East Shore, Staten Island

Credit: Staten Island Borough President's Office

Coastal Protection

New York City's Coastline: Then and Now

Historic wetlands from "Nature's Estuary: The Historic Tidelands of New York New Jersey Estuary" Regional Plan Association, 2003. Historic data compiled by George Colbert and Guenter Vollath from 19th century U.S. Geological Survey, U.S. Coast and Geodetic Survey, New Jersey Geological Survey and the Ratzer Survey of 1776-1777.

When Henry Hudson sailed into what is now known as New York Harbor in 1609, the coastline he encountered was a wondrous place. Archipelagos of small islands dotted near-shore waters. Wetlands and oyster beds stretched for miles. Sloping beaches lay dazzling under the sun. The harbor coastline provided abundant food sources and natural protection from storms. It would prove essential to the survival and growth of the early settlement of New Amsterdam. (*See map: New York City's Coastline: Then and Now*)

This coastline is just as essential to New York City's survival and growth today.

Not surprisingly, New York City's coastline—which stretches a total of 520 miles and is longer than the coastlines of Miami, Boston, Los Angeles, and San Francisco combined—has changed dramatically since the 17th century. The inhabitants of New York City have altered its very topography in many ways, dredging waterways to ease the way for shipping, constructing piers and bulkheads, and even using fill to reshape the shoreline's contours. While some of the historic natural features that once protected what is today New York City have been lost in the process, the changes that were made have enabled commerce and industry to flourish, neighborhoods to thrive, and infrastructure to perform critical functions.

Notwithstanding the important role played by the city's waterfront through most of its history, during the last decades of the 20th century, large sections of the coastline fell into disuse and disrepair. In recent years, however, the city has begun to reconnect with this critical asset. These new connections have taken many forms, from investments in the working waterfront to new housing, parks, and ferry landings. As much as this renewed embrace of what Mayor Bloomberg has referred to as the "sixth borough" has benefitted its citizenry, New York's reengagement with its coastline has also occurred out of necessity—as the city has sought to meet the needs of a growing population and expanding economy.

However, even as the city has reconnected with its waterfront, New Yorkers have known that proximity to the water brings with it certain challenges, especially as global climate change advances—a threat discussed in detail in PlaNYC, the City's sustainability plan, in 2007. Thus, in 2011, building on PlaNYC, the City released *Vision 2020: The New York City Comprehensive Waterfront Plan*, the centerpiece of an effort known as the Waterfront Vision and Enhancement Strategy, or WAVES. This effort set forth broad goals for the shoreline of New York City, including, of course, increased climate resiliency. To this end, the report's accompanying WAVES Action Agenda put forth specific initiatives that already have helped to create a waterfront that is more productive and better prepared for the future.

In October 2012, with the arrival of Sandy, the case for increased climate resiliency—even beyond the initiatives set forth in the WAVES Action Agenda—was forcefully made to all New Yorkers. The storm scoured beaches along New York City's ocean-facing coastline, damaging buildings and infrastructure, flooding neighborhoods, causing dangerous erosion, and most seriously, killing 43 New Yorkers. Areas along the Hudson and East Rivers and the other waterways in the Upper Bay, meanwhile, experienced record-setting flooding, along with damage and destruction to building systems, business inventory, and personal property.

As the impacts of climate change accelerate over time, more damage, more flooding, and more erosion are likely in New York, with sea levels continuing to rise and more of the most intense storms expected. In response to these challenges, the City believes that it must bulk up its defenses, improving the coastline with protective measures. This will not eliminate all flooding from all conceivable storms—an impossible goal—but mitigate the effects of sea level rise where the risk is greatest and reduce the effects of storm waves and storm flooding significantly.

Reaching these resiliency goals—and protecting all of the waterfront assets along the coastline more effectively—requires a deliberate and coordinated approach. This chapter seeks to achieve this goal, presenting the City's new, comprehensive coastal protection plan.

The plan articulates a full menu of proposed coastal protection measures tailored to the specific geomorphology of (described below) and risks facing neighborhoods that are most exposed. These measures, though complementary, also can be implemented independently over time, based on available funding and relative priority. Though ultimately the city will be best served by implementing the entire suite of options, this report sets forth an initial set of projects that targets areas that have particularly large concentrations of businesses or residents (or both), areas that house critical infrastructure, and areas that shelter especially vulnerable populations. Though these projects still come at significant cost, they have been scaled in such a way that the City believes that they not only can but should get under way immediately.

Of course, the City cannot implement these new coastal protection measures alone. Implementing them will require partnerships with the Federal government, likely through the US Army Corps of Engineers (USACE), and other regional stakeholders and governmental entities. To make these new coastal measures as effective as possible, the City itself also will have to improve the way that it administers the shoreline that it controls, ensuring better management, design, and operation of its coastal assets—something that this chapter also addresses. Finally, this chapter also will call on the various regulatory bodies with responsibility for permitting along the waterfront in New York City—from the City, to the State, to the Federal government—to work together to clarify, simplify, and simultaneously make more effective the process of permitting, both in general and for critical flood-protection projects.

Over the centuries, the coastline of New York City has been a sparkling natural resource, a setting for commerce and industry, and a place for housing and recreation. Going forward, it also can reprise a role that it played ably in the early days of New Amsterdam and before. Namely, to provide protection to the people living along and behind this coastline.

The New York City Coastline

The city's 520-mile coastline—bordering the ocean, as well as rivers, bays, and inlets—is both diverse and complex. To understand this coastline, it is critical to understand its geomorphology—or the combination of its natural landforms, underlying geological conditions, and built condition. The geomorphology of today's city is largely the result of a colossal glacier that moved over what is now New York City over 20,000 years ago, combined with the coastal modifications that inhabitants have made in more recent times. This complexity is, in turn, amplified not just in the diverse uses and multiple property owners found today all along the water's edge across the city, but also by the many regulators with responsibility for the coastline's protection.

The Geomorphology of the New York City Coastline

New York City's southernmost waterfront areas—the Rockaway Peninsula, the Coney Island peninsula, and the East and South Shores of Staten Island—generally are characterized by gently sloping sandy beaches with some natural and built dunes, as well as discrete areas containing elevated bluffs. In places, groins (rock and timber structures perpendicular to beaches) and other reinforced structures have been installed to protect these beaches. Communities in these areas typically are less densely populated than other parts of New York City, though they also tend to be much more densely populated than other coastal areas along the eastern seaboard.

Within Jamaica Bay, one of the region's most important and largest natural features, there are many natural edges and marsh islands, some newly reconstituted. Here, portions of the shoreline have been filled in and hardened with bulkheads (vertical retaining walls) and revetments (shoreline protection constructed with armor stone). Many of the areas surrounding Jamaica Bay are particularly low-lying, a result of the glacial outwash plains that were formed at the end of the last Ice Age. Along and within Jamaica Bay and its tributaries, there are a wide array of neighborhoods, as well as several elements of critical city infrastructure, including transportation assets such as John F. Kennedy (JFK) Airport, marine terminals, and wastewater treatment plants.

Further north and within the Upper Bay—the areas along the Hudson and East River shorelines of Manhattan, Brooklyn, and Queens, as well as on the North Shore of Staten Island—the topography historically rose quickly to greater elevations along the coast. However, significant use of landfill to extend the coastline and the filling and development of former marshland have altered the waterfront significantly over the past three centuries, with large areas along these coasts now lying at or near the water level. Examples of these low-lying areas include the southern parts of Manhattan, East Harlem, Red Hook, and the areas adjacent to the Gowanus Canal and Newtown Creek in Brooklyn and Queens. Generally, in these areas, coastal edges have been hardened extensively over time with bulkheads, revetments, and piers supporting maritime, industrial, commercial, residential, and transportation uses.

In the northernmost waterfront areas of the city, the shorelines are quite varied. Some parts are naturally rocky, such as along City Island and Eastchester Bay. Other areas, by contrast, including Orchard Beach, have more gently sloping, sandy edges, some of which are manmade. Along the northern Queens waterfront as well as along large sections of the Harlem and Hudson Rivers in northern Manhattan and the Bronx, the topography is generally quite steep with high bluffs in some neighborhoods. Along parts of the east and south Bronx waterfront, meanwhile, land tends to slope more gently up from the water's edge. A variety of filled land and hardened edges, such as bulkheads and revetments, have been put in place throughout the area over time, with some natural areas reintroduced and restored, such as at Alley Creek in Queens. The land uses in the city's northern waterfront areas are quite diverse, ranging from key infrastructure such as LaGuardia Airport and the multiple power plants in Astoria, Queens, to the Hunts Point Food Distribution Center in the Bronx, to single-family homes on City Island and large, multi-family developments such as Co-Op City in the northeast Bronx.

Generally, New York City's coastline does not have purpose-built coastal defenses; many of the features that serve this function do so coincidentally, rather than by design. For example, recreational beaches—nourished (i.e., provided with additional sand to supplement and replace sand lost to erosion) and expanded over time in a partnership between the Department of Parks & Recreation (DPR) and the USACE—generally have been engineered with recreational goals in mind, though they also provide important protection for adjacent neighborhoods. The city's remaining wetlands and natural areas, which, until recently, often were viewed as underutilized property that could be filled and developed, also play an important protective role, serving to buffer inland areas. Meanwhile, though the coastline is dotted with many of the city's most beloved parks, it is only in recent years that the designs of these recreational areas, such as at Brooklyn Bridge Park and Governors Island, have deliberately incorporated discrete resiliency measures that could provide a model for other parks. Finally, the city's ubiquitous bulkheads also play a role in defending the city from harm, not only holding the land behind them in place—their intended purpose—but also breaking waves during storms.

Because of the uncoordinated fashion in which they were constructed over time, however, these various features, even where they do serve a defensive purpose, lack the robustness, comprehensiveness, and adaptability that the new era of climate change demands.

Regulatory Framework for the Coastline

Over a dozen City, State, and Federal agencies play a role in regulating New York City's waterfront and many waterways. In some cases, efforts by these agencies are not completely aligned. This lack of unified and coordinated regulatory oversight can lead to delayed and unpredictable waterfront activity, complicating the achievement of important public goals, including coastal resiliency.

On the City level, one organization with an important regulatory role is the City Planning Commission, which enacts zoning, reviews land use, and is the local administrator of the Waterfront Revitalization Program, a State program required under the Coastal Zone Management Act. The Department of Small Business Services (SBS), meanwhile, oversees waterfront construction activity through its dockmaster and waterfront permit units.

At the State level, a key role is played by the New York State Department of State, which monitors consistency of Federal actions against the State and City Coastal Management Program policies.

Previous Coastal Protection Studies of New York City

Although this report contains the City's first comprehensive coastal protection plan, many studies conducted in partnership with the US Army Corps of Engineers (USACE) and the State over the years have addressed the need for coastal protections. Some studies—such as those for the Rockaway Peninsula (initially authorized in 1965), Coney Island (1986), and Orchard Beach (1992)—led to beach nourishment projects that included popular recreational components. Other studies that were focused more directly on flood protection, such as the Hurricane and Storm Damage Reduction Project for the South Shore of Staten Island, authorized in 1993, were left uncompleted due to a lack of funding and consensus and have only recently been relaunched and fully funded.

By contrast, a study of Plumb Beach, Brooklyn is a notable success story. The study recommended a reconstituted beach, which was completed in 2012, just days before Sandy, providing significant protection to the Belt Parkway during the storm.

Another important study is the Hudson-Raritan Estuary Comprehensive Restoration Plan. This plan was released in May 2009 by the USACE and the Port Authority of New York & New Jersey, in partnership with the New York New Jersey Harbor Estuary Program. The plan is targeted at improving 11 ecosystem types within the estuary. Though the plan does not focus on flood protection, there is now an opportunity to leverage its findings to achieve ecosystem and flood protection benefits in the areas adjacent to the relevant ecosystems.

Notwithstanding all of the foregoing, a comprehensive flood protection study for the Upper New York Bay, one of the most densely populated and economically important waterways in the world, has never even been undertaken—let alone completed. The opportunity presented by the USACE's North Atlantic Coast Comprehensive Study, which was authorized by Congress in January 2013 and will evaluate flood risks of vulnerable coastal populations in areas affected by Sandy, must not be wasted.

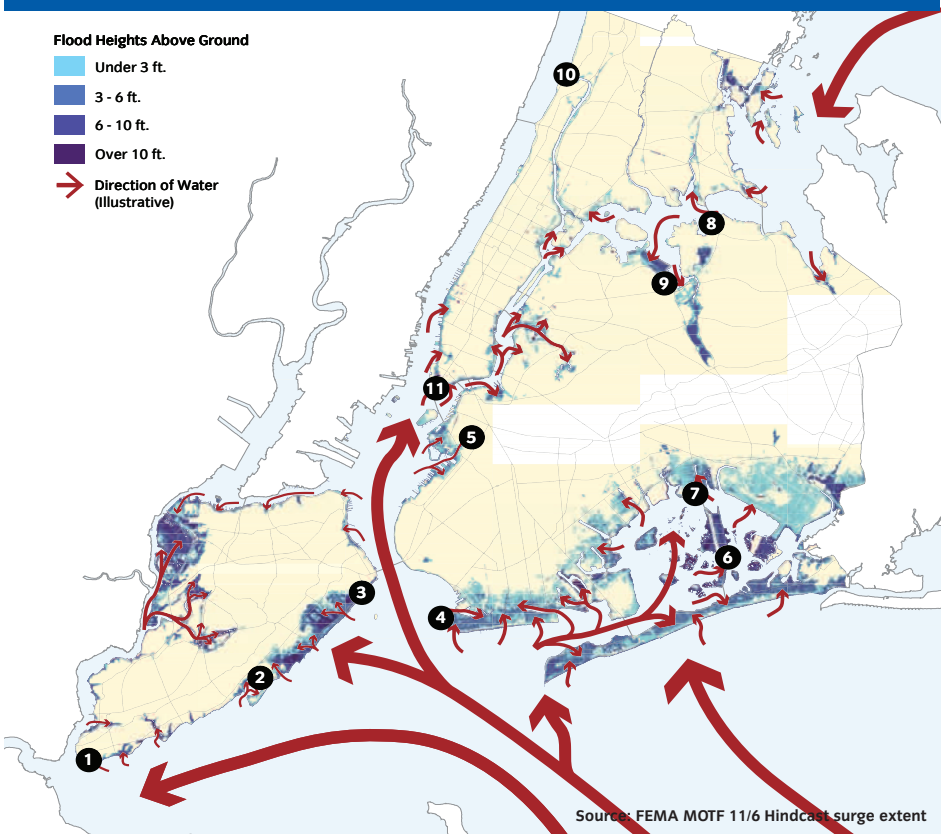
At the same time, the State Department of Environmental Conservation regulates in-water activities, wetlands, and other coastal uses by issuing permits, including water quality certifications, and enforces the Coastal Erosion Hazard Area, pursuant to which the State regulates, and generally seeks to discourage, the construction of hardened structures in areas of high erosion risk like beaches.

Finally, the Federal government's regulatory reach is distributed among many agencies, with the USACE, which has broad authority over the waters of the United States, typically serving as the coordinating body for many Federal agencies, including the US Fish and Wildlife Service and the Environmental Protection Agency. Among the USACE's responsibilities in New York Harbor are regulating its navigable waterways, implementing local public works projects, and protecting against flood risks, all as authorized by Congress. The US Coast Guard also plays a vital role in New York Harbor, regulating vessel traffic and coordinating other waterway activities.

Prior to Sandy, the City had partnered with the USACE and the State on several studies to evaluate protections for vulnerable communities in New York City. These studies typically were initiated following major storms, and some led to important projects that have been completed or are underway. In other cases, though, studies languished due to a lack of consensus on solutions. Moreover, despite the existence of many vulnerable and densely populated coastal areas in New York City, no comprehensive flood protection studies have ever been undertaken for the Manhattan, Brooklyn, Queens, and Bronx riverfronts, or for other areas of the Upper Bay. (*See sidebar: Previous Coastal Protection Studies of New York City*)

Until recently, the types of storms that have prompted studies on coastal protections have occurred infrequently. As a result, following these storms, interest in protection tended to wane, with impacted coastal communities often unable to secure the requisite funding needed to move forward with more effective protection measures. Sandy, however, has focused renewed attention on the need for such measures in New York City and brought into better focus the risks that extreme weather poses for the coast.

Sandy Inundation



Peak Storm Surge Elevations During Sandy

Location	Time Oct. 29, 2012	Water Level in Feet (NAVD88)
1. Tottenville, Staten Island	8:38 p.m.	+16.0
2. Great Kills Harbor, Staten Island	8:52 p.m.	+13.2
3. South Beach, Staten Island	8:23 p.m.	+15.0
4. Sea Gate, Brooklyn	8:23 p.m.	+13.3
5. Gowanus Canal, Brooklyn	9:04 p.m.	+11.1
6. Broad Channel, Queens	9:18 p.m.	+10.4
7. Howard Beach, Queens	9:23 p.m.	+11.2
8. Whitestone, Queens	10:06 p.m.	+10.6
9. World's Fair Marina, Queens	10:06 p.m.	+10.4
10. Inwood, Manhattan	10:06 p.m.	+9.5
11. The Battery, Manhattan	9:24 p.m.	+11.3*

*** Equivalent to 14 feet above Mean Lower Low Water (MLLW)** **Source: USGS, NOAA**

Note: This chart calculates all elevations using the national reference standard known as NAVD88, which establishes a consistent base measurement point from which elevations are determined, unlike other local references to sea level. Press accounts or other sources are known to be reported using many reference standards and require conversion (see Chapter 2, *Climate Analysis*).

What Happened During Sandy

The Effects of the Storm Surge on the Coastline

Storm surge is the increase in water levels brought about by the low pressure and wind field of a coastal storm. When the surge comes into contact with a shoreline, it pushes additional water onto that shoreline, often inundating large inland areas. The impacts of surge are further amplified when entering water bodies that serve as funnels, such as New York Harbor. Overall, Sandy's surge had an incredibly

destructive impact on the coastline of New York City, though different sections of the coastline experienced the storm differently and with different consequences. (*See map: Sandy Inundation*)

Generally, Sandy's coastal inundation took one of three forms. First, floodwaters came directly from the ocean, as water surged over beaches and bulkheads, flooding neighborhoods and critical infrastructure such as tunnels. Extreme water levels were seen citywide as the storm peaked in the evening of October 29, 2012. (*See chart: Peak Storm Surge Elevations During Sandy*)

In many cases, in ocean-facing areas such as Southern Brooklyn, South Queens, and the East and South Shores of Staten Island, from South Beach to Tottenville, the surge brought with it not just large volumes of water but also powerful waves that wreaked havoc on buildings and infrastructure alike. Record ocean waves of over 30 feet were measured in the ocean southeast of the Rockaway Peninsula.

Another impact of the wave action along the city's ocean-facing coastline was massive beach erosion. In fact, estimates indicate that up to 3 million cubic yards of sand, and maybe more, were lost citywide, with the Rockaway Peninsula alone losing about 1.5 million cubic yards of sand (a volume larger than the Empire State Building) and additional losses occurring in Coney Island, Orchard Beach, and the East and South Shores of Staten Island.

The second way Sandy's surge impacted the city was via less direct routes. In these cases, the city's many bays, inlets, and creeks functioned as "backdoor" channels, funneling ocean waters inland. For example, much of the flooding in Southern Brooklyn came not only over the area's beaches, but also via Coney Island Creek and Sheepshead Bay. Likewise, floodwaters from Jamaica Bay contributed to the inundation of the Rockaway Peninsula, where, as area residents explained, "the ocean met the bay." Newtown Creek, meanwhile, overflowed its banks, flooding Maspeth, Greenpoint, East Williamsburg, and Bushwick. Similarly, the Gowanus Canal overflowed its banks, flooding Red Hook and other adjacent neighborhoods.

The third way Sandy's surge impacted New York City was by overtopping the city's extensive shoreline drainage infrastructure, and in some cases infiltrating the roadway drainage and sewer system through catch basins, manholes, and storm drains in the streets, especially in low-lying areas such as in Midland Beach, Staten Island. This network of pipes and other features is designed to drain rainwater away from land and into the area's waterways and is not designed to protect against storm surge. Additionally, several tide gates and floodgates (devices that prevent water from flowing backwards through the drainage system)—including at Oakwood Beach, Staten Island—were damaged during the storm, while others, including at Flushing Meadows Corona Park, lost power and had to be operated manually during Sandy, amid the overwhelming volume of water that they were being asked to handle.

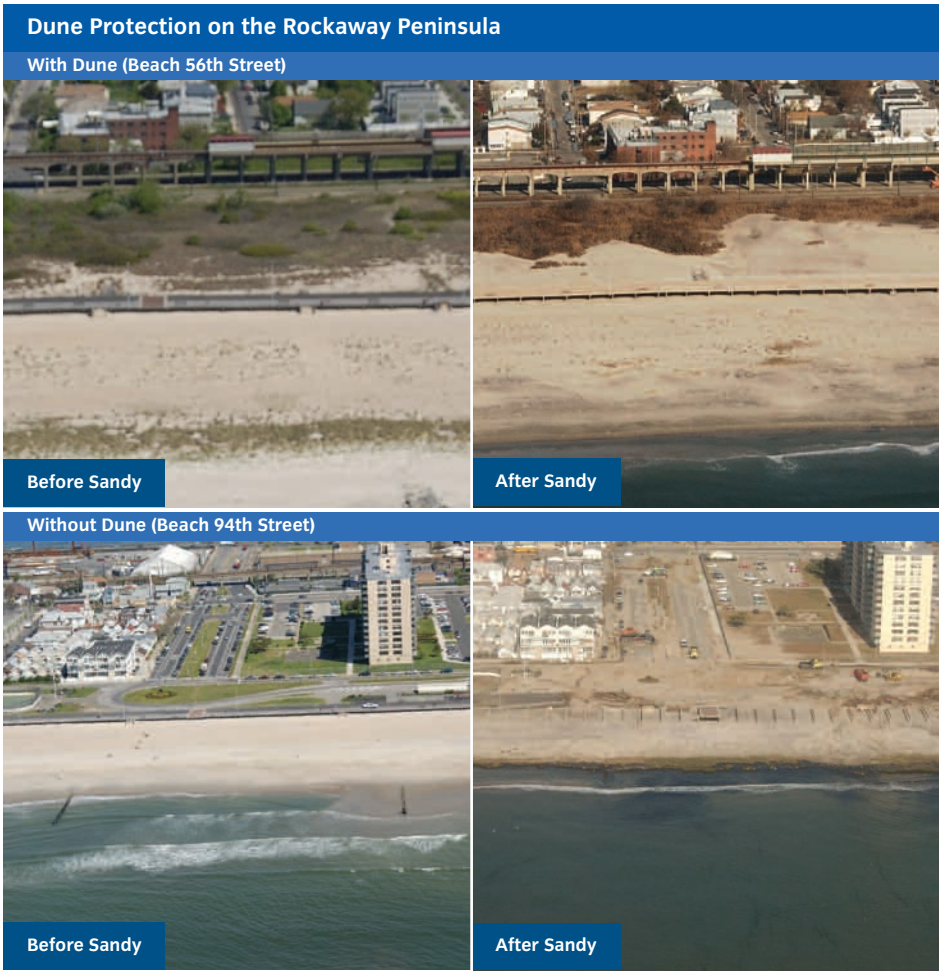
Performance of Existing Coastal Defenses

Though Sandy's surge generally devastated areas that it touched, some coastal features and strategies—such as beaches nourished with sand, dunes, wetlands, new and elevated drainage systems, site elevation, and bulkheads—did offer some protection. For example, many nourished beaches and dunes absorbed the destructive energy of waves and floodwaters, in many cases buffering adjacent neighborhoods. This was the case on the Coney Island peninsula, where the neighborhoods behind the nourished beaches of Coney Island and Brighton Beach suffered far less-destructive wave impact than did Sea Gate, where the beaches had not been nourished. In addition, areas of the Rockaway Peninsula with established dunes, such as Beach 56th Street, suffered substantially less damage and less sand migration into neighborhoods than areas without them, such as Beach 94th Street. (*See photos: Dune Protection on the Rockaway Peninsula*)

Site elevation, too, often proved effective in protecting buildings from destructive waves and flooding. Much of the city's development along the waterfront has occurred on land created by filling in historic wetlands and marshes *at-grade*, leaving them at risk of flooding. However, *elevated* developments—such as Battery Park City in Lower Manhattan and Arverne By The Sea on the Rockaway Peninsula—survived Sandy with minimal damage, particularly compared to other nearby locations that were not elevated.

Drainage systems that took advantage of local landscape and site characteristics also worked well. Though the volume of water that came with Sandy's surge was so massive that, in many cases, these systems were overwhelmed by peak water levels, areas with newer, elevated systems such as Arverne By The Sea were able to drain more quickly as floodwaters receded—sometimes immediately—allowing quicker recovery.

Dune Protection on the Rockaway Peninsula



Credit: NOAA

Risk Assessment: Impact of Climate Change on Coastal Protection

Major Risk Moderate Risk Minor Risk

	Scale of Impact			
Hazard	Today	2020s	2050s	Comments
Gradual				
Sea level rise				Could cause daily or weekly tidal flooding in low-lying neighborhoods
Increased precipitation				Minimal impact
Higher average temperature				Minimal impact
Extreme Events				
Storm surge				Risk likely would increase as sea levels rise
Heavy downpour				Minimal impact
Heat wave				Minimal impact
High winds				Minimal impact

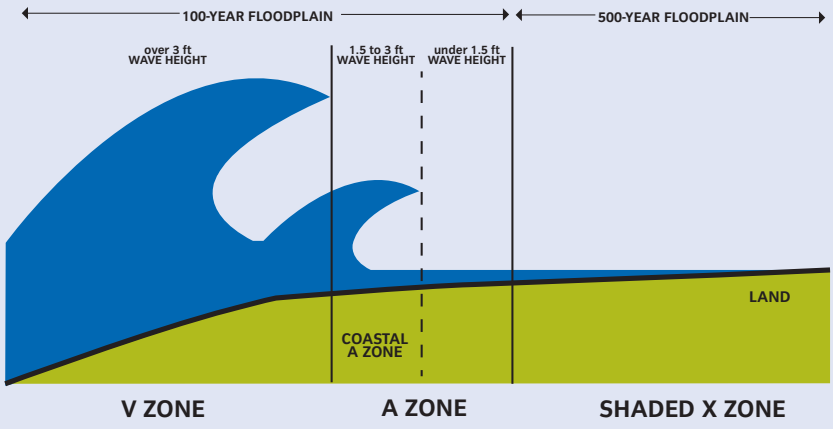
As for wetlands, their ability to reduce damage depended on their specific characteristics. Tidal wetlands on their own have little ability to stop the volume of water seen during Sandy. However, those that had been constructed with elevated edges proved capable of retaining some floodwaters in places such as Alley Creek, in Queens. In these cases, the elevated edges kept floodwaters from infiltrating neighborhoods and critical infrastructure while the wetlands attenuated waves, actually reducing the velocity and destructive force of incoming waves, a role that wetlands are well-suited to serve.

Finally, in some places, bulkheads also were able to break waves and reduce the destructive energy of the storm surge. Although the storm surge did sweep over bulkheads in many areas, those in Lower Manhattan, and along the Belt Parkway near Bay Ridge, helped to disperse wave energy and act as a "shock absorber" for adjacent areas.

What Could Happen in the Future

Going forward, New York City's coastline and waterfront infrastructure face significant climate risks, chief among them risks associated with storm surge and wave action. The New York City Panel on Climate Change (NPCC) projects that the frequency of the most intense storms by the 2050s will increase (see Chapter 2, *Climate Analysis*). Storms packing even the same or lesser power than Sandy, though, will pose greater risk to the area as sea levels raise the base level of water around the five boroughs. All of this is expected to result in inundation, destructive waves, and erosion of the coastline on a more regular basis. At the same time, as sea levels rise, this in and of itself could pose threats to low-lying areas of the city, even in the absence of storm conditions. (*See chart: Risk Assessment: Impact of Climate Change on Coastal Protection*)

Floodplain Zone Diagram



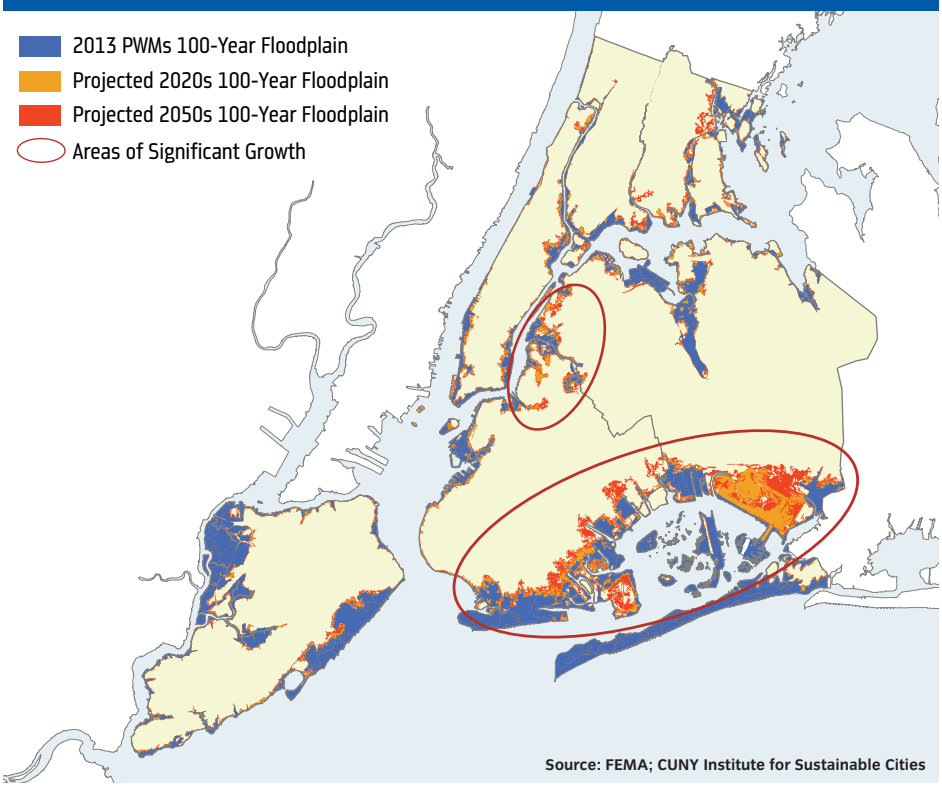
Source: FEMA

Major Risks

The greatest risk to coastal areas in New York City is storm surge.

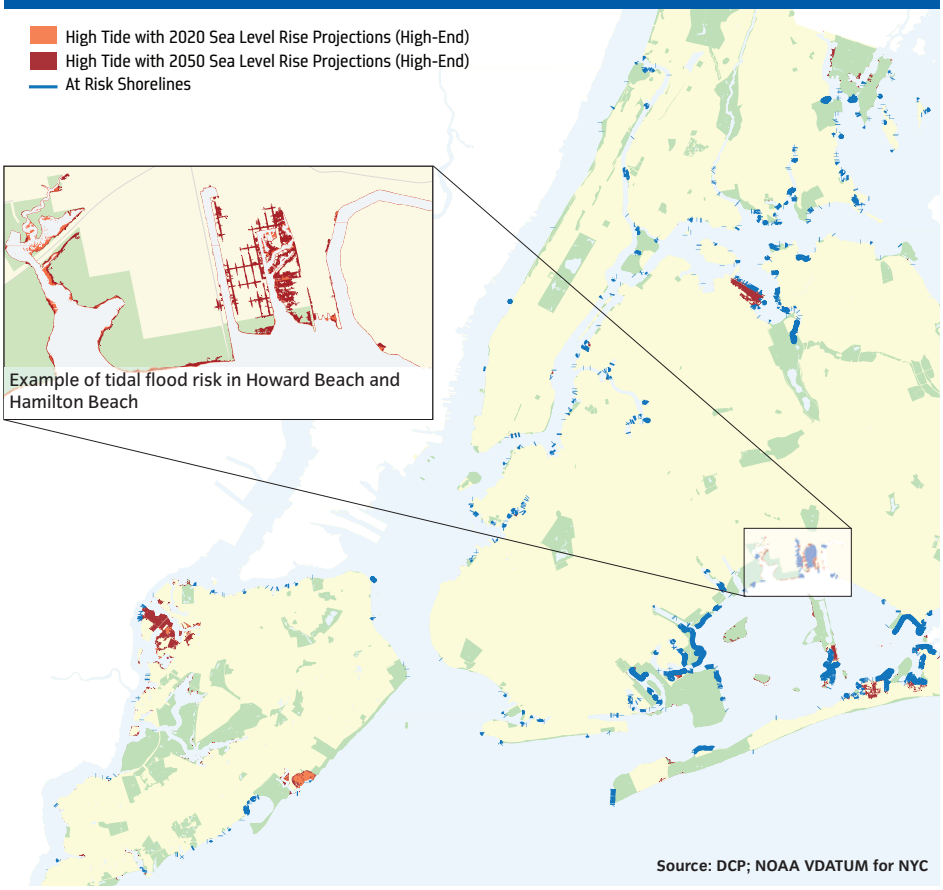
To understand why and to what extent, it is first helpful to understand the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Maps (FIRMs). The FIRMs, which have not significantly changed for New York City since

Future Flood Maps for the 2020s and 2050s



Source: FEMA; CUNY Institute for Sustainable Cities

Sea Level Rise Analysis



Example of tidal flood risk in Howard Beach and Hamilton Beach

Source: DCP; NOAA VDATUM for NYC

1983, represent the Federal government's assessment of coastal flood risk. They serve multiple purposes, including helping to determine premiums under the National Flood Insurance Program (NFIP) and triggering certain flood insurance requirements on Federally backed mortgages (See Chapter 5, *Insurance*). These maps divide coastal areas into several zones of vulnerability:

- **A Zones**: the 100-year floodplain—an area that has a 1 percent or greater chance of flooding in any given year;
- **V Zones**: the portion of the 100-year floodplain subject to high-velocity wave action (defined as a 3 foot or greater breaking wave);
- **Coastal A Zones**: the portion of the 100-year floodplain subject to breaking waves between 1.5 and 3 feet; and
- **Shaded X Zones**: the 500-year floodplain—an area that has a 0.2 percent or greater chance of flooding in any given year. (*See graphic: Floodplain Zone Diagram*)

The 1983 FIRMs indicate a 100-year floodplain in New York City of 33 square miles, or 11 percent of the city's land area. Prior to Sandy, FEMA had already begun the process of updating the 1983 FIRMs with new maps, intended to reflect current flood risks more accurately. In June 2013, new maps, known as Preliminary Work Maps (PWMs), were released by FEMA and reflect an expansion of the city's 100-year floodplain by 15 square miles, or 45 percent, over the 1983 FIRMs. The new floodplain consists of larger portions of all five boroughs, with significant expansion in Brooklyn and Queens. The new 100-year floodplain on the PWMs now includes 67,700 structures (an increase of 91 percent over the number of structures in the 100-year floodplain in the 1983 FIRMs). It is expected that the 100-year floodplain will continue to expand due to sea level rise at a steady pace over the course of the next decade and beyond, eventually reaching 72 square miles, or 24 percent of the city's land area, by the 2050s, with corresponding increases in wave zones. These future floodplains are illustrated on future flood maps that the City has created in collaboration with the NPCC for this report. (*See map: Future Flood Maps for the 2020s and 2050s*)

The V Zones on the PWMs include only slightly more buildings than the V Zones on the 1983 FIRMs. However, these zones are expected to grow further as sea level rise expands the floodplains in areas citywide, potentially including areas such as those south of and within Great Kills Harbor in Staten Island. Since stronger waves are projected to exert more destructive forces on the city's existing coastal edges, the wave action, in addition to being spread over a wider area, is also likely to cause greater damage and erosion.

The foregoing risks of flooding and wave action can be found in many parts of the five boroughs, but are most acute in certain coastal areas of New York City, as indicated in a comprehensive analysis of the coastline that the City undertook as part of the planning for this report. These especially vulnerable areas include exposed neighborhoods of the Rockaway Peninsula, the Coney Island peninsula, and the East Shore of Staten Island, which share a common geologic heritage and therefore a common flood profile. A similar profile is found in several Upper Bay neighborhoods, including Red Hook, East Harlem, Lower Manhattan, the Lower East Side, and the communities adjacent to Newtown Creek and the Gowanus Canal. Flooding is expected to pose a significant risk in these areas through the 2050s as sea levels rise. (*See sidebar: Analysis of Coastal Vulnerabilities and Resiliency Measures*)

Potential Sea Level Rise Impacts

Borough	Waterfront (miles)	At Risk of Tidal Flooding (miles)	(%)
Bronx	86.7	6.2	7%
Brooklyn	113.3	11.5	10%
Manhattan	44.8	1.3	3%
Queens	155.1	21.4	14%
Staten Island	120.1	2.6	2%
Total	**520**	**43**	**8%**

Source: DCP

Other Risks

Sea level rise in and of itself—even without the impact of coastal storms—is a growing risk that already affects certain low-lying neighborhoods. These include Broad Channel in Queens and other areas where homes and other structures in some cases are lower in elevation than corresponding roadway infrastructure, exacerbating flooding. These areas today experience flooding at the highest range of the regular tidal cycle. As sea levels continue to rise, these neighborhoods will flood more frequently, while other low-lying neighborhoods that do not flood regularly with the tides will start to do so. (*See map: Sea Level Rise Analysis; see chart: Potential Sea Level Rise Impacts*)

In fact, current projections indicate that, by the 2050s, approximately 43 miles of coastline—8 percent of the city's total excluding beaches and wetlands—could be at risk of daily or weekly tidal inundation during non-storm conditions. The risk of regular tidal flooding will be most pronounced in neighborhoods around Jamaica Bay in southeastern Queens, particularly Howard Beach and Broad Channel, and on portions of the Rockaway Peninsula, which has the lowest-lying topography in the city. It also will impact neighborhoods along the East River in Brooklyn and Queens. In addition to this regular flooding, sea level rise could also:

- damage buildings by weakening structural elements (particularly in wood-frame structures) and interfering with critical building systems (such as electrical panels, boilers, and hot water heaters);
- increase erosion on the city's beaches, reducing the level of protection provided by beach nourishment programs;
- damage coastal roads, eroding their base layers, leading to sinkholes, potholes, and other roadway failures;
- impair stormwater systems and raise groundwater levels, increasing flooding during heavy downpours;
- increase groundwater salinity, threatening native plant species and leading to a loss of vegetation in wetlands and on dunes, which, in turn, could impair the flood protection offered by these features; and
- exacerbate the effects of storms, particularly higher frequency events such as Nor'easters.

Although a less-significant risk to coastal areas than storm surge and sea level rise, heavy downpours and high winds also could minimally impact these areas in the future by eroding certain coastal protection elements, such as dunes or beaches.

Coastal Protection Strategies

As Sandy illustrated, the forces of nature can be significant, sometimes overwhelming even well-designed coastal defenses. That said, the future of the city lies along its coastline—something that has always been true, but is especially true given the nearly 535 million built square feet lying within the city's 100-year floodplain on the PWMs and the million more residents that will move to the already densely settled five boroughs in the coming decades. Given this reality, the City's plan for coastal protection focuses not on retreat—a strategy that may make sense in only very limited circumstances, but is neither possible nor desirable on a larger scale—and instead focuses on the following strategies:

Increase coastal edge elevations

Sea level rise threatens to inundate some neighborhoods with daily or weekly tidal flooding by the 2050s. To address this risk, the City will increase the height of vulnerable coastal edges with bulkheads, beach nourishment and other measures over time. This adaptive strategy allows for ongoing monitoring of sea level rise and investment as and where needs arise.

Minimize upland wave zones

Storm waves, which are projected to increase in size and strength over time, threaten to cause neighborhood damage, erosion, and the loss of beach sand in vulnerable areas. To address this risk, the City will work to provide significant attenuation of waves—that is, to knock down waves, or diminish their velocity—both off and onshore, before they reach neighborhoods. This approach will reduce potential damage to structures, reduce erosive forces on the shoreline, and protect infrastructure. Moreover, this approach should also influence the delineation of high-risk V and Coastal A Zones on FEMA's future FIRMs, especially if measures are built where possible, to the 100-year flood elevation with an additional allowance for future sea level rise. This, in turn, potentially could reduce the costs of flood insurance and mitigation within protected areas (See Chapter 5).

Protect against storm surge

To address the risk of storm flooding, the City will work to keep water from storm surge out of vulnerable neighborhoods and away from critical infrastructure. To do this, the City will use flood protection structures, such as floodwalls, levees, and local storm surge barriers built, where possible, to the 100-year flood elevation with an additional allowance for future sea level rise. Generally, the City will seek measures that minimize damage if overtopped.

Improve coastal design and governance

To ensure the successful implementation of the strategies outlined above, the City will make improvements to the design and governance of coastal areas. Specifically, the City will study how natural areas and open space can be used to protect adjacent neighborhoods and maintain neighborhood quality of life, and will work to manage its own waterfront assets more effectively, while also developing partnerships to improve permitting and study innovative coastal protections.

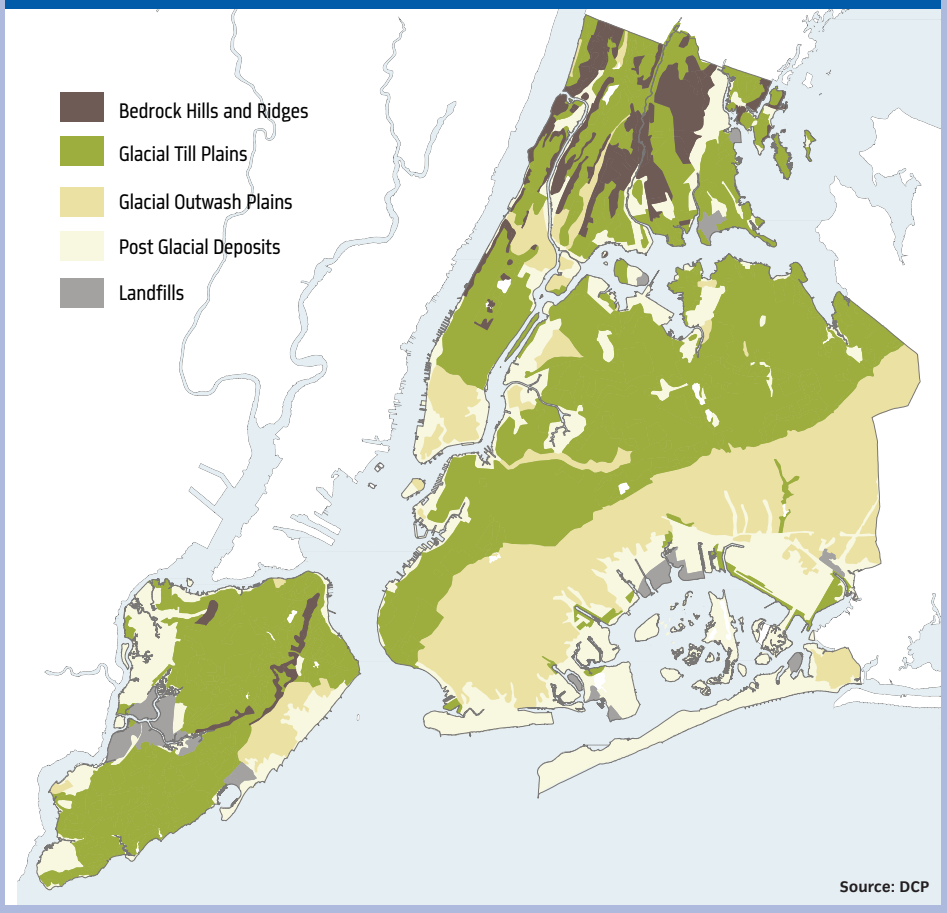
Analysis of Coastal Vulnerabilities and Resiliency Measures

The City's proposals for coastal protection measures are based on a multi-faceted analysis. This analysis considered factors ranging from the nature and likelihood of coastal hazards (such as destructive waves or flooding), to the possible impact of these hazards on the built environment and critical infrastructure, to the likely effectiveness of certain protective measures. The City also considered whether an area included high concentrations of particularly vulnerable populations, such as the elderly or those with disabilities, that would be at greater risk during a storm event.

Another important consideration was the underlying geomorphology of the regions examined, as well as the coastal features already in place. This analysis drew upon the work contained in the Department of City Planning's groundbreaking *Urban Waterfront Adaptive Strategies* (UWAS) study. The UWAS study, which was funded by a US Department of Housing and Urban Development Sustainable Communities Regional Planning grant and will be released shortly after this report, explores how the coastline was shaped by glacial processes, more recent coastline modifications, and other relevant coastal forces.

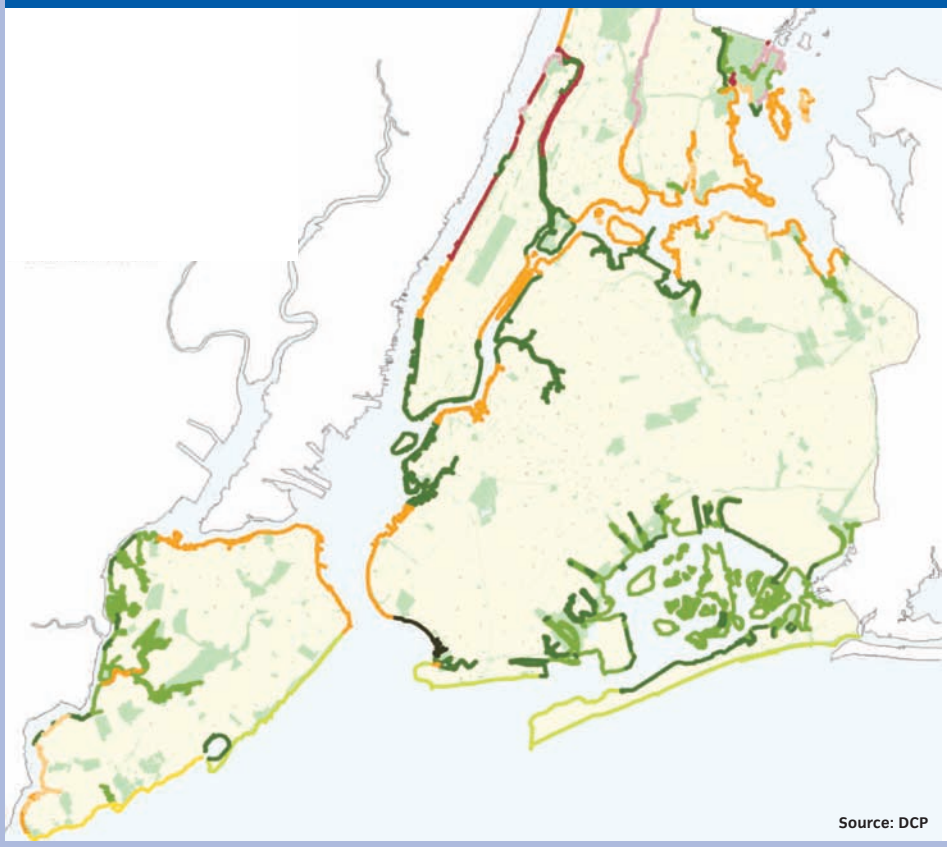
Among the elements of the UWAS study that proved most useful in the creation of this report were three discrete but related UWAS work streams. The first of these work streams involved extensive review of existing soil data, which allowed the UWAS study to map the underlying geology of the city's coast. Based on this survey, the UWAS study was able to demonstrate that certain low-lying land formations—such as Jamaica Bay and its surrounding neighborhoods, the East Shore of Staten Island, Lower Manhattan, East Harlem, and the areas adjacent to Newtown Creek—largely consist of outwash plains and post-glacial deposits, which makes them vulnerable to continued flooding and erosion. By contrast, the UWAS

Geologic Landforms of New York City



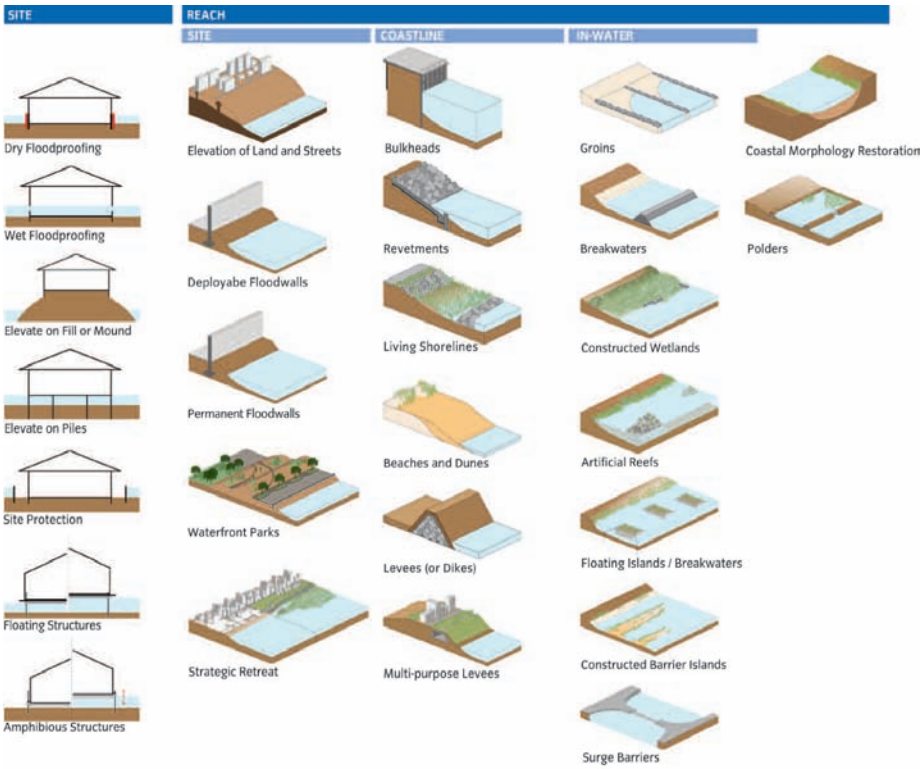
Source: DCP

Coastal Geomorphology



Source: DCP

Typical Coastal Resiliency Measures



Source: DCP

Geomorphology Type	Geology	Elevation	Fetch	Reinforced	Soils
Oceanfront Beaches	Glacial outwash plains	Low	High	No	Soft
Coastal Marshes	Glacial outwash plains	Low	Low	No	Soft
Hardened Sheltered Bay Plains	Glacial outwash plains	Low	Low	Yes	Soft
Hardened Oceanfront Plains	Glacial outwash plains	Low	High	Yes	Soft
Hardened Sheltered Bay Slopes	Glacial till plains & hills	Medium	Low	Yes	Mix of soft & dense
Rocky Sheltered Bay Slopes	Glacial till plains & hills	Medium	Low	No	Mix of soft & dense
Unreinforced Slopes	Glacial till plains & hills	Medium	High	No	Mix of soft & dense
Sheltered, Rocky Bluffs	Sheltered bedrock controlled hills & ridges	High	Low	No	Mix of soft & dense
Sheltered, Hardened Bluffs	Sheltered bedrock controlled hills & ridges	High	Low	Yes	Mix of soft & dense

Source: DCP

study also demonstrated that other areas consisting of harder soils and rock at steeper slopes are much less susceptible to flood hazards. Not surprisingly, during Sandy, the inundation area closely matched the lowest-lying areas with the softest soils. (*See map: Geologic Landforms of New York City*)

Additionally, the UWAS study evaluated the distance over which waves could develop due to the affects of wind ("fetch") to evaluate each area's susceptibility to wind-driven wave action.

A second important work stream of the UWAS study involved an examination of the entirety of the city's shoreline using aerial photography and other data sources to determine whether sections were reinforced with coastal structures—such as revetments, bulkheads, or piers—or were in a more natural state, with either rocky, sandy, or marshy edges. This work was particularly relevant to this report, given that areas that are not reinforced or vegetated tend to be more vulnerable to erosion (except in ocean-facing areas prone to wave action, where structures may actually increase erosion and interrupt natural sediment transport processes). This, together with the aforementioned study of the city's underlying geology, allowed the UWAS study to create a unique and useful map dividing the city's coastline into nine discrete geomorphology types. (*See map: Coastal Geomorphology*)

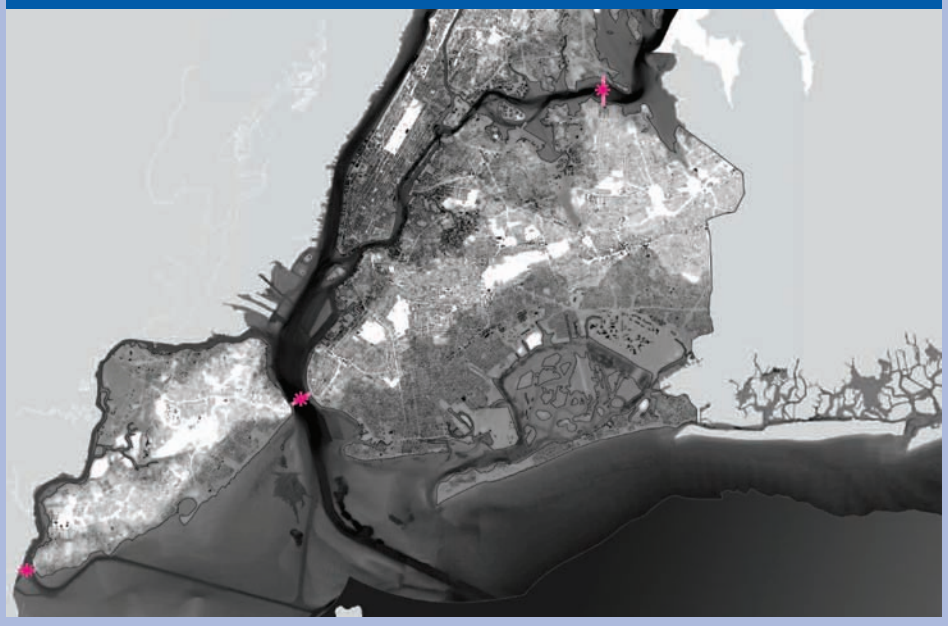
The third important work stream of the UWAS study involved an evaluation of the coastal resiliency measures suitable for the different types of areas observed. This work involved dividing the various types of defenses into several relevant reaches, or categories, including "upland," "coastline," and "in-water." It then assessed the applicability of these categories of defenses to various physical conditions, looking at factors such as the consistency of various defenses with adjacent land use; cost (both upfront and long-term); potential barriers to implementation; risk reduction and other cultural, social, or economic benefits; and potential unintended consequences such as environmental impacts. (*See chart: Typical Coastal Resiliency Measures*)

Thus, the work of the UWAS study provided an analytically rigorous and replicable approach for matching applicable coastal resiliency measures to vulnerable areas of the city, thereby informing the development and adoption of the goals, strategies, and initiatives in this report.

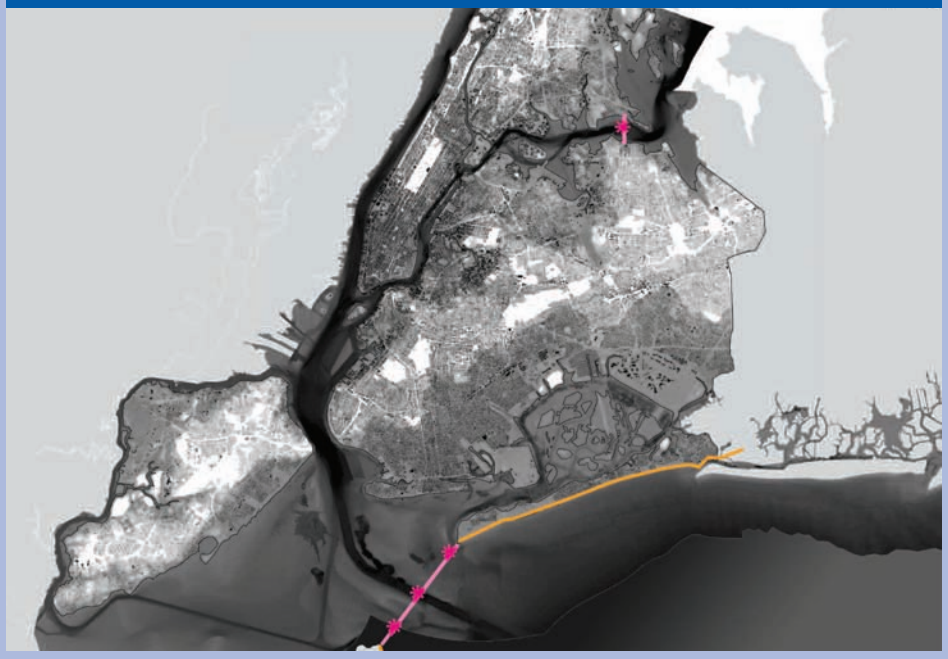
Harborwide Storm Surge Barriers

A variety of observers have raised the idea of harborwide storm surge barriers in response to the threat of coastal storms faced by New York City. One proposal that has been put forth, for example, calls for a three-part design, consisting of closure gates at the Narrows, the Arthur Kill, and the upper reaches of the East River. A second proposal would require two barriers, one at the upper reaches of the East River and one connecting Sandy Hook, NJ with the Rockaway Peninsula. In each case, the closure gates would be navigable channel openings, allowing ship traffic and water to flow through under ordinary circumstances. During storm events, however, the gates would be closed, in theory, blocking surge waters. To make either of these proposals work, a series of levees extending out from the closure gates would need to be constructed to ensure that displaced water is not simply pushed into low-lying areas adjacent to the closure gates. (*See map: Alternative 1: Three Barriers; See map: Alternative 2: Two Barriers*)

Alternative 1: Three Barriers



Alternative 2: Two Barriers



For some observers, the idea of constructing a single piece of engineering offers the appeal of seeming simplicity, as compared to a suite of a more targeted, localized protections. However, the construction of such harborwide storm surge barriers actually presents many complications:

- First, such a system of barriers would be extraordinarily expensive—perhaps costing $20 to $25 billion to build, with substantial operating and maintenance costs—substantially more than the City's proposed Phase 1 coastal protection initiatives and substantially more than any source of funding currently identified.
- Second, harborwide barriers would require a design, approval, and construction process that could, based on past experience with major in-water engineering projects in the New York City area and elsewhere around the globe, take two to three decades to complete.
- Third, the possible hydrodynamic and environmental impacts (on fish migration, siltation, river flow, and water quality) of harborwide barriers are likely to be substantial, are not yet known, and would require extensive study, potentially derailing or requiring substantial redesign of the project. These impacts also could be the subject of lawsuits—which have, in New York's relatively recent past, led to the cancellation of major in-water projects.
- Fourth, as mentioned above, to make a project such as this work, there likely would need to be massive levees (20 feet or more above grade) along adjacent coastal areas, including on the Rockaway Peninsula and possibly Coney Island and Staten Island, depending on which barrier option is chosen. These levees would have dramatic impacts on the character of the beaches and adjacent neighborhoods that may prove to be highly disruptive.
- Fifth, any barriers would create an "insiders/outsiders" dynamic, with only those behind the barriers receiving maximum protection, leaving densely developed communities along the South and North Shores of Long Island and the Jersey Shore outside the protected zone.
- Sixth, a harborwide barrier project may also cause additional flooding in areas outside the barriers (especially in tighter waterways, such as the Upper East River), thus making those communities more vulnerable than they would be without such barriers.
- Seventh, and finally, since the barriers would be open most of the time (to allow navigation), it would represent a major public investment that would end up doing nothing to address the growing problem of rising sea levels.

Comprehensive Coastal Protection Plan

In theory, one way to achieve the City's goals for its coastline may be the construction of massive protective infrastructure, such as harborwide storm surge barriers at the entrances to New York Harbor. As attractive as the concept of a single "silver bullet" solution may be, though, a closer examination of this strategy strongly suggests that relying on such a solution would pose significant risks to the city that far outweigh its theoretical benefits. (*See sidebar: Harborwide Storm Surge Barriers*)

Given this, the City believes that the right approach to coastal protection is an integrated system of discrete coastal projects, that together would constitute the elements of a multilayered approach also involving resiliency measures for buildings and protections for critical infrastructure. The advantage of this approach is three-fold. First, it diversifies the city's exposure to given technologies, reducing the chance of devastating failure, as occurred in New Orleans during Katrina, when the city's main defensive system, its levees, failed, leaving many parts of the city completely unprotected. Second, the City's proposed approach also has the advantage of being scalable to available resources, rather than requiring all resources to be secured before anything moves forward. Finally, certain elements of the City's plan can begin almost immediately, making New Yorkers safer today, rather than waiting years or perhaps even decades for a solution that may never be completed.

Therefore, to achieve its ambitious goals, the City is proposing a broad range of coastal protection measures. This breadth reflects the fact that different coastal areas in the city face different risks and therefore require protection that is specifically tailored to their needs.

Some of the proposed measures mimic existing coastal features that performed well during Sandy. Others have been proven to be successful elsewhere. Where possible, the City has derived inspiration from the historic natural features that once protected the coastline throughout the city. Elsewhere, both traditional and newly developed technologies have been considered.

Coastal protection measures first will be designed to match the risks facing a given area. For example, in areas where land is very low-lying and exposed to daily fluctuations in tide levels, the City will seek to increase edge elevations with bulkheads, revetments, and beach nourishment. Where wave action is expected, wave attenuation measures—such as dunes, offshore breakwaters, wetlands or oyster reefs, and groins—likely will be more suitable. Where stretches of very low-lying land are highly vulnerable to storm surge, protection measures—including higher floodwalls, levees, and local storm surge barriers—are proposed to increase coastline elevations and prevent inundation.

Measures also will consider the geomorphology and land use of neighborhoods. For ocean-facing beaches, beach nourishment and dune construction are viewed as most appropriate, because these areas already feature natural sand movement, sandy soils, and supporting topography. For locations along the Upper Bay with existing built edges (and space constraints), proposed measures include floodwalls and levees. Along the protected coves of the Upper East River and within Jamaica Bay, strengthened or new wetlands and other measures that break waves are likely to be effective. Finally, in areas where small inlets and other passages have served or could serve as "backdoors" for flooding of large inland areas, measures that address these passages, such as local storm surge barriers, are proposed.

In evaluating each risk-reduction measure, and groupings of measures, the City employed sophisticated storm surge modeling to explore the performance of coastal protection measures. The City used these digital hydrodynamic models to test the effectiveness of each measure in reducing wave heights and storm surge levels in Sandy-like storms, as well as in scenarios of future 100-year and 500-year storms assuming the sea level rise projections from NPCC. This analysis informed the location and configuration of each measure, including heights of proposed floodwalls and dunes.

After modeling the effectiveness of different coastal protection options, the next step in the City's analysis was an evaluation of the cost-effectiveness of the approach. Both upfront construction costs and long-term maintenance costs were estimated to calculate total lifecycle expenses. Benefits were then quantified based on each measure's ability to reduce risk, decrease damage, and increase resiliency, based on commonly accepted insurance industry models and predictions. When evaluated at specific locations, cost-benefit ratios were developed and used for comparison with other measures.

Finally, the City also evaluated measures in light of other important public considerations. These included waterfront access, navigation impacts, recreational benefits, environmental impact, contribution to ecosystem restoration, social and environmental justice, and impact on neighborhood character and quality of life for residents and businesses.

Full-Build Recommendations

The following measures will, at full build, form the city's comprehensive coastal protection system. Though, some of these measures can begin immediately, many will require partnerships with other governmental entities, including, perhaps most importantly, the USACE.

To ensure that this plan can be implemented as quickly as possible, the City is therefore calling on the USACE to place the measures that make up the City's proposed plan at the core of any subsequent evaluation or study of flood risk within the five boroughs of New York City that the USACE (or other agencies) undertake. For example, the USACE will complete a North Atlantic Coast Comprehensive Study, or NACCS, which is intended to address the flood risks of vulnerable coastal populations in areas affected by Sandy. The NACCS will guide future Federal investment in flood protection for the entire Northeast region of the United States. It is imperative that the NACCS build upon the work of this report to generate Federally funded projects and to ensure that projects are constructed in New York City on an expedited timeframe.

The City's recommended coastal protection measures are described below, grouped by strategy. (*See map: Comprehensive Coastal Protection Plan | Full-Build Recommendations*)

Strategy: Increase coastal edge elevations

Beach Nourishment

Beaches are an important recreational and economic resource for the city. They are also a critical part of the City's coastal defense network. Regular wave action and the natural sediment transport process (the ongoing movement of sand following the dominant wave direction) continue to erode beaches over time, however. Storms only accelerate this process. A regular program of beach nourishment—that is, adding large quantities of sand to widen and elevate beaches on a regular cycle, as well as after significant storm events—

Beach Nourishment

Credit: NOAA

Comprehensive Coastal Protection Plan | Full-Build Recommendations

Increase Coastal Edge Elevations

Beach Nourishment
- 1 Coney Island, Brooklyn
- 2 Rockaway Peninsula, Queens
- 3 East and South Shores, Staten Island
- A Orchard Beach, Bronx

Armor Stone (Revetments)
- 4 Coney Island Creek, Brooklyn
- 5 Annadale, Staten Island
- B South Shore, Staten Island

Bulkheads
- 6 Citywide Program
- 7 Belt Parkway, Brooklyn
- 8 Beach Channel Drive, Queens

Tide Gates / Drainage Devices
- 9 Oakwood Beach, Staten Island
- 10 Flushing Meadows, Queens
- C Coney Island Creek, Brooklyn
- D Mill Creek, Staten Island

Minimize Upland Wave Zones

Dunes
- 11 Rockaway Peninsula, Queens
- 12 Breezy Point, Queens
- E Coney Island, Brooklyn

Offshore Breakwaters
- 13 Great Kills Harbor, Staten Island
- F South Shore, Staten Island
- G Rockaway Extension
- H City Island, Bronx

Wetlands, Living Shorelines and Reefs
- 14 Howard Beach, Queens
- 15 Tottenville, Staten Island
- 16 Plumb Beach, Brooklyn
- 17 Brant Point, Queens
- I Jamaica Bay
- J Bay Ridge Flats
- K Saw Mill Creek, Staten Island

Groins
- 18 Sea Gate, Brooklyn

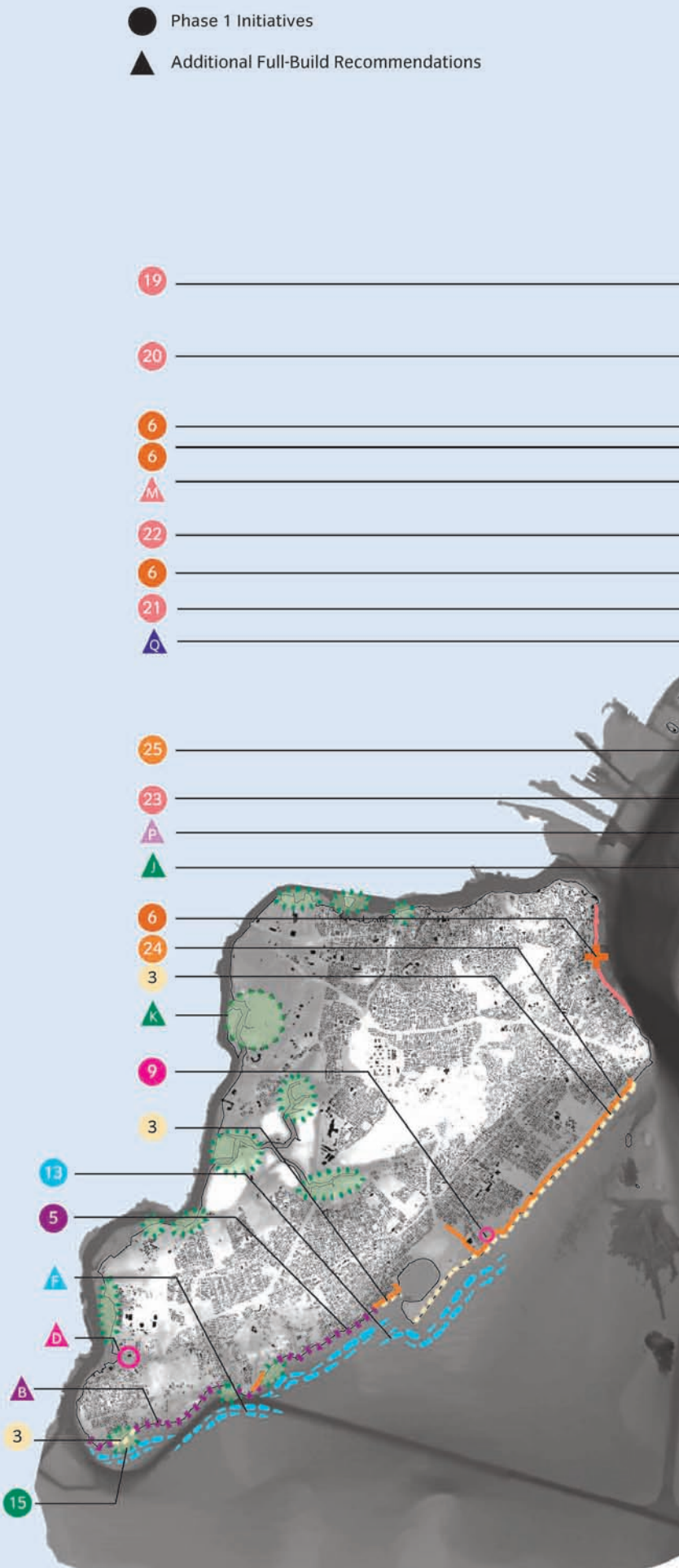
Protect Against Storm Surge

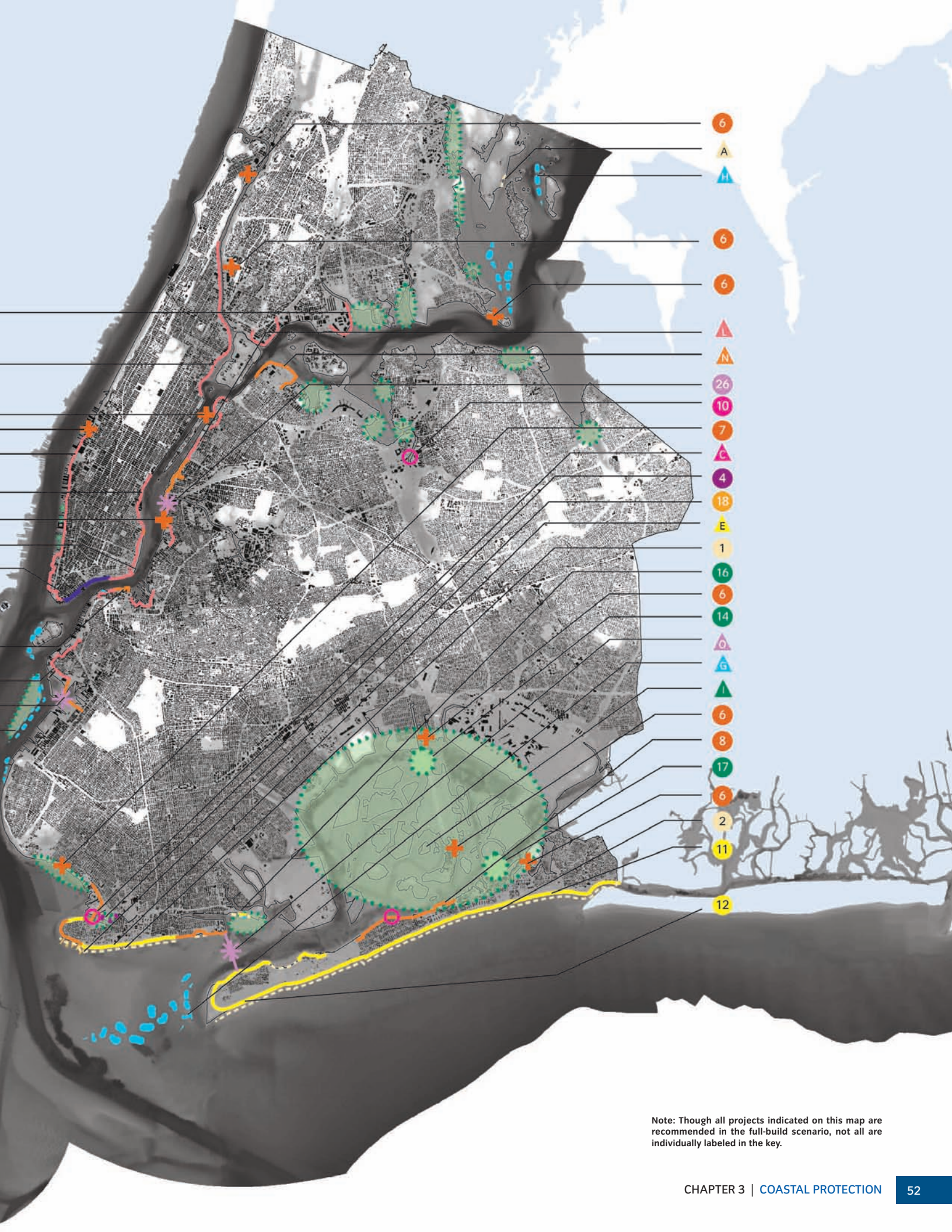
Integrated Flood Protection System
- 19 Hunts Point, Bronx
- 20 East Harlem, Manhattan
- 21 Lower Manhattan / Lower East Side
- 22 Hospital Row, Manhattan
- 23 Red Hook, Brooklyn
- L Brooklyn-Queens Waterfront
- M West Midtown, Manhattan

Floodwalls / Levees
- 24 East Shore, Staten Island
- 25 Farragut Substation, Brooklyn
- N Astoria Generating Station, Queens

Local Storm Surge Barrier
- 26 Newtown Creek
- O Rockaway Inlet
- P Gowanus Canal, Brooklyn

Multi-purpose Levee
- Q Lower Manhattan





Note: Though all projects indicated on this map are recommended in the full-build scenario, not all are individually labeled in the key.

is critical to ensuring that city beaches continue to serve their vital coastal protection role.

Selected Locations: Rockaway Peninsula; Coney Island peninsula; East Shore and South Shore of Staten Island; and Orchard Beach in the Bronx. (*See photo: Beach Nourishment*)

Armor Stone (Revetments)

Hardening exposed shorelines with armor stone (various kinds of massive rocks, including granite), or revetments can protect against erosion caused by storms and rising sea levels. Revetments, also known as rip-rap, are a proven coastal protection technique in New York City and can also be used to raise edge elevations. Experience has demonstrated that revetments require minimal maintenance. In addition, the shallow slopes of revetments can provide near-shore habitat for marine organisms and vegetation.

Armor Stone (Revetments)

Selected Locations: South Shore of Staten Island and Coney Island Creek. (*See photo: Armor Stone (Revetments)*)

Bulkheads

Historically, bulkheads (or structures, usually made of stone or concrete, at the water's edge) have been installed to hold shorelines in place and provide land for commerce adjacent to the city's rivers. They are also used to protect exposed shorelines from erosion. Over time, these bulkheads have taken on an expanded role—supporting parks, esplanades, and highways. Raising bulkheads in targeted locations citywide would mitigate the effects of rising sea levels in low-lying areas shown to be prone to future tidal flooding.

Bulkheads

Selected Locations: Bay side of the Rockaway Peninsula, Broad Channel, and Howard Beach in Queens; West Midtown and Sherman Creek in Manhattan; Locust Point in the Bronx; Greenpoint in Brooklyn; and in the North Shore of Staten Island; as well as other locations that will be evaluated. (*See photo: Bulkheads*)

Tide Gates/Drainage Devices

Tide gates, "duckbill" valves, which seal a pipe end but still allow water to drain, and other backflow-prevention devices are used to ensure that water does not flow backwards through drainage infrastructure. These commonly used devices, although not universally applicable, can be used to improve the performance of the city's drainage network and reduce flood risk, though they must be evaluated on a site-specific basis so as not to impede the ability of upland areas to drain stormwater.

Tide Gates/Drainage Devices

Selected Locations: Oakwood Beach and Mill Creek in Staten Island; Coney Island Creek; Flushing Meadows Corona Park in Queens; and Beach Channel Drive on the Rockaway Peninsula. (*See photo: Tide Gates*)

Strategy: Minimize upland wave zones

Dunes

Dunes—reinforced sand mounds typically located along the back edge of a beach—help break waves and keep floodwaters from inundating neighborhoods. Dunes can be "sacrificial," designed to allow sand to wash away as storm waters recede. Generally, they require maintenance and sand replenishment from time to time, especially after storms. Dunes work well when planted (because plant roots help hold the sand in place) and reinforced (with a structural inner core of rock or geotextiles, on which the sand sits). In some locations, they work even better when there is enough land to allow for both primary and secondary dunes (a double-dune system), which also provide redundant coastal protection.

Selected Locations: Rockaway Peninsula and the Coney Island peninsula. (*See rendering: Primary and Secondary Dune System*)

Offshore Breakwaters

Offshore breakwaters—features typically composed of rock or other robust materials located in an ocean or bay—attenuate wave energy offshore, thereby absorbing the force of destructive waves before they reach the coast and adjacent neighborhoods. By calming nearby waters, these structures also can provide new habitat for in-water organisms such as oysters. Although expensive, offshore breakwaters can reduce risks significantly for areas exposed to significant wave action and erosion.

Selected Locations: Rockaway Extension; City Island in the Bronx; South Shore of Staten Island; and Upper Bay. (*See rendering: Offshore Breakwaters*)

Wetlands, Reefs, and Living Shorelines

Wetlands—swamps, marshes, and bogs—are areas that are inundated or saturated by surface or groundwater sufficiently frequently to support vegetation that thrives in wet soil conditions. Reefs are an offshore feature typically below sea level. Living shorelines are coastal edges that incorporate a combination of reefs, breakwaters, maritime or coastal forests, and tidal wetlands to reduce wave action and erosion. These natural features are known to offer significant ecosystem and water quality benefits, and also to aid in the retention of stormwater, sediment, nitrogen, and other nutrients.

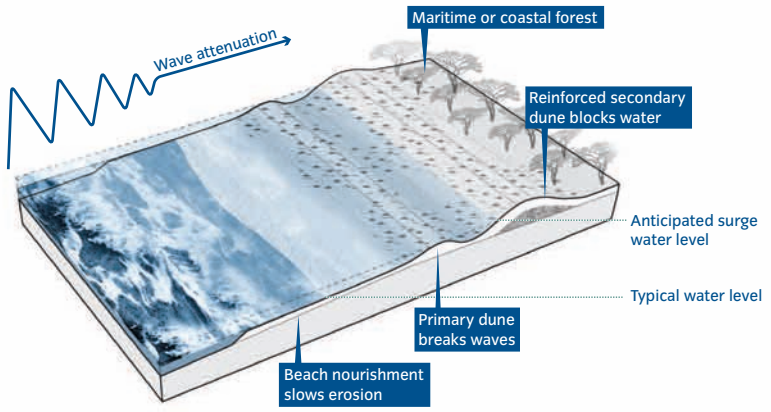
What is less well-understood is their ability to reduce waves during storms, although anecdotal evidence indicates that they can perform this function. More analytical research, including the City's storm surge modeling completed for this report, has shown that, when placed appropriately, wetlands, oyster reefs, and living shorelines, including coastal forests, possess effective wave-attenuation properties. Those properties may be improved even further by altering the depth at which these features are placed or modestly increasing the inclusion of hardened elements such as rock.

Selected Locations: Jamaica Bay; Tottenville in Staten Island; Bay Ridge Flats; along the Arthur Kill and Kill van Kull; and along Long Island Sound. (*See rendering: Wetlands with Wave Attenuation*)

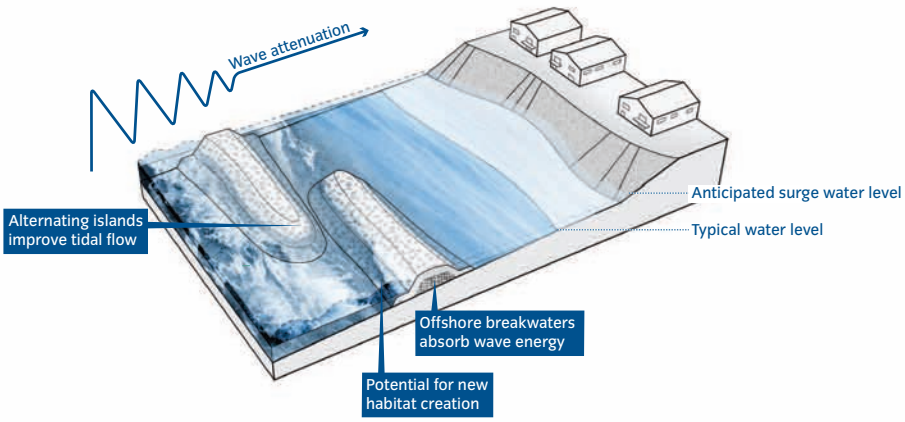
Groins

These installations of rocks or timber, perpendicular to the shoreline, are often referred to as jetties. They can help retain sand from beach nourishment projects on-site and also serve to break waves and absorb wave energy. Though

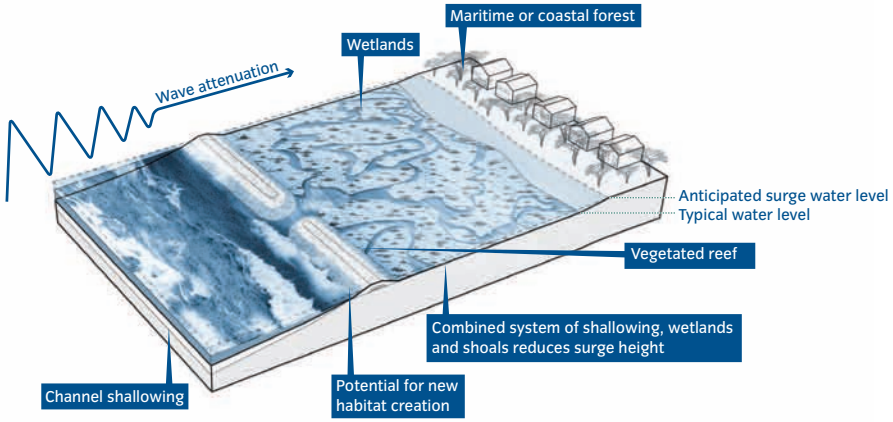
Primary and Secondary Dune System



Offshore Breakwaters

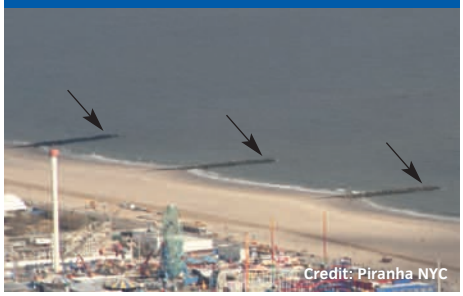


Wetlands with Wave Attenuation



groins must be carefully evaluated because they have the potential to disrupt natural sediment transport processes, with careful planning, they can serve a vital function in protecting oceanfront communities.

Groins



Selected Locations: Sea Gate in Brooklyn and the Rockaway Peninsula (*See photo: Groins*)

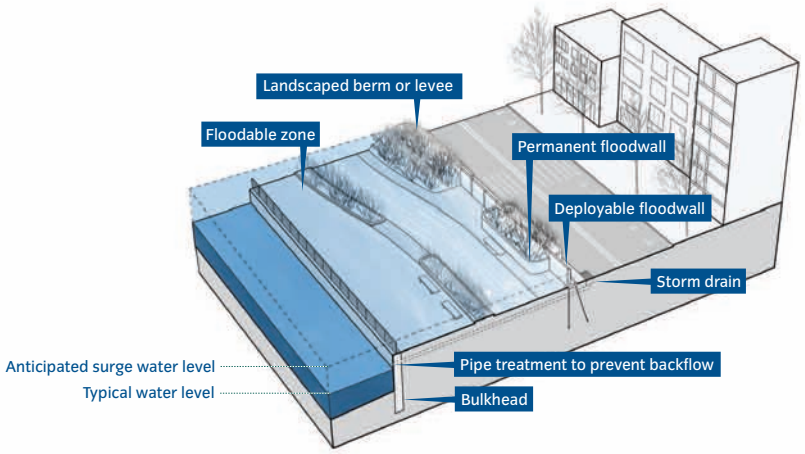
Strategy: Protect against storm surge

Integrated Flood Protection Systems

Flexible and adaptable, integrated flood protection systems are composed of a variety of elements that can be combined and customized in areas where critical infrastructure or vulnerable neighborhoods require a high level of flood protection. Such systems have evolved from traditional floodwalls and can include landscaping features, such as terraced berms at the back end of a waterfront park; benches, park walls, flood-proofed buildings or bridge abutments; drainage improvements, including valves and gates; and temporary features such as deployable floodwalls, which can be erected in advance of an extreme weather event. Passive elements that float into position during flood conditions by reacting to floodwaters can also be a part of an integrated flood protection system in discrete areas such as the entrances to underground parking garages.

In the case of areas that are subject to the risks posed by infrequent, but damaging, extreme weather events—but where permanent features are undesirable or infeasible–one solution is to rely more heavily on deployable floodwalls. These systems, which consist of moveable posts and panels which are, at times of vulnerability, affixed to permanent, in-ground foundations, can be removed immediately after a threat recedes. The advantage of deployable systems is, of course, the fact that they allow the waterfront to remain open and accessible at all times, except during weather events. However, the systems do pose maintenance and operating challenges (e.g., the deployable elements need to be stored, deployment often requires heavy equipment and a sizeable workforce, and regular drills are required to ensure readiness during storms). (*See photos: Deployable Floodwalls*)

Integrated Flood Protection System



Selected Locations: Red Hook in Brooklyn; East Harlem, Lower Manhattan, and the Lower East Side in Manhattan; Hospital Row in Manhattan; Hunts Point in the Bronx; Long Island City and Astoria in Queens; and Stapleton, Staten Island. (*See rendering: Integrated Flood Protection System*)

Floodwalls/Levees

Floodwalls, or permanent vertical barriers, are designed to provide a higher level of surge protection for vulnerable neighborhoods and critical infrastructure, attenuating waves and blocking surge.

Selected Location: Con Edison's Farragut substation on the East River in Brooklyn.

Meanwhile, levees, a traditional approach to flood management, are impervious earthen or

Storm waves at Rockaway Beach

Deployable Floodwalls

Credit: John Doman/St. Paul Pioneer Press

Installation of deployable floodwalls

Credit: thegeographyofblackwoodgsce

Completed deployable floodwalls

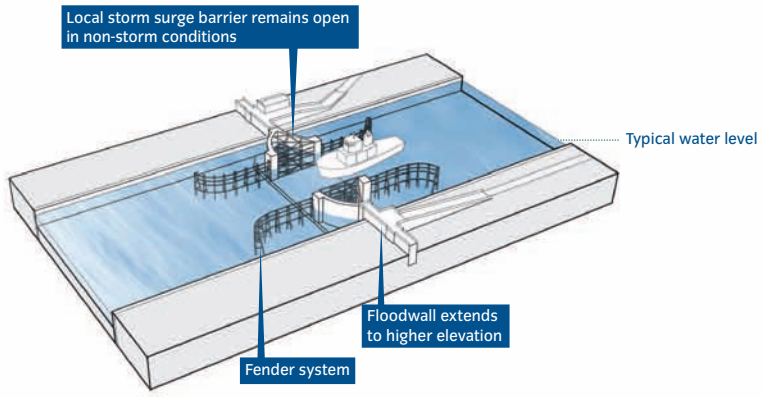
rock embankments that also provide a greater degree of flood protection. However, unless intelligently integrated into the urban landscape, floodwalls and levees can cordon off communities from the water. Strategies designed to reduce obtrusiveness include incorporating walkways or esplanades along the top of levees.

Selected Locations: East Shore of Staten Island and Coney Island Creek. (*See photo: Levees*)

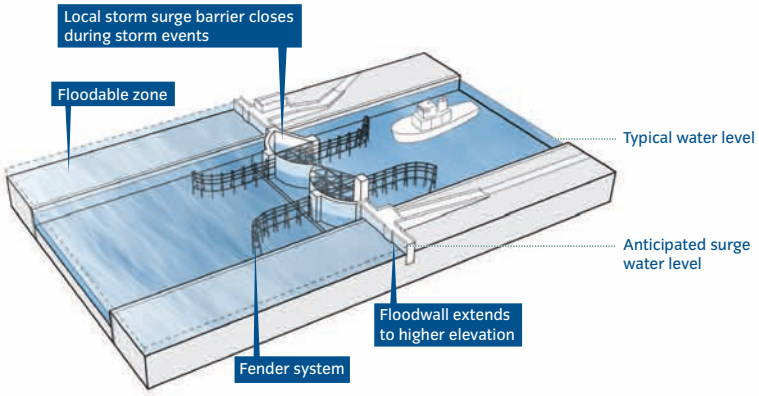
Levees

Credit: Mary Kimball/DCP

Local Storm Surge Barrier—Open



Local Storm Surge Barrier—Closed



Local Storm Surge Barriers

Local storm surge barriers consist of large movable in-water gates and connecting levees or floodwalls on adjacent shores. These barriers are constructed in navigable water bodies to allow for normal maritime commerce and boating in non-storm conditions. However, the barriers also can be closed in advance of an extreme weather event to protect the inland neighborhoods behind them. Although these installations are expensive, local storm surge barriers that are more modest in scope could enhance protection in significant parts of the city in a cost-effective manner.

Selected Locations: Newtown Creek; Rockaway Inlet; and the Gowanus Canal in Brooklyn. (*See rendering: Local Storm Surge Barrier—Open; See rendering: Local Storm Surge Barrier —Closed*)

Multi-Purpose Levees

Multi-purpose levees function much like a simple levee but play additional roles, serving, for example, as transportation infrastructure, providing parking, supporting residential, retail or commercial uses, or serving as open space. In certain high-density locations, multi-purpose levees can serve not only as flood protection for adjacent neighborhoods, but also can provide a cost-effective mechanism to pay for coastal protection by creating land for development, which is also elevated and thus itself not at risk of flooding.

Selected Location: Lower Manhattan.

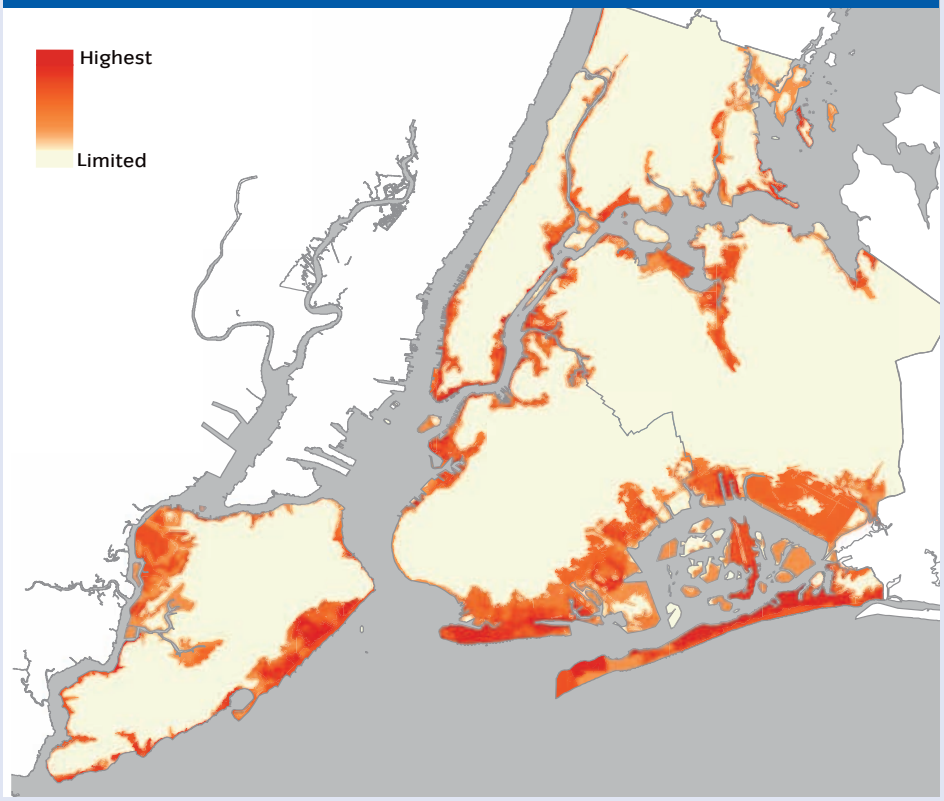
This chapter contains a series of initiatives that are designed to strengthen New York's coastal defenses. In many cases, these initiatives are both ready to proceed and have identified funding sources assigned to cover their costs. With respect to these initiatives, the City intends to proceed with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

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

New York City's Collaboration with the USACE

The USACE, which has broad authority over the waters of the United States, including responsibility for executing Federal flood protection projects, has been an important partner for New York City in the past. The importance of this partnership will only grow as the City seeks to implement the coastal protection projects described in this report. To this end, it is imperative that the initiatives outlined in this report be incorporated into the USACE's overall strategy for the city (including as part of the North Atlantic Coast Comprehensive Study) and into the planning, design, and implementation of any USACE-constructed projects. The City looks forward to continuing to work collaboratively with the USACE to make New York a safer and more resilient city.

Coastal Risk Map



While the City's comprehensive plan for coastal protection includes all of the tactics described above and shown on the Full-Build Recommendations map, implementation of all of these tactics simultaneously would be an expensive proposition. Furthermore, in many cases, it may make sense to monitor the actual rising sea levels before making some of the aforementioned investments where associated risks may not be felt for several decades.

However, the risks faced today coupled with the expected increase in these risks in the years ahead, *do not* give the City the luxury of deferring investment indefinitely. Thus, while the resources available to the City today may be limited, it is incumbent upon—and possible for—the City to think ambitiously and make substantial improvements in its existing coastal defenses in the near-term.

To evaluate where to make its proposed initial set of investments, the City started by developing a Coastal Risk Map. This map analyzed the likelihood of flooding and wave action across all five boroughs and then layered onto this the density of current development, the presence of critical infrastructure and other factors, including the presence of vulnerable populations. (*See map: Coastal Risk Map*)

Based on the City's Coastal Risk Map, the feasibility of potential protective measures, and other considerations, the City is proposing a highly ambitious first phase of its comprehensive coastal protection plan, consisting of 37 projects drawn from its full-build recommendations.

These 37 initiatives include pre-Sandy USACE projects that are now fully funded as well as other projects, some of which will require cooperation with the USACE and other partners, and others that can be implemented by the City alone. Many will also require environmental review. Together, these initiatives will not only significantly reduce the vulnerability of hundreds of thousands of New Yorkers, but also will demonstrate the effectiveness of a wide range of coastal protection technologies that could be scaled up in the future. (*See map: Comprehensive Coastal Protection Plan | Phase 1 Initiatives*)

The City subjected these projects to a cost-benefit analysis to determine how effective they were at reducing future risks. Based on estimated lifecycle costs and using insurance industry-based predictive models, the City concluded that the package of Phase 1 Initiatives has an aggregate cost-benefit ratio that supports moving forward with its implementation.

Strategy: Increase coastal edge elevations

Beach Nourishment

In several parts of the city, beach sand served as a key line of defense when Sandy hit. During the storm, however, large quantities of this sand were washed away. To close the defensive breach created by this loss, the City will support the work of the USACE to complete emergency beach nourishments—replacing not only sand lost during Sandy, but also sand lost since earlier USACE nourishment of these beaches, in some cases many years ago. DPR will ensure that this work makes effective use of existing Federal appropriations and enhances protection during the 2013 hurricane season and beyond. The City also will work with the USACE to develop a plan for ongoing beach maintenance, so that a sand restoration plan is in place in anticipation of future storms.

Initiative 1

Continue to work with the USACE to complete emergency beach nourishment in Coney Island

The City will support the work of the USACE to complete emergency beach nourishment from Corbin Place to West 37th Street, expected to include 1 million cubic yards of sand. This project will start in July 2013, with completion targeted for December 2013.

Initiative 2

Continue to work with the USACE to complete emergency beach nourishment on the Rockaway Peninsula

The City will support the work of the USACE to complete emergency beach nourishment from Beach 19th Street to Beach 149th Street, expected to include 3.6 million cubic yards of sand. This project will start in June 2013, with completion targeted for December 2013.

Initiative 3

Complete short-term beach nourishment, dune construction, and shoreline protection on Staten Island

The loss of sand in Staten Island has left several neighborhoods exposed and vulnerable to future storms. The City, therefore, will complete interim beach nourishment and short-term dune improvements in Staten Island, including beach nourishment in South Beach, Crescent Beach, and Tottenville; dune construction from New Dorp Beach to Oakwood Beach; and shoreline stabilization to close the breach at Wolfe's Pond Park. DPR will ensure that this work, which began in May 2013 and will end by October 2013, makes effective use of existing Federal appropriations and enhances protection during the 2013 hurricane season and beyond.

Initiative 4

Install armor stone shoreline protection (revetments) in Coney Island

Coney Island Creek provides a pathway for the "backdoor flooding" of much of Southern Brooklyn. Subject to available funding, the City, therefore will raise the Creek's lowest edge elevations to a consistent grade with revetments to reduce the risk of flooding and erosion at low spots bordering the Creek. The Mayor's Office of Long-Term Planning and Sustainability (OLTPS) will work with the New York City Economic Development Corporation (NYCEDC) to complete this project. The goal is to begin design work in 2013 and complete the project in three years.

Initiative 5

Install armor stone shoreline protection (revetments) on Staten Island

The South Shore of Staten Island continues to be at risk for future erosion of its beaches and bluffs. Subject to available funding, the City, therefore will implement shoreline protection using revetments in vulnerable locations on the South Shore of Staten Island, such as Annadale. OLTPS will work with NYCEDC to complete this project. The goal is to begin design work in 2013, with completion within three years.

Initiative 6

Raise bulkheads in low-lying neighborhoods across the city to minimize inland tidal flooding

Eight percent of the city's shoreline will be at risk of daily tidal flooding by 2050. Subject to available funding, the City, therefore, will implement a program to raise bulkheads and other shoreline structures to minimize the risk of regular flooding in targeted neighborhoods, including the bayside of the Rockaway Peninsula, Broad Channel and Howard Beach in Queens, West Midtown in Manhattan, Locust Point in the Bronx, Greenpoint in Brooklyn, the North Shore of Staten Island, and other low-lying locations. OLTPS will work with NYCEDC and other agencies to implement this program in conjunction with a new citywide waterfront inspections program that will assess needs throughout the five boroughs. The goal is to begin the first phase of evaluations in 2013.

Initiative 7

Complete emergency bulkhead repairs adjacent to the Belt Parkway in Southern Brooklyn

The failure of bulkheads adjacent to the Belt Parkway has left several portions of this vital roadway exposed and vulnerable to future storms. The City, therefore, will complete bulkhead repairs in areas damaged during Sandy, including at 14th Avenue, 17th Avenue, and 95th Street. DPR will complete this work by December 2013, making effective use of existing Federal appropriations and enhancing protection during the 2013 hurricane season and beyond.

Beach Restoration for Summer 2013

Following Sandy, Mayor Bloomberg made a commitment to open New York City's eight public beaches in time for Memorial Day weekend 2013. However, several key facilities necessary to meet this goal—including bathrooms, lifeguard stations, maintenance and operations offices, and concessions—had been completely destroyed or significantly damaged in the storm. In a coordinated interagency effort led by the Department of Parks & Recreation, with the Department of Design and Construction and other City, State and Federal partners, the City invested over $270 million that not only removed debris, corrected hazardous conditions, restored beach access and renovated damaged buildings, but also replaced the key facilities that were destroyed with new facilities designed to withstand future storms. These 35 prefabricated modular buildings will be used as bathrooms and lifeguard stations on the Rockaway Peninsula, Coney Island, and Staten Island and were designed and constructed to a height ranging from 7 to 14 feet above the existing grade to ensure maximum resiliency. Having met the Memorial Day opening date, the City, State, and Federal governments are now working to restore sand and other protective elements on the beaches .

Comprehensive Coastal Protection Plan | Phase 1 Initiatives

Increase Coastal Edge Elevations

Beach Nourishment
1. Coney Island, Brooklyn
2. Rockaway Peninsula, Queens
3. East and South Shores, Staten Island

Armor Stone (Revetments)
4. Coney Island Creek, Brooklyn
5. Annadale, Staten Island

Bulkheads
6. Citywide Program
7. Belt Parkway, Brooklyn
8. Beach Channel Drive, Queens

Tide Gates / Drainage Devices
9. Oakwood Beach, Staten Island
10. Flushing Meadows, Queens

Minimize Upland Wave Zones

Dunes
11. Rockaway Peninsula, Queens
12. Breezy Point, Queens

Offshore Breakwaters
13. Great Kills Harbor, Staten Island

Wetlands, Living Shorelines and Reefs
14. Howard Beach, Queens
15. Tottenville, Staten Island
16. Plumb Beach, Brooklyn
17. Brant Point, Queens

Groins
18. Sea Gate, Brooklyn

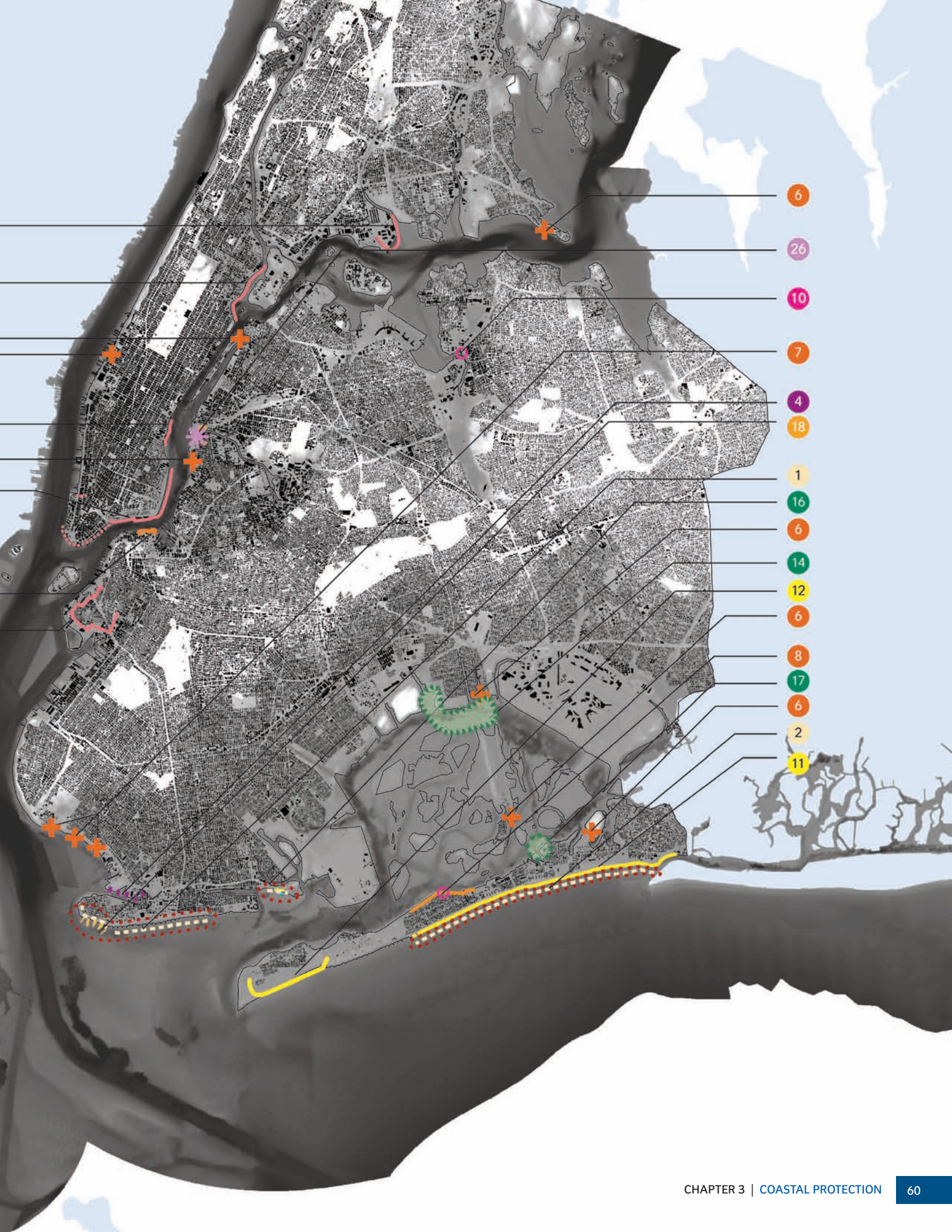
Protect Against Storm Surge

Integrated Flood Protection System
19. Hunts Point, Bronx
20. East Harlem, Manhattan
21. Lower Manhattan / Lower East Side
22. Hospital Row, Manhattan
23. Red Hook, Brooklyn

Floodwalls / Levees
24. East Shore, Staten Island
25. Farragut Substation, Brooklyn

Local Storm Surge Barrier
26. Newtown Creek

Current US Army Corps of Engineers Study and Project Areas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Post-storm flooding and erosion along Coney Island Creek, Brooklyn

Credit: Charles Denson/Coney Island History Project

Initiative 8
Complete bulkhead repairs and roadway drainage improvements adjacent to Beach Channel Drive on the Rockaway Peninsula

The flooding of neighborhoods along Beach Channel Drive on the Rockaway Peninsula exposed additional vulnerabilities along several portions of this vital roadway. The City, therefore, will complete bulkhead repairs from Beach 143rd Street to Beach 116th Street and install duckbill tide gates within a portion of the roadway drainage network in that area, reducing the risk of "backdoor" flooding. NYCEDC will ensure that this work, which began in 2011 and will be completed in 2014, will make effective use of existing funding and enhance protection during the 2013 hurricane season and beyond.

Initiative 9
Continue to work with the USACE to complete emergency floodgate repairs at Oakwood Beach, Staten Island

The failure of a floodgate in Oakwood Beach on Staten Island has left this neighborhood vulnerable to future storms. OLTPS, therefore, will call upon the USACE to complete floodgate repairs at this location, ensuring that this work, which is expected to begin in June 2013 and end by December 2013, makes effective use of existing Federal appropriations and enhances protection during the 2013 hurricane season and beyond.

Initiative 10
Complete tide gate repair study at Flushing Meadows Corona Park, Queens

The malfunction of a tide gate system within Flushing Meadows Corona Park in Queens has left this important public asset vulnerable to future storms and impacts from sea level rise. Subject to available funding, the City, through DPR, therefore will complete a tide gate repair study at this location to identify options to reduce the risk of future flooding. The goal is to complete this study in 2014.

Strategy: Minimize upland wave zones

Initiative 11
Continue to work with the USACE to complete existing studies of the Rockaway Peninsula and implement coastal protection projects

The entire Rockaway Peninsula faces continued risk of floods and wave action. The City, therefore, will call on the USACE to complete the Rockaway reformulation study started in 2003. This authorized study offers an expedited path to rethinking and improving the current flood protections on the Rockaway Peninsula. DPR will ensure that this work makes effective use of existing Federal appropriations to advance meaningful flood protection projects. It is expected that the reformulation study will be completed by 2015. The goal is to complete this project within four years of completing the USACE study. Consistent with this study, the City also will call upon the USACE to implement further beach

nourishment and dune construction projects in the area, working with DPR to complement its future boardwalk restoration plans. DPR also will work with the USACE to determine the feasibility and effectiveness of expanding or strengthening the existing groin fields on the Rockaway Peninsula. In the interim, DPR will complete short-term dune improvements on the Rockaway Peninsula from Beach 9th Street to Beach 149th Street in 2013, using low-cost and readily available solutions to mitigate the effects of storm waves on adjacent neighborhoods during the 2013 hurricane season and beyond.

Initiative 12

Call on and work with the USACE to study and install primary and secondary dune systems in vulnerable Rockaway peninsula neighborhoods (such as Breezy Point)

Neighborhoods such as Breezy Point suffered devastating damage from Sandy and remain exposed to extreme weather events, particularly along the ocean. Subject to available funding, the City, therefore will call on the USACE to study and construct a dune project to protect this neighborhood and to demonstrate the general effectiveness of primary and secondary dune systems as a defense against storm waves and flooding. OLTPS will oversee these efforts. The goal is to complete this project within four years of completing the USACE study.

Any such project would, if federal funding is involved, require public access to impacted areas. Accordingly, before this project could advance, the Breezy Point Cooperative would have to agree to that condition.

Initiative 13

Call on and work with the USACE to study and install offshore breakwaters adjacent to and south of Great Kills Harbor

The area of Staten Island adjacent to and south of Great Kills Harbor faces an increasing risk of wave action and erosion during extreme weather events that could undermine the shoreline bluffs and damage homes. Subject to available funding, the City, therefore will call on the USACE to study and construct a demonstration offshore wave attenuation project in this area, both to offer a first line of protection and to test the effectiveness of such a system. OLTPS will oversee these efforts. The goal is to complete this project within four years of completing the USACE study.

Initiative 14

Call on and work with the USACE to study and install wetlands for wave attenuation in Howard Beach and to study further flood protection improvements within Jamaica Bay

Howard Beach and Hamilton Beach, two Queens communities along the northern coastline of Jamaica Bay, are highly exposed, low-lying neighborhoods. Subject to available funding, the City, therefore will call on the USACE to implement a wetlands restoration project designed to attenuate waves. This project will build upon the existing work of the Hudson-Raritan Estuary Comprehensive Restoration Plan and leverage planning work done by the Nature Conservancy. It will not only protect the two aforementioned neighborhoods, but also will allow the effectiveness of such wetland restorations to be tested. DPR will oversee these efforts. The goal is to complete this project within four years of completing the USACE study.

Subject to available funding, the City also will call upon the USACE, simultaneous with the Howard Beach-Hamilton Beach wetlands restoration, to restart existing studies of the Rockaway Peninsula and of Jamaica Bay. These authorized studies offer an expedited path to project completion. Following completion of these studies, the USACE should implement coastal protection projects to provide flood protection and reconstitute some of the city's most important historic protective wetlands and marsh islands. DPR will ensure that this project makes effective use of existing Federal appropriations to advance combined flood protection and ecosystem restoration projects. If restarted now, this study should be completed by 2016 and would expedite restoration of Jamaica Bay wetlands, improvements to bulkheads in low-lying neighborhoods, and implementation of a local storm surge barrier for Rockaway Inlet.

Initiative 15

Call on and work with the USACE to study and install living shorelines for wave attenuation in Tottenville

Tottenville, the southernmost community in Staten Island, remains vulnerable to wave action in future extreme weather events. Subject to available funding, the City, through DPR, therefore will call on the USACE to develop and implement a living shoreline project, both to protect the neighborhood and to demonstrate the effectiveness of this approach to wave attenuation on the open Lower Bay. This living shoreline project, consisting of oyster reef breakwaters, beach nourishment, and maritime forest enhancements, will be located in an area adjacent to Conference House Park in Tottenville. The goal is to complete this project within four years of completing the USACE study.

Initiative 16

Continue to work with the USACE to complete its Plumb Beach breakwater and beach nourishment project in Southern Brooklyn

During Sandy, the first phase of the Plumb Beach nourishment project along the Belt Parkway in Southern Brooklyn likely prevented a breach of the adjacent highway, thus protecting a vital transportation link. The City will, therefore, call on the USACE to complete the second phase of this project, including the installation of offshore breakwater and additional beach nourishment components. DPR will ensure that this project makes use of existing Federal appropriations to provide meaningful protection to this critical asset. This project will be completed in 2014.

Initiative 17

Complete living shorelines and floating breakwaters for wave attenuation in Brant Point, Queens

Brant Point, on the eastern edge of the Rockaway Peninsula in Jamaica Bay, is a low-lying natural area that faces potential impacts from sea level rise and, during coastal storms, wave action. Subject to available funding, the City, through the Department of Environmental Protection (DEP), therefore will construct and evaluate living shorelines and floating breakwaters in Jamaica Bay. In addition to providing protection to Brant Point, this project will demonstrate that floating breakwaters can attenuate waves during non-storm conditions, protecting existing wetlands and marsh islands from the erosive forces of waves associated with sea level rise. The goal is to complete this project in 2014.

Initiative 18

Continue to work with the USACE to complete its Sea Gate project in Southern Brooklyn

The neighborhood of Sea Gate remains vulnerable to waves and flooding during extreme weather events. The City will, therefore, call upon the USACE to complete its existing groin project to protect this neighborhood. These groins, and associated beach nourishment, are primarily intended to protect the terminal groin at West 37th Street, but will also provide a first line of protection to the neighborhood against wave action. DPR will monitor this project so that it makes use of existing Federal appropriations to provide meaningful protection to an exposed neighborhood. This project will be completed in 2014.

Strategy: Protect against storm surge

Integrated Flood Protection Systems
In several parts of the city, flood risk associated with extreme weather events remains high. Yet, in these areas, existing conditions and land uses preclude the deployment of traditional measures such as levees or permanent floodwalls to reduce this risk. To address this challenge, the City proposes installing integrated flood protection systems.

These systems have been demonstrated to be effective at reducing flood risk around the world, including in the Netherlands, the United Kingdom, and parts of the Midwestern United States. To ensure that the systems constructed in New York City follow the best and latest practices and ideas, and subject to available funding, OLTPS will work with NYCEDC to conduct a global design competition that will seek partners to design these systems to be as efficient and cost-effective as possible. The goal is to launch the competition in 2013, and upon designation of winning ideas, will proceed into design and construction in 2014.

Initiative 19
Install an integrated flood protection system in Hunts Point

Hunts Point in the Bronx is home to the Hunts Point Food Distribution Center, an important part of the city's food supply chain, and is at risk of flooding during extreme weather events. Subject to available funding, the City, therefore will install an integrated flood protection system in Hunts Point. OLTPS will work with multiple agencies to design and construct this project. The expected alignment will be along the future Hunts Point greenway and along the water's edge between the New Fulton Fish Market and the Hunts Point Produce Market and may be designed to protect other adjacent city infrastructure, subject to available funding, include other adjacent City infrastructure. The goal is to complete design in 2014 with project completion by 2016.

Initiative 20
Install an integrated flood protection system in East Harlem

East Harlem is at risk for flooding during extreme weather events. Subject to available funding, the City, therefore will install an integrated flood protection system in East Harlem. OLTPS will work with multiple agencies to design and construct this project. The expected alignment will be along the Franklin D. Roosevelt East River (FDR) Drive esplanade between East 90th Street and East 127th Street, or could potentially follow the highway dividing wall. The goal is to complete design in 2014 with project completion by 2016.

Initiative 21
Install an integrated flood protection system in Lower Manhattan, including the Lower East Side

The Lower East Side includes not just a very large residential population, but also one that lives at among the highest densities in the United States. The area is also home to among the largest numbers of low and moderate income households in Southern Manhattan, with many housing NYCHA housing units alone located in the floodplain. This neighborhood, meanwhile, is the location of critical infrastructure that, if compromised, could have citywide impacts. These include support structures for the subway system, Con Edison substations, a DEP pumping station, and the FDR Drive. Subject to available funding, the City, therefore will install the first phase in the Lower East Side and Chinatown of what is intended eventually to be an integrated flood protection system for all of Southern Manhattan. The protection would be designed to produce only a minimal impact on, and generally support, neighborhood fabric during non-storm conditions. The expected alignment of this first phase would start north of the Brooklyn Bridge and continue north to approximately East 14th Street. The goal is for design work on this first phase to begin in 2014, with completion in 2016.

In addition to the foregoing, the City also will consider extending the first phase of this integrated flood protection system south from the alignment described above to Lower Manhattan, including the Financial District. This is because, though the area contains a smaller and less economically vulnerable residential population and is less densely-populated than the Lower East Side and Chinatown, it is a major hub of commercial activity for the region and, like the Lower East Side and Chinatown, contains vital infrastructure. Accordingly, the City will work with the local community, including the local business community and property owners, to explore alternative, private financing sources for the aforementioned southern extension that could be leveraged to secure new sources of public financing. By way of example, such private sources could include a modest per-square-foot assessment on commercial space that would be protected by this extension. When completed, the expected alignment of this extension would start at the southern end of the system proposed for the Lower East Side and Chinatown and would run south along South Street to Battery Park, with a small section running across West Street, north of Battery Park City. If funding were identified, the timing for the southern extension could be consistent with the schedule above.

Initiative 22
Install an integrated flood protection system at Hospital Row

Bellevue Hospital and its neighboring healthcare facilities flooded during Sandy and remain at risk of flooding during extreme weather events. Subject to available funding, the City, therefore will install an integrated flood protection system at Hospital Row north of 23rd Street in Manhattan. OLTPS will work with multiple agencies to design and construct this project. The expected alignment will be along the service road of the FDR Drive, utilizing floodwalls and other localized measures where appropriate to integrate the system. The system will specifically enhance protection to Bellevue Hospital, a critical trauma facility, and could potentially integrate with existing plans by neighboring facilities operated by New York University and the Veterans Administration. The goal is to complete design in 2014 with project completion by 2016.

Initiative 23
Install an integrated flood protection system in Red Hook

Red Hook is prone to coastal flooding and is home to vulnerable populations at risk during extreme weather events. Subject to available funding, the City, therefore will install an integrated flood protection system in Red Hook. OLTPS will work with multiple agencies to design and construct this project. The expected alignment will use a portion of the Brooklyn Waterfront Greenway and otherwise likely will follow the first mapped street inland of the waterfront. The goal is to complete design in 2014 with project completion by 2016.

Initiative 24
Continue to work with the USACE to complete existing studies on Staten Island and implement coastal protection projects

Sandy demonstrated the significant flood and wave risk on the East and South Shores of Staten Island, where much of the damage to structures and loss of life in the city occurred during the storm. Without additional protective action, those coastal communities remain vulnerable to future storms. The City will, therefore, call on the USACE to expedite the completion and implementation of its flood risk reduction study applicable to the East Shore of Staten Island, authorized by Congress in 1993.

DEP and DPR will work with the USACE to ensure that this work will make effective use of existing Federal appropriations to advance meaningful flood protection and inland drainage projects. It is expected that the first phase of this study will be completed in 2014 and will recommend elements such as buried levees and floodwalls between Fort Wadsworth and Great Kills. The City will work with the USACE to determine the approach and specific location for these protections. As part of this initiative, the City will call on the USACE to develop a plan for ongoing beach nourishment to restore sand rapidly after extreme weather events. The second phase of this study is expected to be completed in 2016, recommending the installation of flood protection projects between Great Kills and Tottenville. The City will call upon the USACE to implement recommended projects along the South Shore of Staten Island. The goal is to complete these projects within four years of completing the USACE studies.

Initiative 25
Call on and work with Con Edison to protect the Farragut substation

Con Edison's Farragut substation came close to flooding during Sandy. This vital element of the city's power distribution network, serving almost 500,000 customers (or approximately 1.25 million people), sits in an area of growing risk from storm surge. The City, therefore, will call on Con Edison to protect this vital electrical substation from the impacts of storm surge. To accomplish this, Con Edison could consider floodwalls along the perimeter of the facility or other measures to meet a higher design standard for flood protection. This project could be incorporated into Con Edison's upcoming rate case at the State's Public Service Commission. OLTPS will monitor and support with technical assistance the rapid implementation of this project.

Initiative 26
Call on and work with the USACE to study and install local storm surge barriers at Newtown Creek

Newtown Creek was the source of extensive flooding during Sandy, providing a prime example of the significant "backdoor flooding" risk posed by inlets and waterways citywide. Subject to available funding, the City, through OLTPS, therefore will call on USACE to implement a project that will minimize damage within Newtown Creek during storm events through the installation of a local storm surge barrier with gates and connecting levees at the mouth of Newtown Creek. These gates will close in advance of an extreme weather event to keep flood waters from flowing into Newtown Creek and its adjacent neighborhoods. As Newtown Creek is a Superfund site, proper coordination with the Environmental Protection Agency and others will be required to ensure successful project implementation. DEP will assist in the evaluation of potential water quality impacts. The goal is to complete this project within six years of completing the USACE studies.

Strategy: Improve coastal design and governance

Initiative 27
Continue to work with the USACE to complete its comprehensive flood protection study of New York Harbor

The USACE is required by statute to conduct a comprehensive study to address the flood risks of vulnerable coastal populations in areas that were affected by Sandy. This study is a unique opportunity to guide Federal investment designed to reduce the future risks of climate change to the region. The recent experience in Louisiana has shown this type of study requires robust local partnership to ensure success. To this end, the City will call on the USACE to: expedite its comprehensive study of flood protection in New York City; adopt this report's goals, strategies, and initiatives for New York City as a key element of its own comprehensive study; and ensure that the comprehensive study translates into projects ready for Congressional authorization. To ensure that all of the foregoing measures are taken, OLTPS, working with DCP, DPR, NYCEDC, DEP, and the New York City Department of Transportation (NYCDOT), will lead the City's collaboration with the USACE in the development of its study. By statute, the USACE must deliver this comprehensive study to Congress by January 2015.

Initiative 28
Implement the WAVES Action Agenda

Although Sandy exposed vulnerabilities on the city's waterfront, the storm did not diminish the City's resolve to continue using this waterfront for a variety of recreational, commercial, and natural purposes. In fact, the City's prior policy objectives on the waterfront, highlighted in *Vision 2020: The NYC Comprehensive Waterfront Plan*, remain critical to the city's future, emphasizing and building upon the coastal resiliency elements contained in PlaNYC. The City will, therefore, redouble its commitment to implementing the entire WAVES Action Agenda, completing several particularly relevant projects in 2013, including the Urban Waterfront Adaptive Strategies study, and revisions to the City's Waterfront Revitalization Program to address sea level rise.

Initiative 29
Implement citywide waterfront inspections to better manage the City's waterfront and coastal assets

The City currently conducts waterfront inspections in a decentralized manner, and according to inconsistent standards. Subject to available funding, the City, therefore will implement a centralized waterfront inspection program for its entire portfolio of coastal and waterfront assets. This program, managed by NYCEDC, will improve safety for the public, apply a consistent set of standards for all inspections, and allow for more cost-effective procurement of inspection contracts. It also will lead to better understanding of the state-of-good-repair of City assets, more effectively maintained waterfront assets, and reduced life-cycle costs. As part of the program, NYCEDC will update the inventory of the City's coastal and waterfront assets and will also update the inspection guidelines manual to incorporate inspection procedures for new asset types, such as beaches, wetlands, integrated flood protection systems, and boardwalks. Funding for subsequent repair and rehabilitation work will be assessed based on the inspection program's findings. The goal is to begin the first round of inspections in 2014.

Initiative 30
Study design guidelines for waterfront and coastal assets to better mitigate the effects of flooding

While Sandy exposed many areas of vulnerability within the city, it also identified effective protections that should be incorporated elsewhere. Subject to available funding, the City, through DPR, therefore will study the cost-effectiveness of new waterfront and coastal asset design guidelines for open spaces and natural areas, assessing whether and how best to use these areas to protect adjacent neighborhoods, to improve landscaping to direct and store excess floodwaters, to ensure that new open space and park designs allow for maximum resiliency of parkland after an extreme weather event, and to build upon existing DPR high-performance landscape guidelines. These projects will improve the predictability of regulatory permitting and provide for better habitat considerations in future designs. The goal is to complete the study in 2014.

Initiative 31

Evaluate soft infrastructure as flood protection and study innovative coastal protection techniques

In the course of developing this comprehensive coastal protection plan, several new and innovative coastal protection ideas emerged that warrant further long-term study to determine whether they could be cost-effective and successful in New York City. Subject to available funding, the City, therefore will partner with academic institutions, the planned the Science and Jamaica Bay Science and Resilience Center, and other interested organizations to evaluate innovative coastal protection techniques, such as employing sand engines (a means of nourishing beaches and supplementing dunes by utilizing natural ocean currents) in areas such as the Rockaway Peninsula, and "shallowing" (reducing the depth of) bays, such as Jamaica Bay, for flood and wave risk reduction. These partnerships, led by OLTPS, working with DEP and DPR, will develop or identify appropriate scientific procedures to evaluate the effectiveness of these and other soft infrastructure investments for flood protection and wave attenuation and will advance other innovative coastal protection ideas. The goal is begin the study in 2013.

Initiative 32

Evaluate the city's vulnerability to drainage pipe flooding and identify appropriate solutions to minimize those risks

Many of the coastal protection measures proposed herein include barriers against storm surges. In connection with these initiatives, existing or proposed drainage infrastructure will be reviewed on a project-by-project basis to evaluate whether tide gates, valves, or other backflow prevention devices could help to reduce the possibility of flood exposure, without impeding stormwater drainage from upland areas. Subject to available funding, the City, through OLTPS and working with DEP, NYCEDC, and NYCDOT, therefore will study how those site-specific pipe networks are likely to perform during extreme surge events and will seek to identify a range of cost-effective proposals to address identified risks. Current plans to install "duckbill" tide gates on existing roadway drainage networks, such as along Beach Channel Drive on the Rockaway Peninsula, also will be monitored to evaluate their effectiveness as protection against storm surge. The goal is to complete these evaluations concurrent with the design of these coastal protection projects.

Initiative 33

Evaluate strategies to fund wetland restoration and explore the feasibility of wetland mitigation banking structures

As discussed earlier in this chapter, wetlands can act as a natural buffer to protect upland communities by retaining some floodwaters and attenuating waves during storm conditions. New York City has thousands of acres of degraded wetlands that could provide increased coastal resiliency if they were restored and expanded. Financing for such projects, however, has proved challenging. Subject to available funding, the City, therefore will work with State and Federal agencies to examine the feasibility of wetland mitigation banking in New York City—an approach to ecosystem restoration that offers greater ecologies and economies of scale than traditional approaches to mitigation. If feasible, the City will pilot a mitigation bank to help fund a restoration project at Saw Mill Creek in Staten Island. The goal is for the first pilot project to be implemented by NYCEDC in 2014.

Initiative 34

Work with agency partners to improve the in-water permitting process

The current waterfront permitting system in New York City requires those seeking permits to navigate an often-confusing series of requirements from multiple agencies. The process to obtain proper permits can stretch for years and is costly, leading, among other things, to delays in the repair and development of waterfront infrastructure necessary for flood protection. The City will, therefore, work with State agency partners to explore development of a one-stop waterfront permitting website that will help applicants better understand the process, answer specific application questions, and facilitate approval of worthy applications. NYCEDC will provide support in the technical development of the website, which is expected to be managed subsequently by the State. The site will launch in 2014.

Initiative 35

Enhance waterfront construction oversight by strengthening the City's waterfront permit and dockmaster units

The City's waterfront permit and dockmaster units oversee waterfront structures that, in addition to their other functions, play an important role in flood protection during both storm and non-storm conditions. The City will explore options to enhance waterfront permitting and strengthen this function. SBS will update its fee schedule in 2014 to offset some of the costs of providing these services. The City also will explore moving waterfront permitting and dockmaster responsibilities from SBS to another agency with a more closely aligned mission.

Initiative 36

Identify a lead entity for overseeing the collaboration on the USACE comprehensive study and for overseeing the implementation of coastal flood protection projects

Without an appropriate investment in governance and oversight, the risk is high that coastal investments requiring long planning and implementation schedules will lose momentum and will not be completed on schedule or in concert with the City's resiliency goals. Therefore, OLTPS will assume the coordination role on coastal protection projects immediately.

Initiative 37

Call on and work with the USACE and FEMA to collaborate more closely on flood protection project standards

Federal investments in coastal protection typically are implemented by the USACE, while the National Flood Insurance Program is managed by FEMA. In certain instances, Federal investments in flood protection projects have not resulted in revised flood maps nor have they reduced the cost of flood insurance for property owners in newly protected areas. The City, therefore, will call on the USACE and FEMA to collaborate more closely on flood protection project standards to ensure that Federal investments that meet appropriate risk-reduction standards, produce a corresponding reduction in flood insurance rates in affected areas. OLTPS, working with DCP, will also call for closer project development coordination between these two Federal agencies to ensure improved project outcomes for those in affected areas. Additionally, OLTPS will call upon FEMA to recognize a variety of effective, yet temporary, deployable floodwall systems in future revisions to FIRMs.

Jamaica Bay

Credit: Ben Huff