
<tr>
<td>River Island North</td>
<td>$2.87</td>
<td>$3.65</td>
<td>$3.15</td>
</tr>
<tr>
<td>Roosevelt Island Main</td>
<td>$6.27</td>
<td>$3.02</td>
<td>$0.70</td>
</tr>
<tr>
<td>Roosevelt Island North</td>
<td>$2.54</td>
<td>$1.66</td>
<td>$8.56</td>
</tr>
<tr>
<td>Roosevelt Island South</td>
<td>$0.63</td>
<td>$0.51</td>
<td>$0.51</td>
</tr>
<tr>
<td>Rosendale</td>
<td>$9.94</td>
<td>$5.22</td>
<td>$26.84</td>
</tr>
<tr>
<td>Saphire Street</td>
<td>$0.80</td>
<td>$3.70</td>
<td>$10.04</td>
</tr>
<tr>
<td>Seagrit Avenue</td>
<td>$2.30</td>
<td>$4.23</td>
<td>$21.75</td>
</tr>
<tr>
<td>South Beach</td>
<td>$2.63</td>
<td>$19.84</td>
<td>$10.93</td>
</tr>
<tr>
<td>Throgs Neck</td>
<td>$5.92</td>
<td>$10.87</td>
<td>$53.00</td>
</tr>
<tr>
<td>Van Brunt Street</td>
<td>$2.74</td>
<td>$0.93</td>
<td>$4.79</td>
</tr>
<tr>
<td>Victory Boulevard</td>
<td>$0.88</td>
<td>$1.65</td>
<td>$9.52</td>
</tr>
<tr>
<td>Wantamale</td>
<td>$0.88</td>
<td>$1.14</td>
<td>$5.87</td>
</tr>
<tr>
<td>Zerenga Avenue</td>
<td>$0.66</td>
<td>$1.28</td>
<td>$6.60</td>
</tr>
</tbody>
</table>

Total: $128 M $218 M $709 M
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 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.

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.
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 analyses, and may be modified within the context of other capital improvements being made.

The study also identified a number of additional resiliency strategies to each facility based on preliminary site analyses, and may be modified within the context of other capital improvements being made.

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.

### Wastewater Treatment Plant Estimated Cost

<table>
<thead>
<tr>
<th>Wastewater Treatment Plant</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowery Bay</td>
<td>$40.26</td>
<td>$112.60</td>
<td>$69.03</td>
</tr>
<tr>
<td>Newtown Creek</td>
<td>$8.85</td>
<td>$28.79</td>
<td>$0.13</td>
</tr>
<tr>
<td>North River</td>
<td>$17.15</td>
<td>$94.10</td>
<td>$445.79</td>
</tr>
<tr>
<td>Owls Head</td>
<td>$11.01</td>
<td>$48.41</td>
<td>$158.81</td>
</tr>
<tr>
<td>Port Richmond</td>
<td>$10.39</td>
<td>$54.85</td>
<td>$60.36</td>
</tr>
<tr>
<td>Red Hook</td>
<td>$18.56</td>
<td>$67.38</td>
<td>$24.95</td>
</tr>
<tr>
<td>Tallman Island</td>
<td>$11.02</td>
<td>$45.18</td>
<td>$32.80</td>
</tr>
<tr>
<td>Wards Island</td>
<td>$1.48</td>
<td>$8.73</td>
<td>$40.46</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$118.74</td>
<td>$460.04</td>
<td>$841.32</td>
</tr>
<tr>
<td>Wastewater Treatment Plants Citywide</td>
<td>$187 M</td>
<td>$901 M</td>
<td>$1,760 M</td>
</tr>
</tbody>
</table>

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.
EXECUTIVE SUMMARY

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, and net changes to wet weather component capacity. This study sought to understand if there have been statistically relevant changes to wet weather rainfall 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.

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.

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 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, 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, and net changes to CSO component capacity. This study sought to understand if there have been statistically relevant changes to wet weather rainfall 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.

Storm Surge Guidance:

26th Ward WWTP

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.

<table>
<thead>
<tr>
<th>Storm Surge Advisory*</th>
<th>Floodplain and elevations</th>
<th>Elevations and areas to be protected</th>
<th>Brooklyn Sewer Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>12'</td>
<td>10.4' 13.4' 16.4' 19.4'  22.4'</td>
<td>North Sludge Gallery, Fuel Oil Tanks near North Building (West Side), Aera- tor and Transformer</td>
<td>Instrument Maintenance Facility, Bulkhead Elevation</td>
</tr>
<tr>
<td>11'</td>
<td>10.0' 13.0' 16.0' 19.0'  22.0'</td>
<td>Fuel Oil Tanks near Emergency Generator Building</td>
<td>Thickener Gallery, Old Chlorination Building</td>
</tr>
<tr>
<td>10'</td>
<td>9.5' 12.5' 15.5' 18.5'  21.5'</td>
<td>MCC23, Secondary Bypass Controls, Sludge Transfer Building</td>
<td>Thickener Gallery, Old Chlorination Building, Dewatering Building, North Building, Waste Gas Burners</td>
</tr>
<tr>
<td>9'</td>
<td>9.0' 12.0' 15.0' 18.0'  21.0'</td>
<td>Air Process Gallery</td>
<td>Thickener Gallery, Old Chlorination Building</td>
</tr>
<tr>
<td>8'</td>
<td>8.5' 11.5' 14.5' 17.5'  20.5'</td>
<td>MCC22, Dewatering Building, North Building</td>
<td>Thickener Gallery, Old Chlorination Building</td>
</tr>
<tr>
<td>7'</td>
<td>8.0' 11.0' 14.0' 17.0'  20.0'</td>
<td>BNR Outdoor Electrical Blower Equipment (North side), Digestor Gallery</td>
<td>Thickener Gallery, Old Chlorination Building, Digester Gallery</td>
</tr>
<tr>
<td>6'</td>
<td>7.5' 10.5' 13.5' 16.5'  19.5'</td>
<td>BNR Building</td>
<td>Thickener Gallery, Old Chlorination Building, Digester Gallery</td>
</tr>
<tr>
<td>5'</td>
<td>7.0' 10.0' 13.0' 16.0'  19.0'</td>
<td>Substation Building, BNR Outdoor Electrical Equipment (South Side-Generator and Transformer), BNR Outdoor Fuel Station (South Side)</td>
<td>Thickener Gallery, Old Chlorination Building, Dewatering Building, North Building, Waste Gas Burners</td>
</tr>
<tr>
<td>4'</td>
<td>6.5' 9.5' 12.5' 15.5'  18.5'</td>
<td>5', 6', 7', 8', 9', 10', 11', 12', 13', 14', 15', 16', 17', 18', 19', 20', 21', 22'</td>
<td>Thickener Gallery, Old Chlorination Building, Digester Gallery</td>
</tr>
<tr>
<td>2'</td>
<td>5.5' 8.5' 11.5' 14.5'  17.5'</td>
<td>3', 4', 5', 6', 7', 8', 9', 10', 11', 12', 13', 14', 15', 16', 17', 18', 19', 20', 21', 22'</td>
<td>Thickener Gallery, Old Chlorination Building, Digester Gallery</td>
</tr>
<tr>
<td>1'</td>
<td>5.0' 8.0' 11.0' 14.0'  17.0'</td>
<td>2', 3', 4', 5', 6', 7', 8', 9', 10', 11', 12', 13', 14', 15', 16', 17', 18', 19', 20', 21', 22'</td>
<td>Thickener Gallery, Old Chlorination Building, Digester Gallery</td>
</tr>
</tbody>
</table>

*Storm surge added to other higher high water at Sandy Hook of 2.1 ft, which is 1.77 ft Brooklyn Sewer Datum. Sea level is expected to rise up to 30 inches by 2050. This storm surge advisory is for current conditions.

**One of the multiple flood pathways into the tunnel system. To protect tunnels, ensure all pathways are protected.

*Storm surge added to other higher high water at Sandy Hook of 2.1 ft, which is 1.77 ft Brooklyn Sewer Datum.
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 area for testing purposes. 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.

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 PlanNYC 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.

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.
CHAPTER 1: 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.

**Citywide Framework**

**Climate Analysis**
- Gather local climate data and existing conditions and base flood elevations
- Establish a critical flood elevation (ex. 100-year floodplain with 30 inches of sea level rise)

**Risk Analysis**
- Identify flood pathways and elevations of facilities
- Identify facilities where flood pathway elevations are below the critical flood elevation
- Determine if at-risk facilities contain critical, non-submersible infrastructure that resides below the critical flood elevation
- Estimate cost of damage to at-risk locations and infrastructure

**Adaptation Analysis**
- Review literature of adaptation strategies considered worldwide
- Identify strategies applicable to NYC
- Evaluate feasibility of using strategies at a facility and estimate cost of implementation
- Provide strategy recommendations per facility based on feasibility, strategy cost, and resiliency level

**Recommended Adaptation Strategies**
- Implement more robust design standards
- Harden pumping stations through capital projects
- Harden wastewater treatment plants through capital projects

**Facilities and Infrastructure Needing Protection**

**Next Steps**

**Critical, Unprotected Infrastructure**

**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. 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>
<thead>
<tr>
<th>Chronic Hazards</th>
<th>Baseline (1971-2000)</th>
<th>2020s</th>
<th>2050s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle Range (25th - 75th percentile)</td>
<td>High End (90th percentile)</td>
<td>Middle Range (25th - 75th percentile)</td>
</tr>
<tr>
<td>Average Temperature</td>
<td>54 °F</td>
<td>+2.0 to 2.8 °F</td>
<td>+3.2 °F</td>
</tr>
<tr>
<td>Precipitation</td>
<td>50.1 in.</td>
<td>+1 to 8%</td>
<td>+10%</td>
</tr>
<tr>
<td>Sea Level Rise</td>
<td>0</td>
<td>+4 to 8 in.</td>
<td>+11 in.</td>
</tr>
</tbody>
</table>

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

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 flooding 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 flooding 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 specific site 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-monetar y 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

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

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.
CHAPTER 2: WASTEWATER TREATMENT PLANTS
The New York City Department of Environmental Protection (DEP) owns 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 Plant Estimated Costs

<table>
<thead>
<tr>
<th>Wastewater Treatment Plant</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Other Wastewater Treatment Plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowery Bay</td>
<td>$40.26</td>
<td>$112.60</td>
<td>$69.03</td>
</tr>
<tr>
<td>Newtown Creek</td>
<td>$8.85</td>
<td>$28.79</td>
<td>$9.13</td>
</tr>
<tr>
<td>North River</td>
<td>$11.15</td>
<td>$94.10</td>
<td>$445.79</td>
</tr>
<tr>
<td>Owls Head</td>
<td>$11.01</td>
<td>$48.41</td>
<td>$158.81</td>
</tr>
<tr>
<td>Port Richmond</td>
<td>$10.39</td>
<td>$54.85</td>
<td>$60.36</td>
</tr>
<tr>
<td>Red Hook</td>
<td>$18.56</td>
<td>$67.38</td>
<td>$24.95</td>
</tr>
<tr>
<td>Tallman Island</td>
<td>$11.02</td>
<td>$45.18</td>
<td>$32.80</td>
</tr>
<tr>
<td>Wards Island</td>
<td>$1.48</td>
<td>$8.73</td>
<td>$40.46</td>
</tr>
<tr>
<td>Subtotal</td>
<td>$118.74</td>
<td>$460.04</td>
<td>$841.32</td>
</tr>
<tr>
<td>Wastewater Treatment Plants Citywide</td>
<td>$187 M</td>
<td>$901 M</td>
<td>$1,760 M</td>
</tr>
</tbody>
</table>

---

**Table:**

- **Wastewater Treatment Plants with Greatest Potential for Affecting Beaches**
- **Source:** FEMA; CUNY Institute for Sustainable Cities
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

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

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.

Source: FEMA; CUNY Institute for Sustainable Cities
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 cleanup and temporary pumping and power, would be approximately $80.4 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 data-base (as of 2/7/2013) of active infrastructure, as well as a cost-risk analysis which compares the cost of implementing, 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 affect critical 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.

Table B: 26th Ward Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Process Gallery</td>
<td>Sandbag</td>
<td>$132,000</td>
<td>$724,000</td>
<td>$369,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>BNR Building</td>
<td>No Action Required</td>
<td>$0</td>
<td>$139,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Chemical Handling</td>
<td>No Action Required</td>
<td>$0</td>
<td>$49,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Chlorination Building (Old)</td>
<td>Flood-proof Equipment and Construct Barrier</td>
<td>$1,201,000</td>
<td>$1,063,000</td>
<td>$3,132,000</td>
<td>High</td>
</tr>
<tr>
<td>Chlorine Contact Tanks</td>
<td>Elevate Equipment</td>
<td>$14,000</td>
<td>$270,000</td>
<td>$90,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Dewatering Building</td>
<td>Sandbag</td>
<td>$697,000</td>
<td>$43,567,000</td>
<td>$31,399,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Digester Gallery</td>
<td>Sandbag</td>
<td>$105,000</td>
<td>$753,000</td>
<td>$654,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Final Settling Tanks</td>
<td>No Action Required</td>
<td>$0</td>
<td>$2,294,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Fire Pump Station</td>
<td>No Action Required</td>
<td>$0</td>
<td>$335,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Instrument Maintenance</td>
<td>No Action Required</td>
<td>$0</td>
<td>$604,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Man Building</td>
<td>Flood-proof Equipment and Seal Building</td>
<td>$1,879,000</td>
<td>$11,815,000</td>
<td>$9,268,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Primary Sludge Gallery</td>
<td>Flood-proof Equipment and Construct Barrier</td>
<td>$3,500,000</td>
<td>$5,083,000</td>
<td>$1,660,000</td>
<td>High</td>
</tr>
<tr>
<td>Return Sludge Gallery</td>
<td>Flood-proof Equipment and Seal Building</td>
<td>$287,000</td>
<td>$3,426,000</td>
<td>$1,064,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Sludge Transfer</td>
<td>Sandbag</td>
<td>$158,000</td>
<td>$6,092,000</td>
<td>$2,274,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Substation Building</td>
<td>No Action Required</td>
<td>$0</td>
<td>$46,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Thickener Gallery</td>
<td>Construct Barrier</td>
<td>$212,000</td>
<td>$6,044,000</td>
<td>$29,544,000</td>
<td>High</td>
</tr>
<tr>
<td>Waste Gas Burners</td>
<td>No Action Required</td>
<td>$0</td>
<td>$86,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
</tbody>
</table>

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

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

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

Storm Surge Guidance:
26th Ward WWTP

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.
**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**

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

Table B: Bowery Bay Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine Tanks</td>
<td>Elevate Equipment</td>
<td>$236,000</td>
<td>$446,000</td>
<td>$124,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Emergency Generation Facilities</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$964,000</td>
<td>$5,940,000</td>
<td>$5,644,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Grit Building</td>
<td>Seal Building</td>
<td>$557,000</td>
<td>$3,318,000</td>
<td>$6,683,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Man Building</td>
<td>Construct Barrier</td>
<td>$1,427,000</td>
<td>$37,313,000</td>
<td>$12,761,000</td>
<td>High</td>
</tr>
<tr>
<td>MCC Room 1541</td>
<td>Sandbag</td>
<td>$132,000</td>
<td>$902,000</td>
<td>$575,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>MCC Room 1548</td>
<td>Sandbag</td>
<td>$132,000</td>
<td>$902,000</td>
<td>$216,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Plant Substation</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,150,000</td>
<td>$7,494,000</td>
<td>$7,149,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Primary Elevator Area - Lower Level</td>
<td>Flood-proof Equipment and Sandbag</td>
<td>$314,000</td>
<td>$405,000</td>
<td>$121,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Service Room</td>
<td>Elevate Equipment and Sandbag</td>
<td>$791,000</td>
<td>$742,000</td>
<td>$372,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Sludge Dewatering Building</td>
<td>Flood-proof and Elevate and Construct Barrier</td>
<td>$3,419,000</td>
<td>$15,315,000</td>
<td>$12,641,000</td>
<td>High</td>
</tr>
<tr>
<td>Sludge Storage Building No. 15</td>
<td>No Action Required</td>
<td>$0</td>
<td>$861,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>South Final Tanks</td>
<td>No Action Required</td>
<td>$0</td>
<td>$3,966,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Substation &quot;A&quot; 1531</td>
<td>Elevate Equipment and Seal Building</td>
<td>$563,000</td>
<td>$3,131,000</td>
<td>$947,000</td>
<td>High</td>
</tr>
<tr>
<td>Substation &quot;B&quot; 1532</td>
<td>Elevate Equipment and Seal Building</td>
<td>$563,000</td>
<td>$3,131,000</td>
<td>$1,221,000</td>
<td>High</td>
</tr>
<tr>
<td>Substation &quot;C&quot; 1533</td>
<td>Elevate Equipment and Seal Building</td>
<td>$563,000</td>
<td>$3,131,000</td>
<td>$2,122,000</td>
<td>High</td>
</tr>
<tr>
<td>Substation &quot;E&quot; 1536</td>
<td>Elevate Equipment and Seal Building</td>
<td>$535,000</td>
<td>$3,131,000</td>
<td>$1,219,000</td>
<td>High</td>
</tr>
<tr>
<td>Tunnels And Corridors</td>
<td>Flood-proof and Elevate and Seal Building</td>
<td>$28,918,000</td>
<td>$21,263,000</td>
<td>$17,230,000</td>
<td>High</td>
</tr>
<tr>
<td>Digester Gallery</td>
<td>No Action Required</td>
<td>$0</td>
<td>$768,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Fire Pump House</td>
<td>No Action Required</td>
<td>$0</td>
<td>$446,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
</tbody>
</table>

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.

Storm Surge Guidance: Bowery Bay WWTP

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

If a storm surge advisory is announced as part of a weather report, locate the forecasted surge level below. Protective measures should be taken for all locations at or below that level. If a small craft advisory is also issued, waves may splash shoreline assets more than 3 ft above the surge level. Adjust protection accordingly.

Storm Surge Advisory* Floodplains and Elevations to be protected by Queens Datum

<table>
<thead>
<tr>
<th>Level (ft)</th>
<th>12'</th>
<th>11'</th>
<th>10'</th>
<th>9'</th>
<th>8'</th>
<th>7'</th>
<th>6'</th>
<th>5'</th>
<th>4'</th>
<th>3'</th>
<th>2'</th>
<th>1'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*These elevations reflect Mean Higher High Water at Kings Point as of 2012, which is 6.94 ft above Queens Datum. Sea level is expected to rise up to 30 inches by 2050. This storm surge advisory is for current conditions.

**One of the multiple flood pathways into the tunnel system. To protect tunnels, ensure all pathways are addressed.

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.
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**

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

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 the cost of 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 grades and providing stoplogs 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.

Primary treatment process equipment can be operated during storms, and robust adaptation strategies are recommended 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**

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

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 Intlet/Shelly 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, filing 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.

Storm Surge Guidance:

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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Type</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Dewatering Facilities</td>
<td>Yes</td>
</tr>
<tr>
<td>Design Dry Weather Flow (MGD)</td>
<td>200</td>
</tr>
<tr>
<td>Maximum Wet Weather Flow (MGD)</td>
<td>400</td>
</tr>
<tr>
<td>Number of Residents Served</td>
<td>684,569</td>
</tr>
<tr>
<td>Discharge Waterbody</td>
<td>Upper East River</td>
</tr>
<tr>
<td>Critical 100-year Flood Elevation + 30 inches of Sea Level Rise</td>
<td>+17.5 ft NAVD88 (+16.0 ft Bronx Sewer Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Elevation</td>
<td>+10.2 ft NAVD88 (+8.7 ft Bronx Sewer Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Damage</td>
<td>Minor</td>
</tr>
<tr>
<td>High Likelihood to Impact Beaches</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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 need to meet basic requirements 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 Substations 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 functionality.

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. These strategies were developed for current site configurations and DEP’s existing plant services. The strategy selection was based on 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 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.

Table B: Hunts Point Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Storage Costs for Critical Flood Plus 30 Inches ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration Building - North</td>
<td>Seal Building</td>
<td>$318,000</td>
<td>$1,100,000</td>
<td>$2,956,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Aeration Building - South</td>
<td>Seal Building</td>
<td>$318,000</td>
<td>$1,100,000</td>
<td>$2,956,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Aeration Gallery</td>
<td>Flood-proof Equipment and Construct Barrier</td>
<td>$749,000</td>
<td>$6,998,000</td>
<td>$4,950,000</td>
<td>High</td>
</tr>
<tr>
<td>Aeration Tank - East</td>
<td>Elevate Equipment</td>
<td>$2,036,000</td>
<td>$8,825,000</td>
<td>$14,185,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Aeration Tank - West</td>
<td>Elevate Equipment</td>
<td>$4,365,000</td>
<td>$19,251,000</td>
<td>$25,905,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Alkalinity Building</td>
<td>Seal Control Room</td>
<td>$269,000</td>
<td>$5,386,000</td>
<td>$7,157,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Centrate Building</td>
<td>Sandbag</td>
<td>$102,000</td>
<td>$1,000,000</td>
<td>$1,195,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Chlorination Building</td>
<td>Elevate Equipment</td>
<td>$1,036,000</td>
<td>$2,030,000</td>
<td>$4,103,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Chlorine Contact Tanks</td>
<td>Elevate Equipment</td>
<td>$142,000</td>
<td>$252,000</td>
<td>$2,752,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Deoxidizing Building</td>
<td>Seal Building</td>
<td>$207,000</td>
<td>$42,716,000</td>
<td>$75,305,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Digestion Building</td>
<td>Sandbag</td>
<td>$103,000</td>
<td>$8,674,000</td>
<td>$24,528,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Effluent Water Pump Station Building - Central</td>
<td>Elevate Equipment and Seal Building</td>
<td>$204,000</td>
<td>$1,141,000</td>
<td>$4,518,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Effluent Water Pump Station Building - East</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,258,000</td>
<td>$1,152,000</td>
<td>$3,365,000</td>
<td>High</td>
</tr>
<tr>
<td>Effluent Water PS Building - West</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,228,000</td>
<td>$1,062,000</td>
<td>$1,137,000</td>
<td>High</td>
</tr>
<tr>
<td>Final Scum Pump Station - East</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$246,000</td>
<td>$1,615,000</td>
<td>$7,905,000</td>
<td>High</td>
</tr>
<tr>
<td>Final Scum Pump Station - North</td>
<td>Elevate Equipment and Seal Building</td>
<td>$400,000</td>
<td>$1,376,000</td>
<td>$6,414,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Final Scum Pump Station - South</td>
<td>Seal Control Room</td>
<td>$269,000</td>
<td>$1,546,000</td>
<td>$7,166,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Final Setting Tank - East</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$11,708,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Final Setting Tank - North</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$2,178,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Final Setting Tank - South</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$2,284,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Final Setting Tank - West</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$13,629,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Fire Pump Building</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$53,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Froth Collection Boxes 3210 and 3211</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$789,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Gas Holding Tank</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$135,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Main Electrical Substation</td>
<td>Flood-proof Equipment and Construct Barrier</td>
<td>$1,252,000</td>
<td>$34,882,000</td>
<td>$38,030,000</td>
<td>High</td>
</tr>
<tr>
<td>Primary Scrub PS - East</td>
<td>Elevate Equipment</td>
<td>$1,224,000</td>
<td>$1,528,000</td>
<td>$3,790,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Primary Scrub PS - West</td>
<td>Elevate Equipment</td>
<td>$1,165,000</td>
<td>$1,228,000</td>
<td>$2,971,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Primary Setting Tanks - East</td>
<td>Elevate Equipment</td>
<td>$1,452,000</td>
<td>$2,461,000</td>
<td>$1,171,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Primary Setting Tanks - West</td>
<td>Elevate Equipment</td>
<td>$2,625,000</td>
<td>$4,287,000</td>
<td>$6,918,000</td>
<td>High</td>
</tr>
<tr>
<td>Primary Sludge PS – Center</td>
<td>Sandbag</td>
<td>$102,000</td>
<td>$366,000</td>
<td>$1,132,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Primary Sludge PS – East</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$38,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Primary Sludge PS – West</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$38,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Return Sludge Building</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$1,365,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Separation Building</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$206,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Sludge Storage Tanks #9, 10</td>
<td>No Action-Required</td>
<td>$0</td>
<td>$2,103,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>US-133 Substation</td>
<td>Seal Building</td>
<td>$378,000</td>
<td>$2,662,000</td>
<td>$3,036,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>US-1540 Substation</td>
<td>Seal Building</td>
<td>$378,000</td>
<td>$2,714,000</td>
<td>$4,016,000</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Total for All 37 Locations At-Risk $243.3M $201.4M $246.4M

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 and 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.

Storm Surge Guidance:
Hunts Point WWTP

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.

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

<table>
<thead>
<tr>
<th>Storm Surge Advisory*</th>
<th>Floodplain and elevations</th>
<th>Elevations and areas to be protected</th>
</tr>
</thead>
<tbody>
<tr>
<td>12'</td>
<td>150 yr.</td>
<td>Bronx Datum</td>
</tr>
<tr>
<td>11'</td>
<td>145'</td>
<td>Main Building, Odor Control System at the Main Building, Water Service Meter and Backflow Preventer Chamber</td>
</tr>
<tr>
<td>10'</td>
<td>140'</td>
<td>Digester, Sludge Storage Tank Is 5, 6, 8, Waste Sludge Building</td>
</tr>
<tr>
<td>9'</td>
<td>135'</td>
<td>Main Electrical Substation, Main Building Service Tunnel Emergency Building</td>
</tr>
<tr>
<td>8'</td>
<td>130'</td>
<td>Diaphragm Building, Sludge Control System at the Primary Tanks, Center, East and West Primary Sludge Pump Stations, Separation Building</td>
</tr>
<tr>
<td>7'</td>
<td>125'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>6'</td>
<td>120'</td>
<td>Effluent Water Pump Station Building West, Effluent Water Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>5'</td>
<td>115'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>4'</td>
<td>110'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>3'</td>
<td>105'</td>
<td>Digester, Sludge Storage Tank Is 5, 6, 8, Waste Sludge Building</td>
</tr>
<tr>
<td>2'</td>
<td>100'</td>
<td>Main Electrical Substation, Main Building Service Tunnel Emergency Building</td>
</tr>
<tr>
<td>1'</td>
<td>95'</td>
<td>Diaphragm Building, Sludge Control System at the Primary Tanks, Center, East and West Primary Sludge Pump Stations, Separation Building</td>
</tr>
<tr>
<td>7.0'</td>
<td>90'</td>
<td>Primary Settling Tanks, East and West, Effluent Water Pump Station Building, Center and East, Final Settling Tanks</td>
</tr>
<tr>
<td>7.5'</td>
<td>85'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>8.0'</td>
<td>80'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>8.5'</td>
<td>75'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>9.0'</td>
<td>70'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>9.5'</td>
<td>65'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>10.0'</td>
<td>60'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>10.5'</td>
<td>55'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>11.0'</td>
<td>50'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>11.5'</td>
<td>45'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>12.0'</td>
<td>40'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>12.5'</td>
<td>35'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>13.0'</td>
<td>30'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>13.5'</td>
<td>25'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>14.0'</td>
<td>20'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>14.5'</td>
<td>15'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>15.0'</td>
<td>10'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
<tr>
<td>15.5'</td>
<td>5'</td>
<td>Effluent Water Pump Station Building East, Effluent Water Pump Station Building, Center and East, Final Settling Tanks and Return Sludge Building</td>
</tr>
<tr>
<td>16.0'</td>
<td>0'</td>
<td>Primary Settling Tanks, East and West</td>
</tr>
</tbody>
</table>

*Storm surge added to those Higher High Water at Highest Point of 2012, which is 4.67’ National Datum. Sea level is expected to rise up to 50 inches by 2100. This storm surge advisory is for current conditions.

*Storm surge added to those Higher High Water at Highest Point of 2012, which is 4.67’ National Datum. Sea level is expected to rise up to 50 inches by 2100. This storm surge advisory is for current conditions.

*Storm surge added to those Higher High Water at Highest Point of 2012, which is 4.67’ National Datum. Sea level is expected to rise up to 50 inches by 2100. This storm surge advisory is for current conditions.
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

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

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. 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.

Table B: Jamaica Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Substation (USS 1533) - Adjacent to Return Sludge Pump Station #3</td>
<td>Sandbagging</td>
<td>$213,000</td>
<td>$1,700,000</td>
<td>$460,000</td>
<td>Moderate-Low</td>
</tr>
</tbody>
</table>

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

Table A: Wastewater Treatment Plant Characteristics

Source: FEMA; CUNY Institute for Sustainable Cities
**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.

In total, the cost to implement all recommended strategies at Newtown Creek is $6.8 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

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

Total Cost for All 10 At-Risk Locations: $8.9 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 offshore 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.

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.
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

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

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.

### Table B: North River Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)1,2</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)1,3</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL 5</td>
<td>Flood-proof Equipment and Seal Building</td>
<td>$17,155,000</td>
<td>$94,100,000</td>
<td>$445,787,000</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

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.

Leaking Expansion Joint
Burst Manhole

Entire first floor flooded with approximately 1 foot of water

Storm Surge Guidance:
North River WWTP

If a storm surge advisory is announced as part of a weather report, locate the forecasted surge level below. Protective measures should be taken for all locations at or below that level. Once at-risk areas are identified, plant staff may proactively protect locations at or below the forecasted surge levels.
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>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Type</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Dewatering Facilities</td>
<td>Yes</td>
</tr>
<tr>
<td>Design Dry Weather Flow (MGD)</td>
<td>40</td>
</tr>
<tr>
<td>Maximum Wet Weather Flow (MGD)</td>
<td>120</td>
</tr>
<tr>
<td>Number of Residents Served</td>
<td>244,918</td>
</tr>
<tr>
<td>Discharge Waterbody</td>
<td>Lower New York Bay</td>
</tr>
<tr>
<td>Critical 100-year Flood Elevation + 30 inches of Sea Level Rise</td>
<td>+16.5 ft NAVD88 (+14.4 ft Staten Island Highway Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Elevation</td>
<td>+13.1 ft NAVD88 (+11.0 ft Staten Island Highway Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Damage</td>
<td>Major</td>
</tr>
<tr>
<td>High Likelihood to Impact Beaches</td>
<td>No</td>
</tr>
</tbody>
</table>

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.

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 area-ways 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.

Table B: Oakwood Beach Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($)</th>
<th>Damage Cost for Critical Flood without Protective Measures ($)</th>
<th>Cumulative Risk Avoided Over 50 Years ($)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine Building</td>
<td>Elevate Equipment and Seal Building</td>
<td>$1,265,000</td>
<td>$3,701,000</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Dewatering Building</td>
<td>Sandbag</td>
<td>$966,000</td>
<td>$2,831,000</td>
<td></td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Diesel Generator</td>
<td>Elevate Equipment</td>
<td>$454,000</td>
<td>$4,982,000</td>
<td></td>
<td>Very High</td>
</tr>
<tr>
<td>Existing Substation</td>
<td>No Action Required</td>
<td>$0</td>
<td>$13,984,000</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Maintenance Building</td>
<td>Construct Barrier</td>
<td>$212,000</td>
<td>$3,525,000</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Meter Building</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$328,000</td>
<td>$443,000</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Microstrainer Building</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,101,000</td>
<td>$6,202,000</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Sludge Pump Building</td>
<td>No Action Required</td>
<td>$0</td>
<td>$0</td>
<td></td>
<td>No Protection</td>
</tr>
<tr>
<td>Sludge Storage Building</td>
<td>Flood-proof and Elevate</td>
<td>$522,000</td>
<td>$11,082,000</td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Transformer Enclosure</td>
<td>Construct Barrier</td>
<td>$482,000</td>
<td>$1,058,000</td>
<td></td>
<td>High</td>
</tr>
</tbody>
</table>

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

Total for All 10 At-Risk Locations $5.3 M $21.0 M $44.3 M
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.

Storm Surge Guidance: Oakwood Beach WWTP

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**

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

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.

**FEMA Flood Zones near Owls Head Wastewater Treatment Plant**

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

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

Source: FEMA; CUNY Institute for Sustainable Cities
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 areas at risk. 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.

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

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine Contact Tanks</td>
<td>Elevate Equipment</td>
<td>$45,000</td>
<td>$121,000</td>
<td>$69,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Chlorination Building</td>
<td>Elevate Equipment and Seal Building</td>
<td>$1,284,000</td>
<td>$2,426,000</td>
<td>$12,031,000</td>
<td>High</td>
</tr>
<tr>
<td>Electrical Substation #2</td>
<td>Elevate Equipment</td>
<td>$394,000</td>
<td>$3,745,000</td>
<td>$210,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Electrical Substation #4</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,146,000</td>
<td>$3,518,000</td>
<td>$1,379,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Grit and Scum Building</td>
<td>Flood-proof Equipment</td>
<td>$34,000</td>
<td>$12,000</td>
<td>$12,000</td>
<td>High</td>
</tr>
<tr>
<td>Grit and Scum Tunnel</td>
<td>Flood-proof Equipment</td>
<td>$320,000</td>
<td>$733,000</td>
<td>$3,591,000</td>
<td>High</td>
</tr>
<tr>
<td>Main Electrical Substation</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,146,000</td>
<td>$4,271,000</td>
<td>$3,054,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Primary Tank Tunnel</td>
<td>Flood-proof and Elevate</td>
<td>$3,218,000</td>
<td>$3,746,000</td>
<td>$18,382,000</td>
<td>High</td>
</tr>
<tr>
<td>Pump and Blower Building – Blowroom</td>
<td>Flood-proof Equipment and Seal Building</td>
<td>$2,963,000</td>
<td>$15,826,000</td>
<td>$71,289,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Solids Handling Complex</td>
<td>Seal Control Room</td>
<td>$460,000</td>
<td>$13,603,000</td>
<td>$47,795,000</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

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

85 OWLS HEAD WASTEWATER TREATMENT PLANT

NYC WASTEWATER RESILIENCY PLAN 86
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 floodwaters 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.

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.

Flood pathways and areas flooded during Hurricane Sandy are highlighted in red.
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 +1.5 feet NAVD88.

Table A: Wastewater Treatment Plant Characteristics

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

Table B: Port Richmond Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration Blowers</td>
<td>Sandbag</td>
<td>$213,000</td>
<td>$1,371,000</td>
<td>$363,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Chlorine Contact Tanks</td>
<td>Elevate Equipment</td>
<td>$63,000</td>
<td>$73,000</td>
<td>$380,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Distributed Equipment</td>
<td>No Action Required</td>
<td>$0</td>
<td>$410,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Electrical Substation</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,834,000</td>
<td>$6,129,000</td>
<td>$4,129,000</td>
<td>Very High</td>
</tr>
<tr>
<td>New Sludge Storage Tank</td>
<td>Construct Barrier</td>
<td>$347,000</td>
<td>$4,278,000</td>
<td>$20,920,000</td>
<td>High</td>
</tr>
<tr>
<td>Office/Admin Building</td>
<td>Construct Barrier</td>
<td>$482,000</td>
<td>$2,623,000</td>
<td>$776,000</td>
<td>High</td>
</tr>
<tr>
<td>Primary Settling Tank</td>
<td>Flood-proof Equipment</td>
<td>$2,214,000</td>
<td>$3,983,000</td>
<td>$974,000</td>
<td>High</td>
</tr>
<tr>
<td>Raw Sewage Pumps</td>
<td>Flood-proof Equipment and Seal Building</td>
<td>$2,127,000</td>
<td>$9,145,000</td>
<td>$2,040,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Screens and Grit</td>
<td>Flood-proof Equipment and Construct Barrier</td>
<td>$1,898,000</td>
<td>$9,761,000</td>
<td>$3,723,000</td>
<td>High</td>
</tr>
<tr>
<td>Service Tunnel 1 and 2</td>
<td>No Action Required</td>
<td>$0</td>
<td>$83,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Sludge Process Building</td>
<td>Seal Building</td>
<td>$659,000</td>
<td>$14,851,000</td>
<td>$23,503,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Sludge Pumping Station</td>
<td>Seal Building</td>
<td>$557,000</td>
<td>$2,143,000</td>
<td>$3,389,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Total for All 12 At-Risk Locations</td>
<td></td>
<td>$10.4 M</td>
<td>$54.8 M</td>
<td>$60.4 M</td>
<td></td>
</tr>
</tbody>
</table>

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.

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.
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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Type</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Dewatering Facilities</td>
<td>Yes</td>
</tr>
<tr>
<td>Design Dry Weather Flow (MGD)</td>
<td>60</td>
</tr>
<tr>
<td>Maximum Wet Weather Flow (MGD)</td>
<td>120</td>
</tr>
<tr>
<td>Number of Residents Served</td>
<td>192,050</td>
</tr>
<tr>
<td>Discharge Waterbody</td>
<td>Lower East River</td>
</tr>
<tr>
<td>Critical 100-year Flood Elevation + 30 inches of Sea Level Rise</td>
<td>+14.5 ft NAVD88 (+13.0 ft Brooklyn Highway Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Elevation</td>
<td>+11.7 ft NAVD88 (+10.2 ft Brooklyn Highway Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Damage</td>
<td>Minor</td>
</tr>
<tr>
<td>High Likelihood to Impact Beaches</td>
<td>No</td>
</tr>
</tbody>
</table>
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 table below 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 a large storm, risk avoided over a 50-year time span, and level of resiliency the adaptation measure may provide to the selected location.

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration Tanks</td>
<td>No Action Required</td>
<td>$0</td>
<td>$301,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Chlorine Contact Tanks</td>
<td>Elevate Equipment</td>
<td>$44,000</td>
<td>$24,000</td>
<td>$11,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Centrifuge Building</td>
<td>Sandbag</td>
<td>$320,000</td>
<td>$5,061,000</td>
<td>$1,571,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Chlorination Building</td>
<td>Elevate Equipment</td>
<td>$511,000</td>
<td>$651,000</td>
<td>$220,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Digestor Building</td>
<td>Seal Building</td>
<td>$557,000</td>
<td>$7,068,000</td>
<td>$2,324,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Electrical Substation</td>
<td>Elevate Equipment and Seal Bar</td>
<td>$993,000</td>
<td>$8,220,000</td>
<td>$3,842,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Main Building</td>
<td>Elevate Equipment and Seal Bar</td>
<td>$8,896,000</td>
<td>$33,561,000</td>
<td>$11,998,000</td>
<td>High</td>
</tr>
<tr>
<td>Primary Settling Tank</td>
<td>Flood-proof Equipment and Seal</td>
<td>$8,891,000</td>
<td>$4,635,000</td>
<td>$4,248,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Thickener Building</td>
<td>Flood-proof Equipment and Seal</td>
<td>$1,352,000</td>
<td>$7,296,000</td>
<td>$2,536,000</td>
<td>High</td>
</tr>
<tr>
<td>Truck Loading Building</td>
<td>No Action Required</td>
<td>$0</td>
<td>$556,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
</tbody>
</table>

| 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.

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**

**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.
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.
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**

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

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.

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.
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 considering the probability of storm occurrence, costs of implementation, cost of damage avoided, and 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 $151.1 million. While this cost is high, the potential damage cost that a large surge may impose totals $49.3 million. Furthermore, since Rockaway is susceptible to flood damage from an interconnected, underground tunnel system, constructing barriers or elevating equipment at risk in 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.

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. The alternative selected, some resiliency upgrades will likely be needed.

Table B: Rockaway Adaptation Strategy Recommendations

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorination Building</td>
<td>Elevate Equipment</td>
<td>$2,048,000</td>
<td>$1,729,000</td>
<td>$8,900,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Chlorine Contact Tanks (N. of Beach Channel Dr.)</td>
<td>Elevate Equipment</td>
<td>$58,000</td>
<td>$127,000</td>
<td>$660,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Electrical Substation</td>
<td>Elevate Equipment and Construct Barrier</td>
<td>$1,604,000</td>
<td>$4,568,000</td>
<td>$23,453,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Final Setting Tanks</td>
<td>No Action Required</td>
<td>$0</td>
<td>$1,382,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Heating Plant</td>
<td>Elevate Equipment</td>
<td>$37,000</td>
<td>$1,169,000</td>
<td>$815,000</td>
<td>Low</td>
</tr>
<tr>
<td>Main Sewage Pump Station</td>
<td>Seal Building</td>
<td>$751,000</td>
<td>$5,135,000</td>
<td>$23,778,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>New Digester Building</td>
<td>No Action Required</td>
<td>$0</td>
<td>$1,139,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>New Sludge Storage Building</td>
<td>Seal Building</td>
<td>$483,000</td>
<td>$404,000</td>
<td>$1,872,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Old Digester Building</td>
<td>Sandbag</td>
<td>$158,000</td>
<td>$1,569,000</td>
<td>$662,000</td>
<td>Moderate-Low</td>
</tr>
<tr>
<td>Primary Scum Building</td>
<td>Flood-proof and Elevate</td>
<td>$2,142,000</td>
<td>$2,872,000</td>
<td>$14,270,000</td>
<td>High</td>
</tr>
<tr>
<td>Pump and Compressor Building</td>
<td>Elevate Equipment and Seal Building</td>
<td>$2,594,000</td>
<td>$9,694,000</td>
<td>$48,094,000</td>
<td>High</td>
</tr>
<tr>
<td>Return and Waste Sludge Pump Building</td>
<td>Elevate Equipment and Seal Building</td>
<td>$3,147,000</td>
<td>$8,248,000</td>
<td>$40,822,000</td>
<td>High</td>
</tr>
<tr>
<td>Sludge Thicker Building</td>
<td>Seal Building</td>
<td>$1,332,000</td>
<td>$7,300,000</td>
<td>$33,804,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tunnels</td>
<td>Construct Barrier</td>
<td>$752,000</td>
<td>$3,957,000</td>
<td>$967,000</td>
<td>High</td>
</tr>
</tbody>
</table>

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 protection for storms in the future.
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, 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, and electrical equipment and conduits in the tunnels were exposed to floodwaters (which will 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, 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.

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.
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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Type</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Dewatering Facilities</td>
<td>Yes</td>
</tr>
<tr>
<td>Design Dry Weather Flow (MGD)</td>
<td>80</td>
</tr>
<tr>
<td>Maximum Wet Weather Flow (MGD)</td>
<td>120</td>
</tr>
<tr>
<td>Number of Residents Served</td>
<td>410,812</td>
</tr>
<tr>
<td>Discharge Waterbody</td>
<td>East River</td>
</tr>
<tr>
<td>Critical 100-year Flood Elevation + 30 inches of Sea Level Rise</td>
<td>+15.5 ft NAVD88 (+13.9 ft Queens Highway Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Elevation</td>
<td>+10.1 ft NAVD88 (+8.5 ft Queens Highway Datum)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Damage</td>
<td>Minor</td>
</tr>
<tr>
<td>High Likelihood to Impact Beaches</td>
<td>No</td>
</tr>
</tbody>
</table>
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 flood damage and recovery time after a surge event, 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 2/27/2013) 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. Such, waterproofing chemical feed pumps and sealing the building with water-tight windows and doors is recommended. Likewise, the Grit Building and Thickener Buildings are also key locations that require several protection measures, since they have thresholds below the critical flood which lead to the tunnel system.

Table B provides a complete list of at-risk locations at Tallman Island. 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

<table>
<thead>
<tr>
<th>Location</th>
<th>Recommended Protective Measure</th>
<th>Cost of Protective Measures ($M)</th>
<th>Damage Cost for Critical Flood without Protection ($M)</th>
<th>Cumulative Risk Avoided Over 50 Years ($M)</th>
<th>Resiliency Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine Building</td>
<td>Flood-proof Equipment and Seal Building</td>
<td>$1,792,000</td>
<td>$1,298,000</td>
<td>$6,372,000</td>
<td>High</td>
</tr>
<tr>
<td>Chlorine Contact Tanks</td>
<td>Elevate Equipment</td>
<td>$37,000</td>
<td>$28,000</td>
<td>$1,500,000</td>
<td>Very High</td>
</tr>
<tr>
<td>Dewatering Building</td>
<td>Seal Control Room</td>
<td>$460,000</td>
<td>$11,023,000</td>
<td>$3,799,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Final Setting Tank</td>
<td>No Action Required</td>
<td>$0</td>
<td>$2,162,000</td>
<td>$0</td>
<td>No Protection</td>
</tr>
<tr>
<td>Grit Building</td>
<td>Sandbag</td>
<td>$320,000</td>
<td>$542,000</td>
<td>$190,000</td>
<td>Low</td>
</tr>
<tr>
<td>Mixed Flow Pump Station</td>
<td>Flood-proof and Elevate and Construct Barrier</td>
<td>$846,000</td>
<td>$1,550,000</td>
<td>$5,045,000</td>
<td>High</td>
</tr>
<tr>
<td>Sludge Storage Tanks</td>
<td>Construct Barrier</td>
<td>$347,000</td>
<td>$2,833,000</td>
<td>$7,037,000</td>
<td>High</td>
</tr>
<tr>
<td>South and North Thickener Buildings</td>
<td>Seal Building</td>
<td>$804,000</td>
<td>$12,163,000</td>
<td>$4,531,000</td>
<td>Moderate</td>
</tr>
<tr>
<td>Storage Building</td>
<td>Flood-proof and Elevate and Seal Building</td>
<td>$6,417,000</td>
<td>$13,521,000</td>
<td>$5,800,000</td>
<td>Very High</td>
</tr>
</tbody>
</table>

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.

Primary Settling Tanks

West Pipe Gallery

Chlorine Building

Dewatering Building

Chlorine Contact Tanks

Sludge Storage Pumping Station

Final Setting Tank

East Pipe Gallery

RAS Pump Station and Blower Building

North Sludge Thickeners

Grit Building

South Sludge Thickeners

Preliminary Sludge Pump Station

Digester

Pump and Blower Building

Office Building

Storage Building

27kV Substation

Aeration Tanks

Primary Settling Tanks

Storm Surge Guidance: Tallman Island WWTP

Floodentréeways and areas flooded during Hurricane Sandy are highlighted in red.

If a storm surge advisory is announced as part of a weather report, locate the forecasted surge level below. Protective measures to reduce the extent of flooding and to prevent or mitigate damage from flooding should be completed prior to the forecasted levels. Floodwaters may splash shoreline assets more than 3 ft above the surge level. Adjust protective measures accordingly.

Storm Surge Advisory* Floodplain Elevations and areas to be protected

Queens Datum

12' 11' 10' 9' 8' 7' 6' 5' 4' 3' 2' 1' 17.0' 16.5' 16.0' 15.5' 15.0' 14.0' 13.0' 12.5' 12.0' 11.0' 10.0' 9.0' 8.0' 7.0' 6.5' 1' 0.5' 0.0' 1.0' 2.0' 3.0' 4.0' 5.0' 6.0' 7.0' 8.0' 9.0' 10.0' 11.0' 12.0' 13.0' 14.0' 15.0' 15.5' 16.0' 16.5' 17.0' Storm Surge Advisory: Tallman Island WWTP

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.

*Storm surge is calculated from High Water Above Mean High Water (HWM) and the High Water Above Mean Higher High Water (HW) levels. HW is the highest high water recorded in a given month for the past 30 years. HW is expected to increase by 2022. The storm surge advisory is for current conditions. **One of the multiple flood pathways into the tunnel system. To protect tunnels, ensure all pathways are addressed.
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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Type</td>
<td>Activated Sludge</td>
</tr>
<tr>
<td>Dewatering Facilities</td>
<td>Yes</td>
</tr>
<tr>
<td>Design Dry Weather Flow (MGD)</td>
<td>275</td>
</tr>
<tr>
<td>Maximum Wet Weather Flow (MGD)</td>
<td>550</td>
</tr>
<tr>
<td>Number of Residents Served</td>
<td>1,061,558</td>
</tr>
<tr>
<td>Discharge Waterbody</td>
<td>Upper East River</td>
</tr>
<tr>
<td>Critical 100-year Flood Elevation + 30 inches of Sea Level Rise</td>
<td>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)</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Elevation</td>
<td>+10.7 ft NAVD88</td>
</tr>
<tr>
<td>Hurricane Sandy Flood Damage</td>
<td>Minor</td>
</tr>
<tr>
<td>High Likelihood to Impact Beaches</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: FEMA; CUNY Institute for Sustainable Cities
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 $6.7 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.

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

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

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.
CHAPTER 3: PUMPING STATIONS
The New York City Department of Environmental Protection (DEP) owns 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 health, 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 resilience 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 Cost of Protective Measures ($M)\(^1\)

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

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.
**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 El-

**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.

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

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

**Pumping Station Summary**

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Combined</th>
<th>Pump Type</th>
<th>Submersible</th>
<th>Operating Capacity (MGD)</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affected Area (Acre)</td>
<td>376</td>
<td>Population in Affected Area</td>
<td>34,003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>N</td>
<td>Connected to Other Stations</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>Y</td>
<td>Beach Affected</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>N</td>
<td>Recommended Protective Measure</td>
<td>Elevate Electrical in New Building</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Protective Measures</td>
<td>$1,910,000</td>
<td>Damage Cost for Critical Flood without Protection</td>
<td>$1,318,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years</td>
<td>$6,783,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resiliency Level</td>
<td>Very High</td>
<td>Source: FEMA; CUNY Institute for Sustainable Cities</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

**Critical Elevations**

- Critical Flood Elevation (12.5)
- Hurricane Sandy (10.0)
- Local Grade (6.0)
- Electrical Controls (-2.4)
- Pump Motor Base (-8.6)

**Background Risk**

<table>
<thead>
<tr>
<th>FEMA Flood Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 Advisory 100-Year Floodplain</td>
</tr>
<tr>
<td>Projected 2020s 100-Year Floodplain</td>
</tr>
<tr>
<td>Projected 2050s 100-Year Floodplain</td>
</tr>
</tbody>
</table>

**Elevations (NAVD 88)**

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

**Station Type**

- Combined

**Pump Type**

- Submersible

**Operating Capacity (MGD)**

- 1.0

**Affected Area (Acre)**

- 376

**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

**Recommended Protective Measure**

- Elevate Electrical in New Building

**Cost of Protective Measures**

- $1,910,000

**Damage Cost for Critical Flood without Protection**

- $1,318,000

**Cumulative Risk Avoided Over 50 Years**

- $6,783,000

**Resiliency Level**

- Very High
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.

**Recommended Adaptation Strategy:**

- Elevate Electrical in New Building

**Adaptation Cost:**

- $2,866,000

---

**Station Type:** Sanitary

**Pump Type:** Submersible

**Operating Capacity (MGD):** 0.7

**Affected Area (Acres):** 8

**Population in Affected Area:** 163

**Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area:** 0

**Historic Flooding:**

- **Affected by Hurricane Sandy:** No
- **Historic Loss of Power:** Yes

**Connected to Other Stations:** No

**Beach Affected:** No

**Recommended Protective Measure:** Elevate Electrical in New Building

**Cost of Protective Measures:** $2,866,000

**Damage Cost for Critical Flood without Protection:** $1,370,000

**Cumulative Risk Avoided Over 50 Years:** $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.
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.

**15th Avenue Pumping Station**

**15th Avenue Pumping Station Summary**

<table>
<thead>
<tr>
<th>15th Avenue Pumping Station</th>
<th>Recommended Adaptation Strategy: Elevate Electrical in New Building &amp; Submersible Pump Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adaptation Cost:</strong></td>
<td>$2,664,000</td>
</tr>
</tbody>
</table>

**15th Avenue Pumping Station Summary Table**

<table>
<thead>
<tr>
<th>Pumping Station Summary</th>
<th>Station Type</th>
<th>Sanitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Non-submersible</td>
<td></td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Affected Area (Acres)</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>793</td>
<td></td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Beach Affected</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended Protective Measure</th>
<th>Elevate Electrical in New Building &amp; Submersible Pump Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Protective Measures</td>
<td>$2,664,000</td>
</tr>
<tr>
<td>Damage Cost for Critical Flood without Protection</td>
<td>$3,510,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years</td>
<td>$995,000</td>
</tr>
<tr>
<td>Resiliency Level</td>
<td>High</td>
</tr>
</tbody>
</table>

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.
**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.

**Recommended Adaptation Strategy:**
Seal Building

**Adaptation Cost:**
$300,000

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Sanitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Non-submersible</td>
</tr>
<tr>
<td>Operating Capacity</td>
<td>5.6</td>
</tr>
<tr>
<td>Affected Area (Acres)</td>
<td>25</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>0</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>0</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>N</td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>N</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>N</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>N</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>N</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommended Protective Measure</th>
<th>Seal Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Protective Measures</td>
<td>$300,000</td>
</tr>
<tr>
<td>Damage Cost for Critical Flood without Protection</td>
<td>$3,680,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years</td>
<td>$1,432,000</td>
</tr>
<tr>
<td>Resiliency Level</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

---

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 surge up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.
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.

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

Adaptation Cost: $1,482,000

Critical Elevations

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

FEMA Flood Zones

Source: FEMA; CUNY Institute for Sustainable Cities

Background Risk Adaptation

Years 1, 3 $15,751,000
Cumulative Risk Avoided Over 50 Years $5,029,000
Damage Cost for Critical Flood without Protection $1,482,000
Recommended Protective Measure $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.

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>5.0</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>78</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>1</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>N</td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>N</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>N</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>N</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>N</td>
</tr>
<tr>
<td>Recommended Protective Measure</td>
<td>Sandbagging</td>
</tr>
<tr>
<td>Cost of Protective Measures</td>
<td>$59,000</td>
</tr>
<tr>
<td>Damage Cost for Critical Flood without Protection</td>
<td>$3,850,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years</td>
<td>$3,850,000</td>
</tr>
<tr>
<td>Resiliency Level</td>
<td>Moderate-Low</td>
</tr>
</tbody>
</table>

Critical Elevations

<table>
<thead>
<tr>
<th>Elevations (ft NAVD 88)</th>
<th>20</th>
<th>15</th>
<th>10</th>
<th>5</th>
<th>0</th>
<th>-5</th>
<th>-10</th>
<th>-15</th>
<th>-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Flood Elevation (14.5)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Local Grade (12.9)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Electrical Controls (0.7)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Pump Motor Base (-17.3)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

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.
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 plans drawings, comparing the elevation of critical components to that of the FEMA March 2013 Advisory Base Flood Elevations (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 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 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.

**Critical Elevations**

- Critical Flood Elevation (14.5)
- Electrical Controls (10.0)
- Hurricane Sandy (9.1)
- Local Grade (8.1)
- Pump Motor Base (-22.2)

**Station Summary**

<table>
<thead>
<tr>
<th>Background</th>
<th>Sanitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>2.0</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>13,895</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>4</td>
</tr>
<tr>
<td>Number of Critical Facilities</td>
<td>Affected by Hurricane Sandy</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>N</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>N</td>
</tr>
<tr>
<td>Recommended Protective Measure</td>
<td>Seal Building</td>
</tr>
<tr>
<td>Cost of Protective Measures Without Protection</td>
<td>$509,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years</td>
<td>$8,316,000</td>
</tr>
</tbody>
</table>

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 surge up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.
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.

Recommended Adaptation Strategy: Elevate Electrical in New Building
Adaptation Cost: $2,866,000

source: FEMA; CUNY Institute for Sustainable Cities

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 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.

**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.

### Critical Elevations

- **Critical Flood Elevation (15.5)**
- **Local Grade (14.9)**
- **Electrical Controls (11.1)**
- **Pump Motor Base (-11.6)**

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 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.

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

**Adaptation Cost:** $1,066,000

---

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 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.

**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.

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

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

---

**Station Characteristics**

- **Station Type:** Sanitary
- **Pump Type:** Non-submersible
- **Operating Capacity (MGD):** 11.5
- **Affected Area (Acres):** 719
- **Population in Affected Area:** 50,793
- **Number of Critical Facilities:** 37
- **Historic Flooding:** No
- **Affected by Hurricane Sandy:** No
- **Historic Loss of Power:** No
- **Connected to Other Stations:** No
- **Beach Affected:** No

**Recommended Protective Measure:** Elevate Electrical in Building & Submersible Pump Motors

**Cost of Protective Measures:** $2,600,000

**Damage Cost for Critical Flood without Protection:** $3,700,000

**Cumulative Risk Avoided Over 50 Years:** $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 surge up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.
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 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.

**Recommended Protective Measure:** Flood-Proof Controls

**Cost of Protective Measures:** $171,000

**Damage Cost for Critical Flood without Protection:** $1,143,000

**Cumulative Risk Avoided Over 50 Years:** $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.

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.

Recommended Adaptation Strategy: Seal Building & Submersible Pump Motors

Adaptation Cost: $1,943,000

149

PUMPING STATIONS

NYC WASTEWATER RESILIENCE PLAN 150

Background

Station Type
Combined

Pump Type
Non-submersible

Operating Capacity (MGD)
3.9

Affected Area (Acres)
63

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

Recommended Protective Measure
Seal Building & Submersible Pump Motors

Cost of Protective Measures
$1,943,000

Damage Cost for Critical Flood without Protection
$3,241,000

Cumulative Risk Avoided Over 50 Years
$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.
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.

**Recommended Adaptation Strategy:**

- **Elevated Electrical in New Building**
  - **Adaptation Cost:** $2,400,000

The map and chart below provide additional details on the critical elevations and station summary:

**Station Characteristics**

- **Station Type:** Sanitary
- **Pump Type:** Submersible
- **Operating Capacity (MGD):** 4.1
- **Affected Area (Acres):** 145
- **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 Summary**

- **Recommended Protective Measure:** Elevate Electrical in New Building
- **Cost of Protective Measure:** $2,400,000
- **Damage Cost for Critical Flood without Protection:** $2,337,000
- **Cumulative Risk Avoided Over 50 Years:** $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.
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.

**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.

**Recommended Adaptation Strategy:**

- **Elevate Electrical on Building**
- **Adaptation Cost:** $587,000

**Bush Terminal Pumping Station**

**Station Characteristics**

- **Station Type:** Combined
- **Pump Type:** Submersible
- **Operating Capacity (MGD):** 7.2
- **Affected Area (Acres):** 57
- **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

**Recommended Protective Measure**

- **Elevate Electrical on Building:** $587,000

**Damage Cost for Critical Flood Without Protection**

- **1, $3,467,000**

**Cumulative Risk Avoided Over 50 Years**

- **1, $17,839,000**

**Resilience 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.
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.

**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.

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

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

---

**Station Characteristic:**
- **Pump Type:** Non-submersible
- **Operating Capacity (MGD):** 2.2
- **Affected Area (Acres):** 37
- **Population in Affected Area:** 3,193
- **Number of Critical Facilities:** 2
- **Historic Flooding:** No
- **Affected by Hurricane Sandy:** Yes
- **Historic Loss of Power:** No
- **Connected to Other Stations:** No
- **Beach Affected:** No
- **Recommended Protective Measure:** Elevate Electrical on a Platform/Pad & Submersible Pump Motors
- **Cost of Protective Measures:** $2,419,000
- **Damage Cost for Critical Flood without Protection:** $2,710,000
- **Cumulative Risk Avoided Over 50 Years:** $13,332,000
- **Resiliency Level:** High

---

**Background Risk Assessment:**
- **2013 Advisory 100-Year Floodplain:**
- **Projected 2020s 100-Year Floodplain:**
- **Projected 2050s 100-Year Floodplain:**

---

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.
### 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 greater depth of flooding from larger storms or more extreme conditions. 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 casings, doors, and building sealants are not increase the vulnerability of an additional pumping station.

**Elevations (NAVD 88)**

- **Critical Flood Elevation (13.5)**
- **Hurricane Sandy (9.1)**
- **Local Grade (6.6)**
- **Electrical Controls (-3.7)**
- **Pump Motor Base (-6.1)**

**Background Risk Adaptation**

- **Years**
  - 1, 3: $20,460,000
  - Cumulative Risk Avoided Over 50 Years: $4,388,000
- **Damage Cost for Critical Flood Affected Area**
  - $20,460,000
- **Population in Affected Area**
  - 1,388
- **Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area**
  - 0
- **FEMA Flood Zones**
  - Cannon Ave Pumping Station
  - 2013 Advisory 100-Year Floodplain
  - Projected 2020s 100-Year Floodplain
  - Projected 2050s 100-Year Floodplain

**FEMA Flood Zones**

- Source: FEMA; CUNY Institute for Sustainable Cities

**Pumping Station Summary**

- **Station Type**: Sanitary
- **Pump Type**: Non-submersible
- **Operating Capacity (MGD)**: 1.1
- **Population in Affected Area**: 76
- **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
- **Recommended Protective Measure**: Seal Building & Submersible Pump Motors
- **Cost of Protective Measures**: $1,428,000
- **Damage Cost for Critical Flood**: $4,388,000
- **Cumulative Risk Avoided Over 50 Years**: $20,460,000

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 surge up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.

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

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

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.
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 affected. 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.

### Recommended Adaptation Strategy:

**Elevate Electrical on Platform/Pad**

**Adaptation Cost:** $634,000

---

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.
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.
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.

Recommended Adaptation Strategy:
Seal Building

Adaptation Cost: $350,000
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.

**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.

---

**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.

---

**Recommended Adaptation Strategy:**

Elevate Electrical in New Building

**Adaptation Cost:**

$7,389,000

---

**Douglaston Bay Critical Flood Elevation (18.5 ft NAVD88)**

**Elevations (ft NAVD88)**

- Critical Flood Elevation (18.5)
- Local Grade (10.1)
- Electrical Controls (5.6)
- Pump Motor Base (-15.5)

---

**FEMA Flood Zones**

Source: FEMA; CUNY Institute for Sustainable Cities

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.
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.

Large structure within Fresh Kills Landfill

Recommended Adaptation Strategy: Seal Building

Adaptation Cost: $588,000

Recommended Protective Measure

Seal Building

Cost of Protective Measures 1

$588,000

Damage Cost for Critical Flood without Protection 2

$9,508,000

Cumulative Risk Avoided Over 50 Years 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.
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.

Recommended Adaptation Strategy: Seal Building

Adaptation Cost: $470,000

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

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 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.

**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.

**Recommended Adaptation Strategy:**

- **Construct Barrier**
- **Adaptation Cost:** $1,256,000

---

**Background Risks:**

- **Risk:**
  - **Station Type:** Sanitary
  - **Pump Type:** Submersible
  - **Operating Capacity (MGD):** 1.2
  - **Affected Area (Acres):** 25
  - **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

**Recommended Protective Measure:**

- **Construct Barrier**
- **Cost of Protective Measures:** $1,256,000
- **Damage Cost for Critical Flood without Protection:** $1,742,000
- **Cumulative Risk Avoided Over 50 Years:** $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.
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.

**Recommended Adaptation Strategy:**

Elevate Electrical on a Platform/Pad

**Adaptation Cost:**

$895,000

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.

**Critical Elevations**

- Critical Flood Elevation (16.5)
- Electrical Controls (13.5)
- Local Grade (13.5)
- Pump Motor Base (-17.3)
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.

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.
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.

Critical Elevations

<table>
<thead>
<tr>
<th>Elevations (NAVD 88)</th>
<th>Elevations (NAVD 88)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>-5</td>
</tr>
<tr>
<td>-5</td>
<td>-10</td>
</tr>
<tr>
<td>-10</td>
<td>-15</td>
</tr>
<tr>
<td>-15</td>
<td>-20</td>
</tr>
<tr>
<td>-20</td>
<td>20</td>
</tr>
</tbody>
</table>

Station Type: Sanitary
Pump Type: Submersible
Operating Capacity (MGD): 1.4
Affected Area (Acres): 842
Population in Affected Area: 508
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

Recommended Protective Measure: Elevate Electrical in New Building
Cost of Protective Measures: $2,484,000
Damage Cost for Critical Flood without Protection: $2,824,000
Cumulative Risk Avoided Over 50 Years: $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.
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 no 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.

### Recommended Adaptation Strategy

- **Construct Barrier**
- **Adaptation Cost:** $8,165,000

### Historical Flooding

- **Affected by Hurricane Sandy:** Yes
- **Historic Loss of Power:** No
- **Connected to Other Stations:** No
- **Beach Affected:** Yes

### Protective Measures

- **Cost of Protective Measures:** $8,165,000

### Damage Costs

- **Without Protection:** $17,438,000
- **With Protection:** $20,649,000

### Resilience Level

- **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.
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.

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

**Adaptation Cost:** $730,000

---

**Background Risk Adaptation**

<table>
<thead>
<tr>
<th>2013 Advisory 100-Year Floodplain</th>
<th>Projected 2020s 100-Year Floodplain</th>
<th>Projected 2050s 100-Year Floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station Type</td>
<td>Sanitary</td>
<td>Submersible</td>
</tr>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>5.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Affected Area (Acres)</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Recommended Protective Measure</td>
<td>Elevate Electrical on a Platform/Pad &amp; Sandbagging</td>
<td></td>
</tr>
<tr>
<td>Cost of Protective Measures1</td>
<td>$730,000</td>
<td></td>
</tr>
<tr>
<td>Damage Cost for Critical Flood without Protection1, 2</td>
<td>$1,859,000</td>
<td>$1,859,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years1, 3</td>
<td>$5,654,000</td>
<td>$5,654,000</td>
</tr>
<tr>
<td>Resiliency Level</td>
<td>Moderate-Low</td>
<td></td>
</tr>
</tbody>
</table>

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 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.

**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.

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

**Adaptation Cost:** $4,800,000

**Historic Flooding**
- Affected by Hurricane Sandy: No
- Historic Loss of Power: N
- Connected to Other Stations: N
- Beach Affected: N

**Recommended Protective Measure:**
- Elevate Electrical on Platform/Pad & Submersible Pump Motors
- Cost of Protective Measures: $4,800,000
- Damage Cost for Critical Flood without Protection: $6,230,000
- Cumulative Risk Avoided Over 50 Years: $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.
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.

Recommended Adaptation Strategy: Elevate Electrical on a Platform/Pad

Adaptation Cost: $1,153,000
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. 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 flood about 6 inches and the station experienced minor impacts.

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 used, water tight cases can allow the waters to withstand the critical flood elevation. A visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The Marble Hill pumping station is related to a greater depth of flooding from larger storms 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.

Recommended Adaptation Strategy:
Seal Building

Adaptation Cost:
$624,000

Critical Elevations

<table>
<thead>
<tr>
<th>Elevations (NAVD 88)</th>
<th>20</th>
<th>15</th>
<th>10</th>
<th>5</th>
<th>0</th>
<th>-5</th>
<th>-10</th>
<th>-15</th>
<th>-20</th>
<th>-25</th>
<th>-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Grade (6.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hurricane Sandy (7.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Controls (7.3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump Motor Base (-25.1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Elevations (NAVD 88)

Critical Flood Elevation (12.5)

Pump Motor Base (-25.1)

Recommended Protective Measure: Seal Building

Adaptation Cost:
$624,000

FEMA Flood Zones

Source: FEMA; CUNY Institute for Sustainable Cities

Background
Risk
Adaptation
Cost of Protective Measures1
$624,000
Damage Cost for Critical Flood without Protection1, 2
$3,383,000
Cumulative Risk Avoided Over 50 Years2, 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 surge up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.
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 Colleagues 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 potential for leaks, inflows to the wells, or unidentified flowpaths. 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.

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 flowpaths. 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.

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.

Adaptation

- Seal Building

Recommended Protective Measure: Seal Building

Adaptation Cost: $549,000

FEMA Flood Zones

Source: FEMA; CUNY Institute for Sustainable Cities

Critical Elevations

<table>
<thead>
<tr>
<th>Elevations (Ft NAVD 88)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20</td>
</tr>
<tr>
<td>-15</td>
</tr>
<tr>
<td>-10</td>
</tr>
<tr>
<td>-5</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
</tbody>
</table>

Station Type: Sanitary
Pump Type: Non-submersible
Operating Capacity (MGD): 2.7
Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools): 0
Historic Loss of Power: N
Historic Flooding: Y
Affected by Hurricane Sandy: Y
Connected to Other Stations: N
Beach Affected: Y

<table>
<thead>
<tr>
<th>Affected Area (Acres)</th>
<th>362</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population in Affected Area</td>
<td>8,293</td>
</tr>
<tr>
<td>Damage Cost for Critical Flood 100-Year:</td>
<td>$3,369,000</td>
</tr>
<tr>
<td>Damage Cost for Critical Flood 2050s:</td>
<td>$15,601,000</td>
</tr>
<tr>
<td>Cost of Protective Measures without Protection:</td>
<td>$494,000</td>
</tr>
<tr>
<td>Cost of Protective Measures:</td>
<td>$5,000,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years:</td>
<td>$15,601,000</td>
</tr>
<tr>
<td>Resiliency Level:</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Background Risk

<table>
<thead>
<tr>
<th>Years</th>
<th>Probability of Storm Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 3</td>
<td>$15,601,000</td>
</tr>
<tr>
<td>50</td>
<td>$15,601,000</td>
</tr>
<tr>
<td>100</td>
<td>$15,601,000</td>
</tr>
<tr>
<td>200</td>
<td>$15,601,000</td>
</tr>
<tr>
<td>500</td>
<td>$15,601,000</td>
</tr>
</tbody>
</table>

Adaptation Summary

- Mason Avenue Pumping Station
- Recommended Adaptation Strategy: Seal Building
- Adaptation Cost: $549,000

| Station Type | Pump Type | Operating Capacity (MGD) | Number of Critical Facilities | Historic Loss of Power | Historic Flooding | Affected by Hurricane Sandy | Connected to Other Stations | Beach Affected | Affected Area (Acres) | Population in Affected Area | Damage Cost for Critical Flood 100-Year | Damage Cost for Critical Flood 2050s | Cost of Protective Measures without Protection | Cost of Protective Measures | Cumulative Risk Avoided Over 50 Years | Resiliency Level |
|--------------|-----------|--------------------------|-------------------------------|------------------------|------------------|-----------------------------|----------------------------|---------------|------------------------|---------------------------------------------|---------------------------------------------|-----------------------------------------------|-----------------------------|------------------------------------------|------------------------|
| Sanitary     | Non-submersible | 2.7                      | 0                            | N                      | Y                | Y                           | N                          | Y             | 362                   | 8,293                                      | $3,369,000                                | $15,601,000                                | $494,000                               | $5,000,000                             | $15,601,000                        | Moderate                            |
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.

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 solution. 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.

Recommended Adaptation Strategy: Sandbagging
Adaptation Cost: $40,000

Mayflower Avenue Pumping Station

Recommended Protective Measure: Sandbagging
Cost of Protective Measures: $40,000
Damage Cost for Critical Flood without Protection: $6,500,000
Cumulative Risk Avoided over 50 Years: $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.
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.

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

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

---

**Station Characteristics**

- **Station Type:** Sanitary
- **Pump Type:** Non-submersible
- **Operating Capacity (MGD):** 0.3
- **Affected Area (Acres):** 9
- **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

---

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.
**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 8,053. 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.

---

**RISK ASSESSMENT**

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

---

**Nautilus Court**

<table>
<thead>
<tr>
<th>Critical Elevations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation (NAVD 88)</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>-5</td>
</tr>
<tr>
<td>-10</td>
</tr>
<tr>
<td>-15</td>
</tr>
</tbody>
</table>

**Pumping Station Summary**

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>0.9</td>
</tr>
<tr>
<td>Affected Area (Acres)</td>
<td>374</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>8,053</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>0</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>Y</td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>Y</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>N</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>Y</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Recommended Protective Measure:** Elevate Electrical in New Building

| Cost of Protective Measures | $2,420,000 |
| Damage Cost for Critical Flood without Protection | $3,275,000 |
| Cumulative Risk Avoided Over 50 Years | $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.

---

**Background**

<table>
<thead>
<tr>
<th>Source</th>
<th>FEMA; CUNY Institute for Sustainable Cities</th>
</tr>
</thead>
</table>

---

**Elevations (NAVD 88)**

<table>
<thead>
<tr>
<th>Elevations (NAVD 88)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>-5</td>
</tr>
<tr>
<td>-10</td>
</tr>
<tr>
<td>-15</td>
</tr>
</tbody>
</table>

**Electrical Controls (10.2)**

**Local Grade (8.1)**

---

**Critical Elevations**

---

**Pump Motor Base (-11.7)**

---

**Generator plug and new pump controls panel located above grade**
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.

**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.

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

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

---

**Background**

- **Risk:** Very High
- **Resiliency Level:** Very High

---

**Critical Elevations**

<table>
<thead>
<tr>
<th>Elevations (NAVD 88)</th>
<th>Pump Motor Base (-15.4)</th>
<th>Electrical Controls (-1.1)</th>
<th>Local Grade (7.3)</th>
<th>Hurricane Sandy (11.3)</th>
<th>Critical Flood Elevation (12.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

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 New York Times sanitary pumping station is located near the corner of 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.

**Recommended Protective Measure:** Elevate Electrical on a Platform/Pad

**Cost of Protective Measures**

- **Damage Cost for Critical Flood without Protection:** $1,988,000
- **Recovery Cost:** $5,562,000
- **Cumulative Risk Avoided Over 50 Years:** $10,230,000

**Resilience 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.
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.

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

**Adaptation Cost:** $738,000

---

**Old Douglaston Pumping Station Summary**

- **Station Type:** Sanitary
- **Pump Type:** Submersible
- **Operating Capacity (MGD):** 8.5
- **Affected Area (Acres):** 2,566
- **Population in Affected Area:** 58,400
- **Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area:** 21
- **Historic Flooding:** No
- **Affected by Hurricane Sandy:** No
- **Historic Loss of Power:** No
- **Connected to Other Stations:** No
- **Beach Affected:** Yes

**Recommended Protective Measure:** Elevate Electrical on a Platform/Pad

**Cost of Protective Measures:** $738,000

**Damage Cost for Critical Flood without Protection:** $4,071,000

**Cumulative Risk Avoided Over 50 Years:** $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.
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.

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 identified to meet 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.

recommended adaptation strategy:
Elevate Electrical on a Platform/Pad
adaption cost:
$662,000

New pumping station still under construction with transformer and panels above grade
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.

---

**Recommended Adaptation Strategy:**

- **Construct Barrier**

**Adaptation Cost:** $16,960,000

---

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 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.

**Critical Elevations**

- **Critical Flood Elevation**: 14.5 ft NAVD88
- **Local Grade**: 14.4 ft NAVD88
- **Pump Motor Base**: 7.4 ft NAVD88
- **Electrical Controls**: -1.9 ft NAVD88

**Station Type**: Sanitary

**Pump Type**: Non-submersible

**Operating Capacity (MGD)**: 6.1

**Affected Area (Acres)**: 894

**Population in Affected Area**: 23,188

**Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area**: 6

**Historic Flooding**: N

**Connected to Other Stations**: N

**Beach Affected**: N

**Recommended Protective Measure**: Sandbagging

**Cost of Protective Measures**: $11,000

**Damage Cost for Critical Flood without Protection**: $5,490,000

**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.
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.

**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.

**Critical Elevations**

```
Station Type: Sanitary
Pump Type: Submersible
Operating Capacity (MGD): 4.6
Affected Area (Acres): 124
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: Y
Beach Affected: N
Recommended Protective Measure: Construct Barrier
Cost of Protective Measures: $2,874,000
Damage Cost for Critical Flood without Protection: $3,140,000
Cumulative Risk Avoided Over 50 Years: $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.
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 in 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.

---

**Recommended Adaptation Strategy:**

Seal Building

**Adaptation Cost:**

$266,000
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. This visit to the pumping station to view its exterior confirmed that it appears consistent with the plan drawings.

The critical flood elevation would be above an elevation that would completely inundate 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.

**Recommended Adaptation Strategy:**

**Elevate Electrical in New Building**

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

---

**Roosevelt Island North Pumping Station Summary**

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Sanitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>2.3</td>
</tr>
<tr>
<td>Population Affected Area</td>
<td>22,045</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) affected</td>
<td>0</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>No</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>No</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>Yes</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>No</td>
</tr>
</tbody>
</table>

**Recommended Protective Measure:** Elevate Electrical in New Building

**Cost of Protective Measures:** $2,539,000

**Damage Cost for Critical Flood without Protection:** $1,963,000

**Cumulative Risk Avoided Over 50 Years:** $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.
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.

Recommended Adaptation Strategy: Seal Building

Adaptation Cost: $658,000

Critical Elevations

<table>
<thead>
<tr>
<th>Elevations (Ft AGL)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurricane Sandy</td>
<td>17.1</td>
<td>15.5</td>
<td>13.1</td>
<td>14.0</td>
<td>12.9</td>
</tr>
<tr>
<td>Local Grade</td>
<td>15.5</td>
<td>13.1</td>
<td>14.0</td>
<td>14.0</td>
<td>12.9</td>
</tr>
<tr>
<td>Electric Controls</td>
<td>14.0</td>
<td>14.0</td>
<td>14.0</td>
<td>14.0</td>
<td>12.9</td>
</tr>
<tr>
<td>Pump Motor Base</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
<td>12.9</td>
</tr>
</tbody>
</table>

Source: FEMA; CUNY Institute for Sustainable Cities
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 Con- seleyeas 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.

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.

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.

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.

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.

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 Con- seleyeas 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.

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.

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 surge up to and including the 100-year flood plus 30 inches. This estimate incorporates the probability of storm occurrence.
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.

**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.

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

**Adaptation Cost:** $800,000

---

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.
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.

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

Adaptation Cost: $2,304,000

---

223          PUMPING STATIONS  NyC waStewateR ReSiLieNCy PLaN         224

FEMA Flood Zones

Seagirt Avenue
Critical Flood Elevation 14.5 ft NAVD88

Below grade pumping station under repair due to Hurricane Sandy damage
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.

**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.

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

**Adaptation Cost:** $286,000

---

**Critical Elevations**

<table>
<thead>
<tr>
<th>Elevation (NAVD 88)</th>
<th>Station Type</th>
<th>Pump Type</th>
<th>Operating Capacity (MGD)</th>
<th>Population in Affected Area</th>
<th>Affected Area (Acres)</th>
<th>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</th>
<th>Historic Flooding</th>
<th>Affected by Hurricane Sandy</th>
<th>Historic Loss of Power</th>
<th>Connected to Other Stations</th>
<th>Beach Affected</th>
<th>Cost of Protective Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sanitary</td>
<td>Non-submersible</td>
<td>1.5</td>
<td>2,165</td>
<td>69</td>
<td>1</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>$286,000</td>
</tr>
<tr>
<td>-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Recommended Protective Measures:**
- Seal Building & Install Submersible Pump Motors

**Cost:**
- $286,000

**Cumulative Risk Avoided Over 50 Years**
- $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.
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.

**Recommended Adaptation Strategy:** Construct Barrier

**Adaptation Cost:** $5,920,000

---

**Throgs Neck Pumping Station Summary**

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>36.7</td>
</tr>
<tr>
<td>Affected Area (Acres)</td>
<td>2,639</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>67,498</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>33</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>Y</td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>Y</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>Y</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>N</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>Y</td>
</tr>
<tr>
<td>Recommended Protective Measure</td>
<td>Construct Barrier</td>
</tr>
<tr>
<td>Cost of Protective Measures</td>
<td>$5,920,000</td>
</tr>
<tr>
<td>Damage Cost for Critical Flood without Protection</td>
<td>$10,672,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years</td>
<td>$53,001,000</td>
</tr>
</tbody>
</table>

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.
**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.

---

**Pumping Station Summary**

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>1.4</td>
</tr>
<tr>
<td>Affected Area (Acres)</td>
<td>19</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>388</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>1</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>Y</td>
</tr>
<tr>
<td>Affected by Hurricane Sandy</td>
<td>Y</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>Y</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>N</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Recommended Protective Measure**

- Elevate Electrical in New Building

**Cost of Protective Measures**

$2,745,000

**Failure Damage Cost**

$931,000

**Cumulative Risk Avoided Over 50 Years**

$4,790,000

**Resilience Level**

Very High
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.

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

**Adaptation Cost:** $876,000

---

**Victory Boulevard Pumping Station**

**Station Characteristics**

- **Location:** Staten Island, New York City
- **Type:** Sanitary
- **Pump Type:** Submersible
- **Operating Capacity (MGD):** 4.3
- **Affected Area (Acres):** 117
- **Population in Affected Area:** 970
- **Number of Critical Facilities:** 1

**Historic Flooding**

- **Affected by Hurricane Sandy:** No
- **Historic Loss of Power:** No
- **Beach Affected:** No

**Recommended Protective Measure:** Elevate Electrical on Platform/Pad

**Cost of Protective Measures:** $876,000

**Damage Cost for Critical Flood without Protection:** $1,849,000

**Cumulative Risk Avoided Over 50 Years:** $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.
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.

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Sanitary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Type</td>
<td>Submersible</td>
</tr>
<tr>
<td>Operating Capacity (MGD)</td>
<td>&lt;1 MGD</td>
</tr>
<tr>
<td>Population in Affected Area</td>
<td>170</td>
</tr>
<tr>
<td>Number of Critical Facilities (e.g., Hospitals, Public Safety, Schools) in Affected Area</td>
<td>0</td>
</tr>
<tr>
<td>Historic Flooding</td>
<td>N</td>
</tr>
<tr>
<td>Historic Loss of Power</td>
<td>N</td>
</tr>
<tr>
<td>Connected to Other Stations</td>
<td>Y</td>
</tr>
<tr>
<td>Beach Affected</td>
<td>N</td>
</tr>
<tr>
<td>Recommended Protective Measure</td>
<td>Elevate Electrical on a Platform/Pad</td>
</tr>
<tr>
<td>Cost of Protective Measures</td>
<td>$880,000</td>
</tr>
<tr>
<td>Damage Cost for Critical Flood without Protection</td>
<td>$1,142,000</td>
</tr>
<tr>
<td>Cumulative Risk Avoided Over 50 Years</td>
<td>$5,875,000</td>
</tr>
<tr>
<td>Resiliency Level</td>
<td>Very High</td>
</tr>
</tbody>
</table>

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.

Critical Elevations

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.
CHAPTER 4: PRECIPITATION, WATERSHED, AND TIDE GATE ANALYSIS
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

<table>
<thead>
<tr>
<th>Sea Level Rise</th>
<th>Air Temperature Variations</th>
<th>Precipitation Variations</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Physical inundation</td>
<td>- Change in energy use</td>
<td>- Changes in the frequency of street flooding</td>
</tr>
<tr>
<td>- Changed hydraulics</td>
<td>- Increased operation and maintenance requirements</td>
<td>- Change in combined sewer overflow quantities, frequency, and water quality</td>
</tr>
<tr>
<td>- Changed influent wastewater characteristics</td>
<td>- Increased occurrence of days greater than 90°F and impact on energy use</td>
<td>- Changes in stormwater discharge quantities, frequency, and water quality</td>
</tr>
<tr>
<td>- Saltwater intrusion</td>
<td>- Increased probability of electrical grid failure</td>
<td>- Material strain</td>
</tr>
<tr>
<td>- Impact on storm surge elevations</td>
<td>- Increased operation and maintenance requirements</td>
<td>- Increased operation and maintenance requirements</td>
</tr>
<tr>
<td>- Increased operation and maintenance requirements</td>
<td>- Shifting of inundation zones</td>
<td>- Increased frequency of emergency management actions</td>
</tr>
<tr>
<td>- Flooding of pump stations (especially if not waterright)</td>
<td>- Typo</td>
<td></td>
</tr>
</tbody>
</table>

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 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.
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.

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Station name</th>
<th>Record length</th>
<th>15-minute data availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>Central Park, NY</td>
<td>1876-2011</td>
<td>None</td>
</tr>
<tr>
<td>Hourly</td>
<td>Ave V, Brooklyn, NY</td>
<td>1948-1976</td>
<td>None</td>
</tr>
<tr>
<td>Hourly</td>
<td>Westerleigh, NY</td>
<td>1948-1992</td>
<td>None</td>
</tr>
<tr>
<td>Hourly</td>
<td>Central Park, NY</td>
<td>1948-2011</td>
<td>None</td>
</tr>
<tr>
<td>Hourly</td>
<td>Newark Airport, NJ</td>
<td>1948-2011</td>
<td>None</td>
</tr>
<tr>
<td>Hourly</td>
<td>Mineola, NY</td>
<td>1948-2011</td>
<td>1972-2010</td>
</tr>
<tr>
<td>Hourly</td>
<td>LaGuardia Airport, NY</td>
<td>1948-2011</td>
<td>None</td>
</tr>
<tr>
<td>Hourly</td>
<td>JFK Airport, NY</td>
<td>1949-2011</td>
<td>None</td>
</tr>
</tbody>
</table>
Figure 2: Number of Large Rainfall Events Each Year since 1948

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, 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 station 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.

The majority of the city’s sewer network, depending on the size of the collection area, 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.

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). 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 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 2005-2006—to test the robustness of various CSO mitigation approaches under a range of average and extreme conditions.
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 well 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.

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.
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).

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).

Current or Baseline: This scenario is the scenario against which future scenarios are compared to quantify changes, and it is intended to reflect the climate and operational conditions of the present or recent past.

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 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 surface drainage to the surface drain- age 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 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.
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.
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 under-way, 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 upon which DEP can build future efforts to respond to climate change and sea level rise.

References


New York City Panel on Climate Change, 2009. Climate Risk Information.
