A. HAZARD PROFILE

i. Hazard Description

Floods are the natural disasters that occur most frequently in the United States. One in three federal disaster declarations is related to flooding, and many of them affect heavily populated coastal communities—including New York City.

Flood Characteristics

Flood events, the temporary inundation of normally dry land, can vary significantly in their causes, rates of development, duration, and geographic scale. Floods can be caused by excess water from oceans, rivers, groundwater, rainfall, or sewers and are commonly induced by a rain or storm event. Seasonal and intra-annual variations in tidal and hydrological cycles, along with effects attributed to climate change (such as sea level rise, intense precipitation, and more frequent, severe storms), can also contribute to flooding. Some floods develop gradually, over a period of hours or days, such as those that can occur during hurricanes or other coastal storms. Other floods happen more quickly, sometimes in a matter of minutes, and are associated with a sudden event such as a thunderstorm. Similarly, the duration of a flood depends on many factors including paths for water to exit the flooded area, such as land gradients, waterways, sewers, or percolation into soils. A flood can be site-specific, impacting a single building or component of a piece of infrastructure; local, impacting a block or neighborhood; or regional, affecting an entire river basin or stretch of coastline.

Flood Types

There are four types of flood events that can affect New York City:

- Coastal Flooding
- Tidal Flooding
- Riverine Flooding
- Inland Flooding

Coastal Flooding

Coastal floods affect areas along the open ocean, bays, rivers, streams, or estuaries of tidal influence. In New York City, coastal floods are most commonly caused by storm surge from a strong coastal storm, such as a hurricane or other tropical storm or a nor'easter.

Storm surge is the increase in water levels brought about by the low pressure and wind field of a storm. When a storm approaches land, the storm surge "piles" up at the edge of the water body, raising water levels and leading to coastal flooding. The height of the surge can be measured by taking the difference between the observed storm tide and the astronomic (or normal) tide (see Figure 1). The geography of New York Harbor amplifies the impacts of a storm surge. The New York Bight—the 90-degree angle formed by the shorelines of Long Island and New Jersey—serves as a funnel directing storms towards New York City.

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Storm surge can cause "stillwater" flooding, or a rise in water levels without significant waves, or it can result in flooding accompanied by waves. With or without waves, coastal flooding can cause erosion and structural damage and create hazardous conditions. The salt or brackish water that comes with coastal flooding can ruin mechanical and electrical equipment and harm vegetation. Sea level rise is projected to exacerbate coastal flooding hazards (See Future Environment).

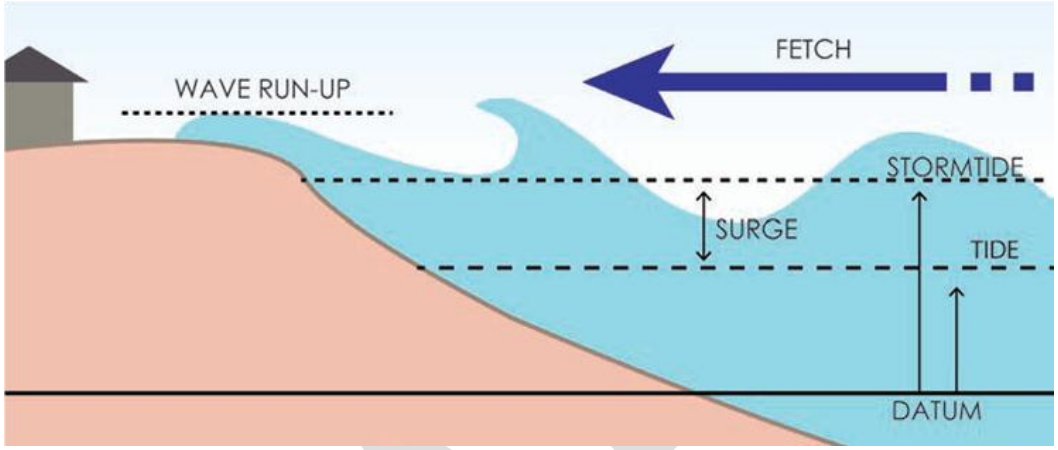

Figure 1: Storm Surge Height, Wave Run Up, Storm Tide, and Tide

Tidal Flooding

Sea levels fluctuate daily due to gravitational forces and the orbital cycles of the moon, sun, and earth. Each day there are two high tides and two low tides. These daily high tides are at their highest twice a month, during what is known as "spring tides," when the earth, sun, and moon are in a straight line.

Flooding from high tides affects some low-lying sections of the city today. The neighborhoods that are lowest-lying with extensive shoreline exposures are particularly vulnerable to tidal flooding. As sea levels rise, these neighborhoods can be expected to flood more frequently, while other low-lying neighborhoods that do not currently flood regularly with the tides will start to do so, in the absence of other measures. Regular tidal flooding could result in significant disruptions to neighborhoods and also bring about gradual erosion.

Riverine Flooding

Riverine flooding occurs when freshwater rivers and streams exceed local flow capacity and water spills over their banks. Flooding from large rivers usually results from large-scale weather systems that generate prolonged rainfall over expansive areas. These same weather systems may cause flooding of smaller basins that drain into major rivers, contributing to riverine flooding. Narrow rivers and streams are susceptible to flooding from more localized weather systems that bring intense rainfall over small areas. While riverine flooding is the most common type of flood event across New York State, it occurs less frequently and severely in New York City, where most freshwater rivers and streams are short and drain small areas.

Inland Flooding

Inland floods—commonly called "flash floods"—can be caused by short-term, high-intensity rainfall, often associated with sudden small-scale thunderstorms or hurricanes and other large-scale storms. Inland floods can also be caused by moderate rainfall over several days, typically brought on by weaker storms that drift slowly or stall over an area.

Inadequate drainage—due to condition or design capacity of the sewer and stormwater management infrastructure, along with natural drainage conditions and the surface characteristics of an area—can also contribute to inland flooding. In New York City, impervious surfaces—such as buildings, streets, sidewalks, and parking lots—reduce the amount of rainfall absorbed into the ground and can increase surface run-off volumes into the city's aging drainage infrastructure, increasing the likelihood of inland flooding. This effect is most pronounced in low-lying areas with limited natural drainage capacity, including parts of the city that once were marshes or creeks but were filled in years ago.

ii. Severity

Flood severity depends on flood type, cause, duration, and existing conditions, such as drainage design capacity and pathways for water to exit. The National Weather Service (NWS) categorizes flooding as minor, moderate, and major.

Category	Description
Minor	• Minimal or no property damage • Possibly some public inconvenience
Moderate	• Inundation of secondary roads • Transfer to higher elevation necessary to save property • Some evacuation may be required
Major	• Extensive inundation and property damage • Often involves the evacuation of people and the closure of both primary and secondary roads

Table 1: National Weather Service Flood Categories

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iii. Probability

Probability analysis helps determine the likelihood of a flood occurring in any given year and is a critical first step in developing flood mitigation practices. The foundation for flood probability analysis is an examination of the frequency of past flood events of different intensities and their recurrence intervals. The relationship between the probability of a flood and its impact on an area is complex and can range from low probability, high impact (as illustrated by Hurricane Sandy) to high probability, low impact (as demonstrated by monthly high-tide flooding).

The City relies on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) to determine flood risk probability for coastal and riverine flooding. These maps represent the federal government's official assessment of flood risk in an area. FIRMs indicate the geographic extent and height of a flood that has a 1% chance of occurring each year, referred to as the 100-year flood, and the extent and height of a flood that has a 0.2% annual chance (the 500-year flood). Mandatory flood insurance purchase and floodplain management standards apply to the 100-year flood zone. However, the terms "100-year" and "500-year" can be misleading, and perhaps even provide a false sense of security. A 100-year flood is not the flood that happens once every 100 years. Rather, it is the flood that has a 1% or greater chance of occurring in any given year. Experiencing a 100-year flood does not decrease the chance of a second 100-year flood occurring that same year or any year that follows. Even the 1% concept can be misleading—because when the years add up so does the probability. For example, a 100-year flood today, without considering future impacts from sea level rise or climate change, has a 26% chance of occurring at least once over the life of a 30-year mortgage. Similarly, a 100-year flood today has a 45% chance of occurring over the 60-year life of a power substation.

FEMA's FIRMs subdivide the 100-year floodplain, also referred to as the Special Hazard Flood Area (SHFA), into flood zones. These zones are geographic areas classified according to levels of flood risk and/or type of flooding (see Table 2).

Flood Zone Category	*Description*
V/VE*	Areas along coasts subject to inundation by a 1% annual chance flood with additional hazards associated with storm-induced waves over 3 feet high.
Coastal A	Areas landward of a V Zone or landward of an open coast without a mapped V-Zone subject to inundation by a 1% annual chance flood with additional hazards associated with storm-induced waves of 1.5 to 3 feet high. (These zones are not mapped in the 2007 effective FEMA FIRMs, but are included in the Preliminary Work Maps (PWMs) and will be included in future FEMA FIRMs for the New York Region.)
A/AE*	Areas subject to inundation by a 1% annual chance flood without wave action. Mandatory flood insurance purchase and floodplain management standards apply.
B/X (shaded)	Areas of moderate flood hazard subject to inundation by a 0.2% annual chance flood. Also called the 500-year flood zone.
*"E" indicates on the FIRMs that there is a base flood elevation determined.	

Table 2: Firm Flood Zone Categories

Coastal and Riverine Flooding

The coastal and river flood risk probability is determined by a number of factors, including severe weather events, like hurricanes, and regular high tide. The Federal government's official assessment of flood risk in a particular community is represented in FEMA Flood Insurance Rate Maps (FIRMs) which designate special flood-hazard areas and risk-premium zones. The 100-year floodplain, also referred to as the Special Flood Hazard Area (SFHA), identifies locations that have a one-percent or greater chance of experiencing coastal or riverine flooding in any given year and is broken down into subzones. The flood zones shown on the FIRMs are geographic areas classified according to levels of flood risk, with each zone reflecting the severity and/or type of flooding (See Table 2). Special flood hazard areas identify the probability of a coastal or riverine flood event is likely to increase in the future due to sea level rise and other climate change related factors. However, FIRMs do not include sea level rise projections, and therefore do not reflect full future coastal and riverine flooding risk.

The probability of coastal or riverine flooding is likely to increase in the future due to sea level rise and other climate change-related factors (see Future Environment, below). However, FIRMs do not include sea-level-rise projections and therefore may not reflect full future coastal and riverine flooding risk.

Tidal Flooding

The probability of tidal flooding is linked to both the lunar cycle and proximity to a tidal area. Low-lying sections of New York City have the highest probability of experiencing regular floods from high tides, with many areas already experiencing regular flooding today. As sea levels rise, the lowest-lying areas of the city will gradually become more vulnerable to regular flooding from daily and monthly high tides.

Inland Flooding

Inland floods can strike with little or no warning and are unrelated to the 100-year floodplain designation. Slow-moving thunderstorms repeatedly moving over the same area or a hurricane or other coastal storm can produce intense rainfalls leading to several inches of rain in a matter of seconds or hours. The heavy downpours can overwhelm New York City's sewer system and cause flooding and backups. Over the last several years, storms and precipitation events of great magnitude have been occurring more frequently than they did in the past. For instance, on June 7th 2013, the remnants of Tropical Storm Andrea brought 4.16 inches of rain to Central Park—an amount close to the total rain (4.41 inches) that typically falls during the entire month of June. The flooding that resulted forced officials to suspend subway service in northern Manhattan.

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iv. Location

New York City's 520 miles of waterfront are incredibly diverse, and each area faces different levels and types of flood risk. Low-lying areas, such as Staten Island's East Shore, southern Brooklyn and Queens, and portions of Lower Manhattan and Red Hook, Brooklyn, are particularly vulnerable to flooding from storm surge and sea level rise, but as shown in Figure 2 through Figure 6, all five boroughs have 100-year floodplain designations.

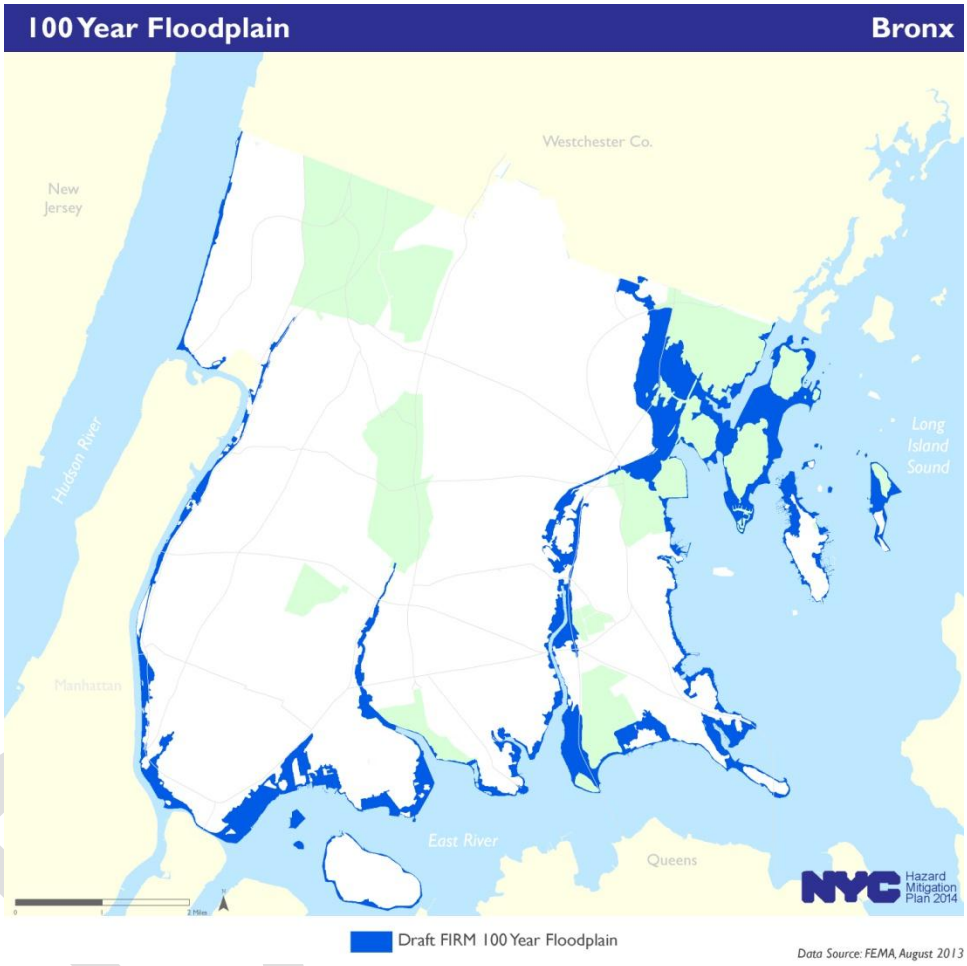

Figure 2: Bronx 100-Year Floodplain

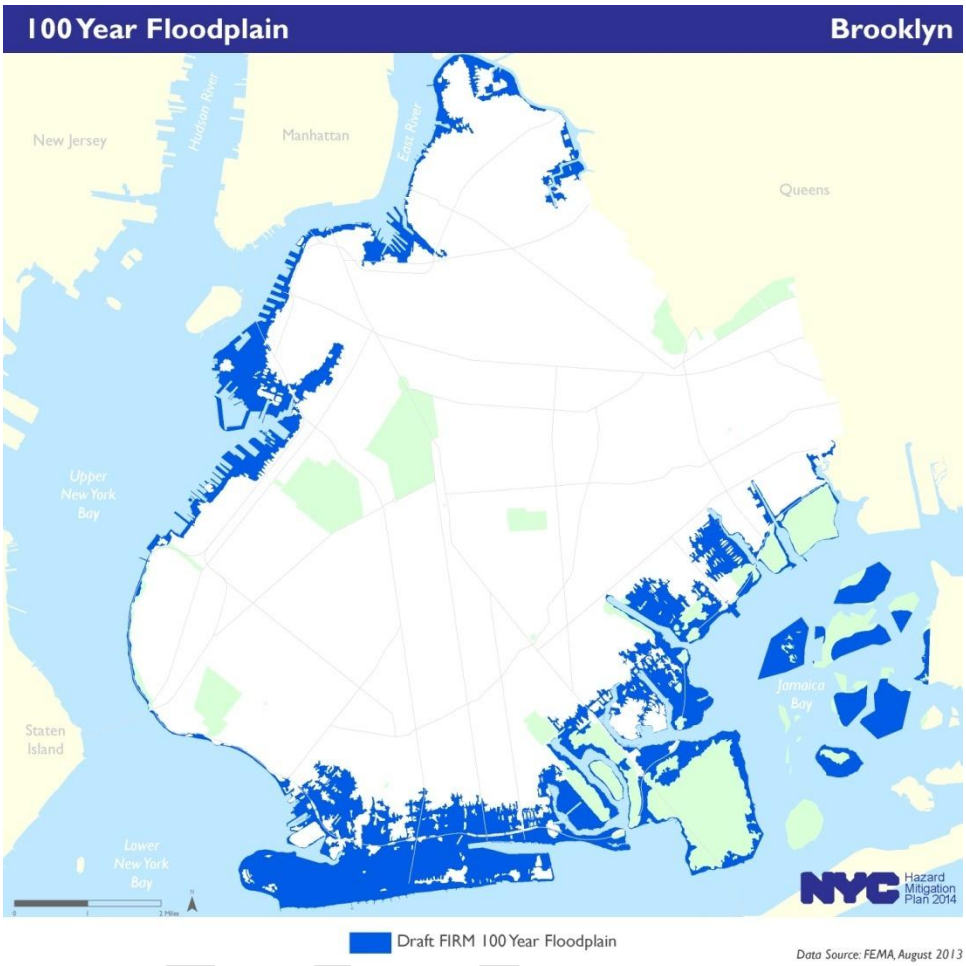

Figure 3: Brooklyn 100-Year Floodplain

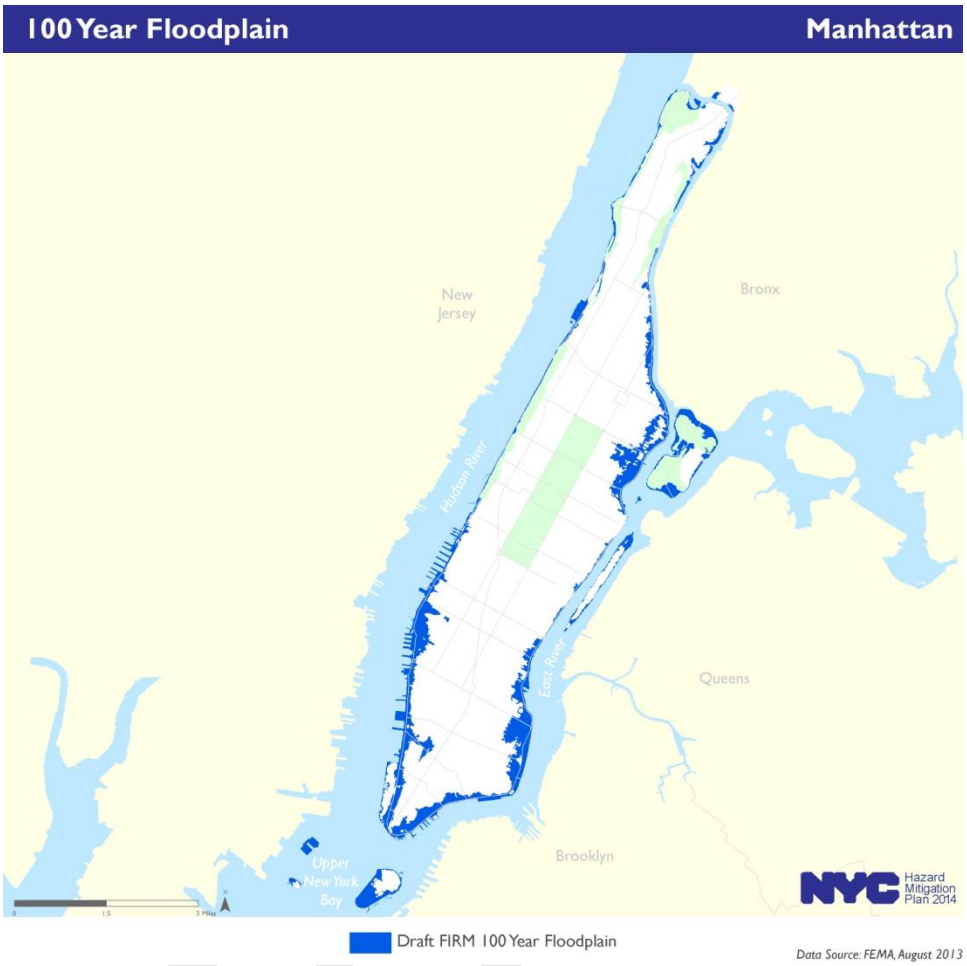

Figure 4: Manhattan 100-Year Floodplain

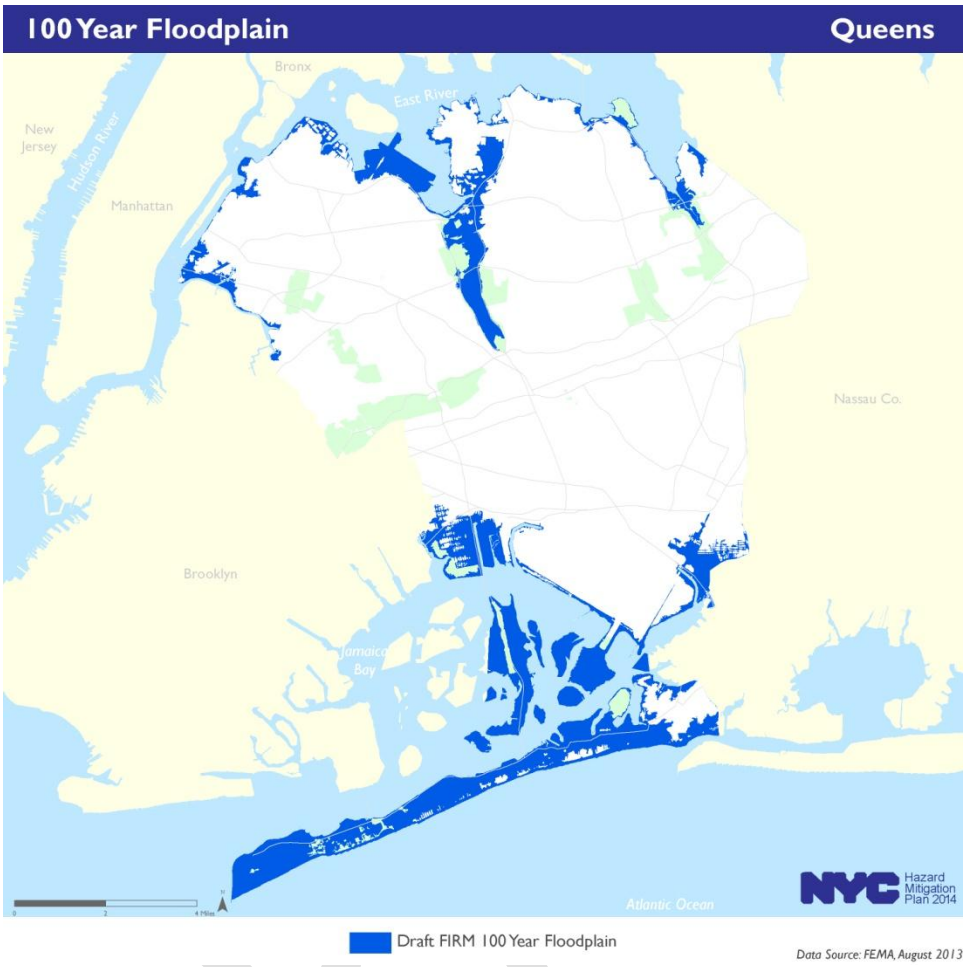

Figure 5: Queens 100-Year Floodplain

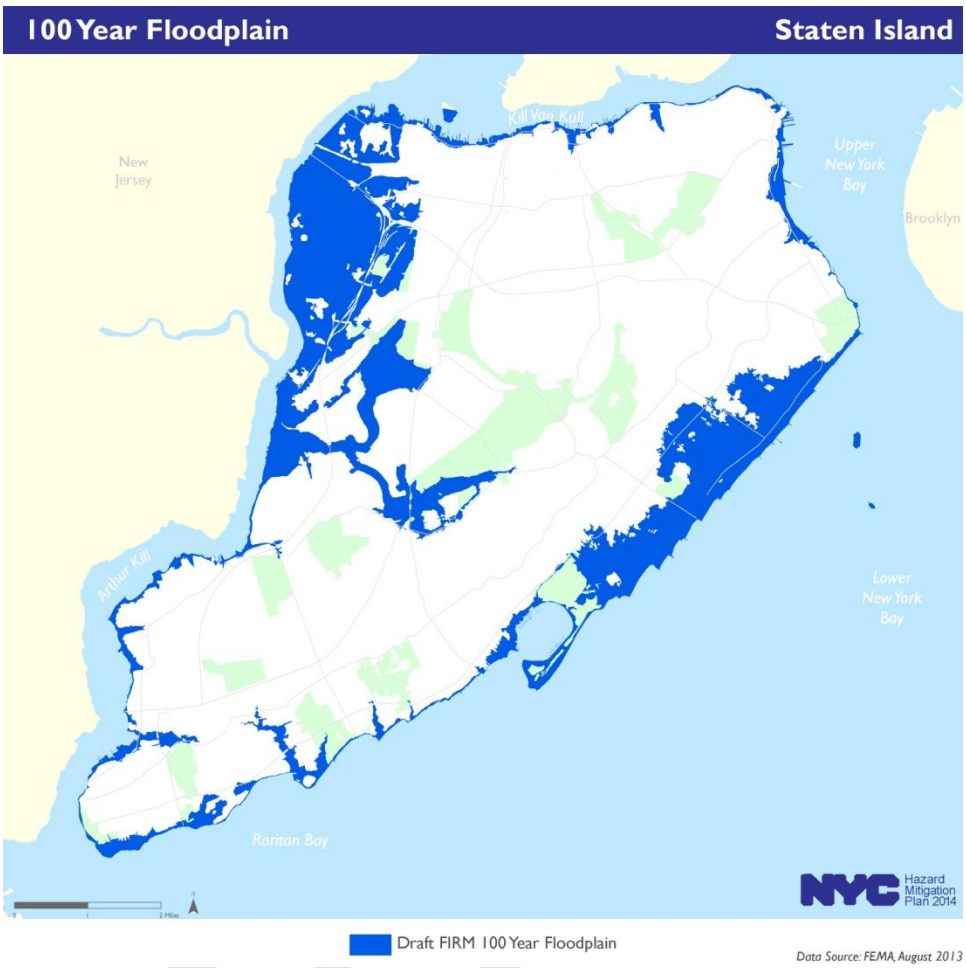

Figure 6: Staten Island 100-Year Floodplain

Coastal Flooding

All 520 miles of New York City's shoreline are affected by coastal flooding, though the height of flooding and the extent of the flood zone inland vary widely across the city.

In the lowest-lying areas of the city, where slopes towards the coast are gradual, flood heights are high and the flood zone extends far inland; these areas include those around Jamaica Bay in southern Brooklyn and southern Queens, the West and East Shores of Staten Island, portions of Lower Manhattan and Brooklyn along the New York Harbor, and sections of east Harlem and the South Bronx along the Long Island Sound. In other areas, where slopes rise quickly upland from the coast, flood heights are lower and the flood zone does not extend significantly inland; these areas include the North Shore of Staten Island, Bay Ridge and Sunset Park in Brooklyn, and the North Shore of Queens.

Wave forces most directly affect sections of Queens, Brooklyn, and Staten Island along the Atlantic Ocean. These areas include Coney Island and the Rockaway Peninsula, as well as areas of the Bronx along the Long Island Sound. As in much of the rest of the city, on the Rockaway Peninsula and around Jamaica Bay, the shoreline configuration has changed considerably over the past 50 years due to sediment movement, dredging, and filling. These changes affect wave propagation, particularly in areas such as Rockaway Point and Rockaway Inlet, where the configuration of the point controls the direction of incoming waves.

Inundation of low-lying coastal areas in the city, such as Staten Island's East Shore and southern Brooklyn and Queens, is primarily the result of storm surges, wave setup, and wave run-up, which occur during hurricanes and nor'easters.

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Though Hurricane Sandy was an exceptional event, with its record-high water level of 14.06 feet above Mean Lower Low Water and extensive flooding beyond the 500-year floodplain, it provides insight into the potential impact of coastal flooding across the city (See Figure 7). For more information on the combined effects of wind and storm surge on New York City, see Risk Assessment Section 6: Coastal Storms.

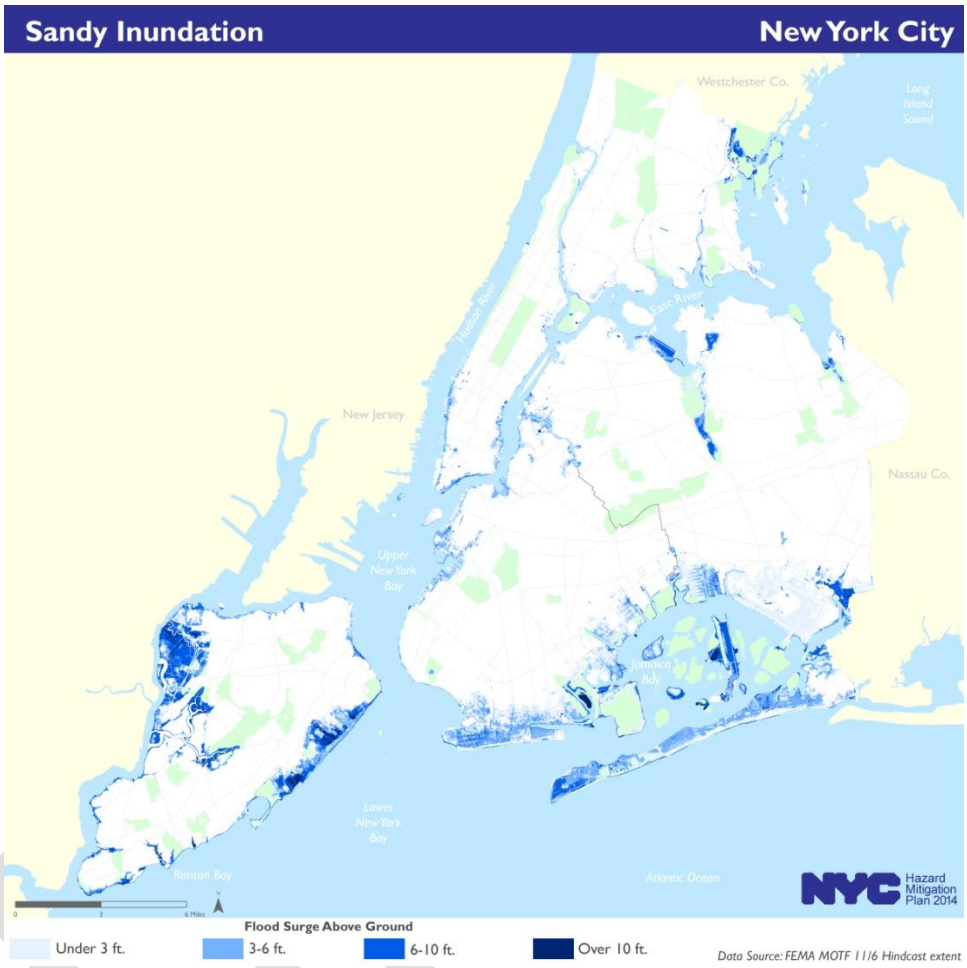

Figure 7: Sandy Inundation Area

Tidal Flooding

Low-lying neighborhoods throughout the city are vulnerable to regular flooding from high tides that result from the normal lunar cycle. As sea levels rise, these low-lying neighborhoods will gradually become more vulnerable to regular flooding from daily and monthly high tides if steps are not taken to prevent water from overtopping the shoreline. The risk of regular tidal flooding will be most pronounced in neighborhoods around Jamaica Bay in southeastern Queens, particularly Broad Channel and Hamilton Beach, and on portions of the bay side of the Rockaway Peninsula, which have some of the lowest-lying topography in the city.

Riverine Flooding

Riverine freshwater flooding affects only a small portion of flood-prone areas in New York City. Staten Island and the Bronx are the boroughs most vulnerable to riverine flooding given the

watershed characteristics in those boroughs. In the Bronx such flooding can come from the Bronx and Hutchinson Rivers, and on Staten Island from stream and river networks along the South shore and Mid-Island.

Inland Flooding

In New York City, areas prone to inland flooding often have low-lying topography, higher levels of impervious surfaces, and issues with drainage design capacity and condition. Certain neighborhoods—particularly those located on historically filled wetlands or with limited drainage infrastructure—have been subject to inland floods for many years.

In recent years more intense rainfall events have caused inland flooding in a broader range of communities. For example, in Staten Island and parts of the Bronx, inland flooding has increased from heavy or rapid precipitation that overwhelms the flow capacity of rivers, streams, and local storm sewers. Parts of the city that have antiquated or not fully built-out storm sewer systems—sections of southern Brooklyn (such as areas in Sheepshead Bay) and southern Queens including portions of Broad Channel, Edgemere, Bayswater, Far Rockaway, Rockaway Beach, and Arverne, as well as surrounding neighborhoods in southeastern Queens, such as Rosedale and Jamaica—currently experience street flooding during heavy rainfalls. Such flooding may be exacerbated if rainfall intensity increases with climate change.

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National Flood Insurance Program

Data from the National Flood Insurance Program (NFIP), which is administered by FEMA, helps to indicate the location of potential flood events. Through the program, which requires flood insurance for structures that carry a federal mortgage located within FEMA's effective 100-year floodplain, FEMA collects a vast quantity of information on insured structures, including the number and location of flood insurance policies, number of claims per insured property, dollar value of each claim, and "repetitive loss" (RL) claims—those for which a policyholder submits two or more claims after flood events within any rolling 10-year period and receives payments of $1,000 or more.

Figure 8 through Figure 10 spatially present several types of NFIP insurance data for each borough of New York City. Since 1976 there have been almost 43,000 claims. From 2012 to 2013, the city had 30,200 NFIP policies amounting to $39 million in premiums in the city. As of July 2013, there have been 16,400 claims filed since Hurricane Sandy, totaling in $980 Million in payouts.

If a policy holder submits two or more claims after flood events within any rolling 10-year period, and received payments of $1,000 or more from NFIP, this property is considered a Repetitive Loss (RL) structure. As of July 2013, New York City had a recorded 4,100 RL policies amounting to $200 million in payouts. Such properties are a high priority for flood mitigation.

A Severe Repetitive Loss property is one covered by NFIP and:

- Has at least four claim payments over $5,000 each that cumulatively exceed $20,000;
- Has at least two separate claim payments where the amount exceeds the market value of the building; and
- Has at least two claims that occurred within a 10-year period and greater than 10 days apart.

As of April 2012, there were 14 Severe Repetitive Loss properties, amounting to 1.3 million in payouts.

In July 2012, the U.S. Congress passed the Biggert Waters Flood Insurance Reform Act, which calls on FEMA and other agencies to make a number of changes to the way the NFIP is run. Some of these changes have been put in place, and others will be implemented in the coming months. The legislation requires the NFIP to raise rates to better reflect true flood risk, and make the program more financially stable. The changes will mean premium rate increases for some policyholders over time.

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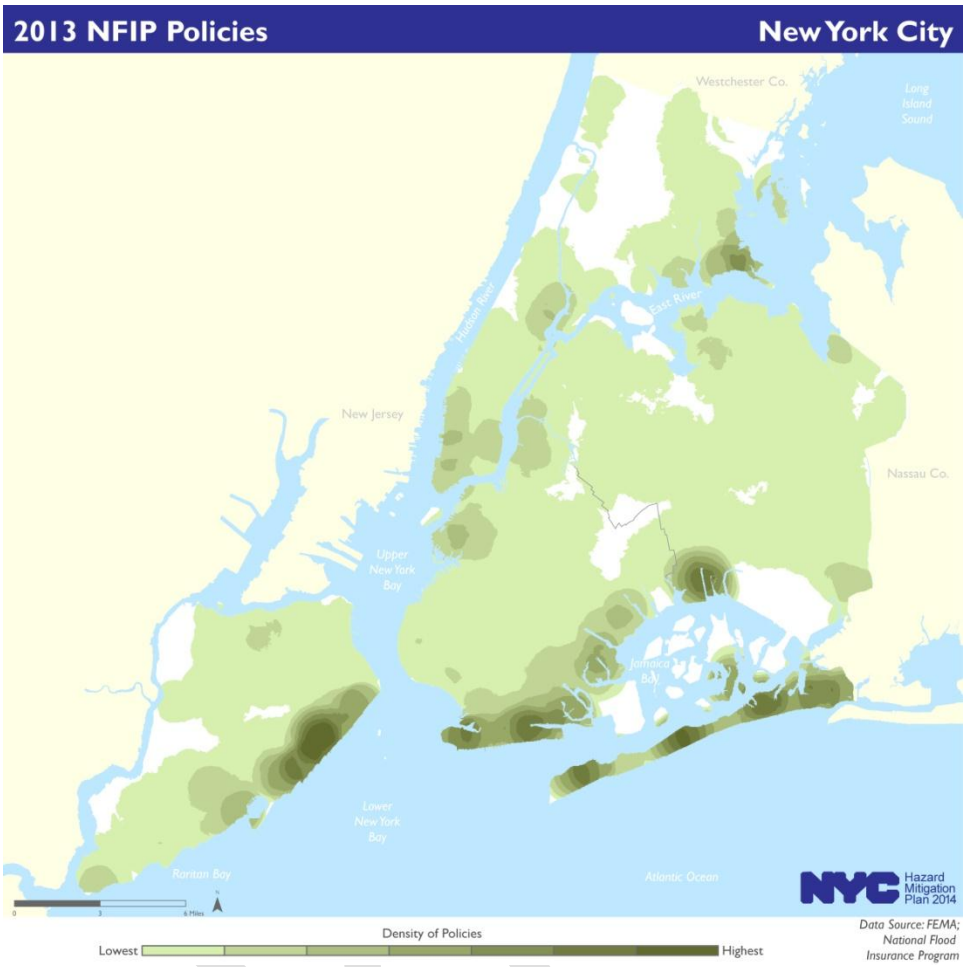

Figure 8: NFIP Policies

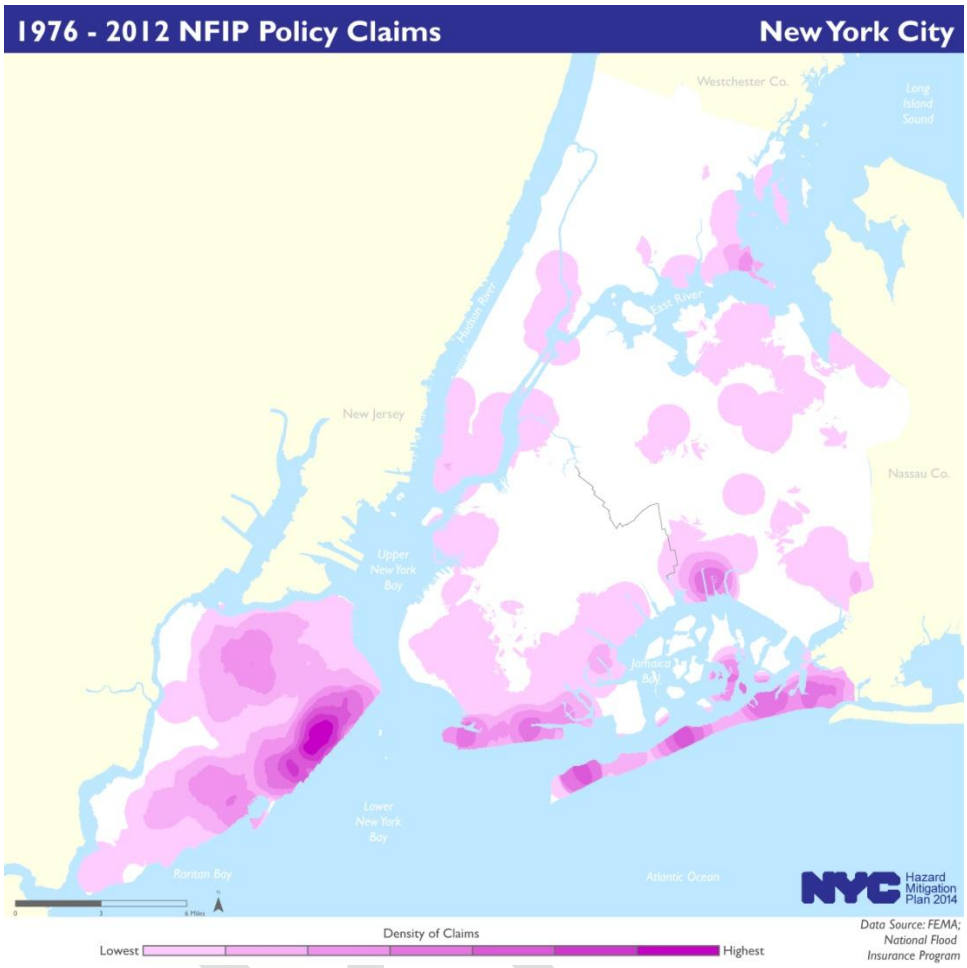

Figure 9: NFIP Policy Claims

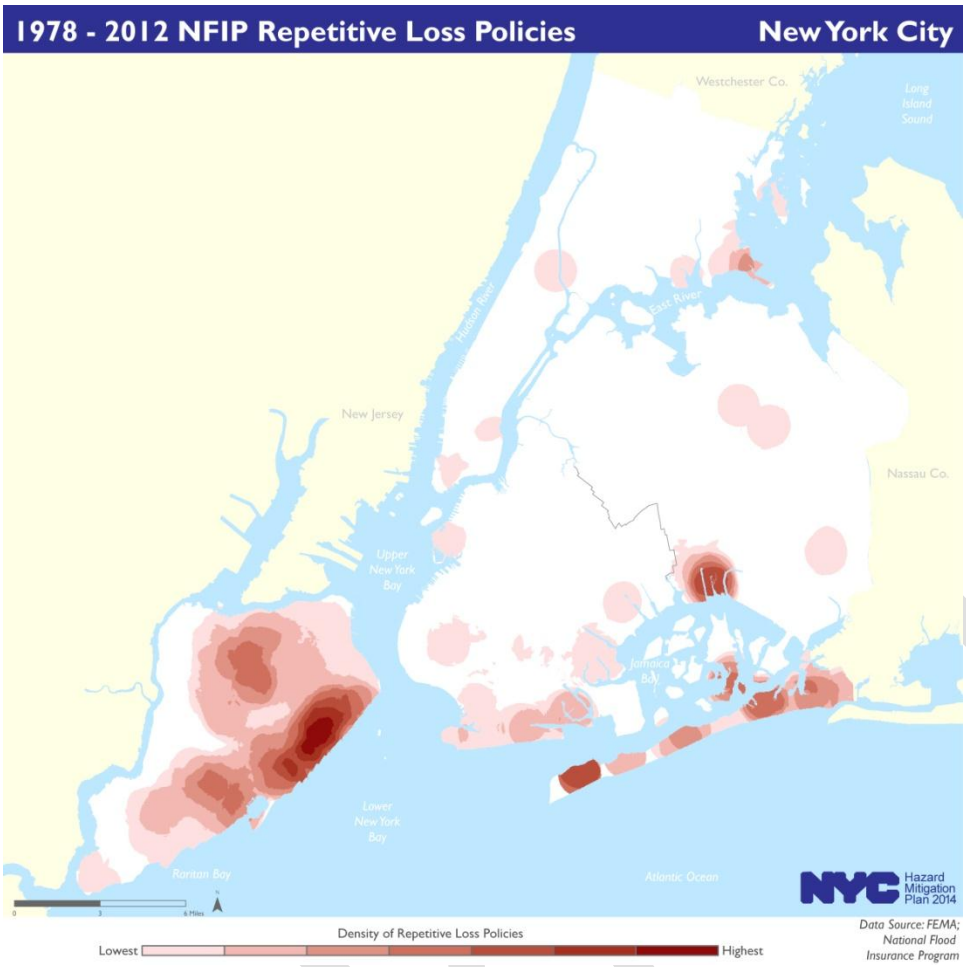

Figure 10: NFIP Repetitive Loss Properties

Historic Occurrences

New York City has suffered from numerous floods over the last decade. Table 3 includes select flooding events from 1993 to 2013.

Date	Event	Location(s)	Description
August 16, 1993	Inland flood	Manhattan	Widespread rain embedded with thunderstorms Floodwaters partially cover cars, stranding several people on their car roofs
June 29, 1994	Inland flood	Citywide	Torrential rains of nearly 2.5 inches produce substantial road and highway flooding Many basements flooded
June 22, 1995	Inland flood	Brooklyn, Queens	No information available

Date	Event	Location(s)	Description
July 1, 1995	Inland flood	Staten Island	Several homes damaged 3 people injured at a movie theater when ceiling tiles fall because of standing water on the roof
July 17, 1995	Inland flood	Bronx, Manhattan, Queens	Rainfall of 2 to 4 inches Many roadways closed
July 23, 1995	Inland flood	Bronx, Queens	No information available
October 21, 1995	Inland flood	Manhattan, Queens	No information available
November 14, 1995	Coastal flood	Queens	No information available
January 12, 1996	Inland flood	Citywide	No information available
January 27, 1996	Inland flood	Queens	No information available
April 16, 1996	Inland flood	Citywide	No information available
June 3, 1996	Inland flood	Citywide	No information available
July 3, 1996	Inland flood	Queens, Staten Island	Cars trapped in floodwaters on the Long Island Expwy. Serious road flooding reported along Richmond Pkwy.
July 8, 1996	Inland flood	Manhattan	High winds, large hailstones, and torrential rain
July 13, 1996	Flood	Brooklyn	Tropical Storm Bertha, serious, widespread flooding is reported along the Brooklyn-Queens Expwy.
July 31, 1996	Inland flood	Brooklyn, Queens, Staten Island	2 to 5 inches of rain in 3 hours Several houses damaged in mudslides at Richmond town, Staten Island Serious widespread flash flooding of roads and numerous basements flooded across Brooklyn and Queens
September 8, 1996	Inland flood	Bronx, Brooklyn, Staten Island	Thunderstorms produce torrential rain Significant flash flooding of low- lying and poor drainage areas, including many streets
October 19, 1996	Inland and coastal flood	Citywide	Heavy rains 3 to 5 inches of rainfall with isolated higher amounts Serious flooding of basements and first floors causes damage to 226 homes in Flushing and 70 homes in Springfield Gardens in Queens Numerous cars damaged in floodwaters
January 10, 1997	Coastal flood	Queens	Tidal flooding along Rockaway Blvd. in Brookville Moderate tidal flooding reported at Howard Beach

11. FLOODING

Date	Event	Location(s)	Description
November 2, 1997	Inland flood	Staten Island	Police scuba divers use rubber raft to rescue people from submerged car on Arthur Kill Road in Greenridge
January 23, 1998	Inland flood	Citywide	Heavy rainfall of 2 to just over 4 inches
March 9, 1998	Inland flood	Citywide	Widespread heavy rainfall including thunderstorms Many low-lying and poor drainage areas, including streets, are flooded
August 17, 1998	Flood	Bronx, Manhattan, Queens, Staten Island	Rainfall rates of up to 2 inches per hour LaGuardia Airport has 3.54 inches of rain
January 3, 1999	Inland flood	Citywide	People require rescue from flooded basement apartments in Springfield Gardens, Queens Water rises within 6 inches of ceilings in several apartments
January 15, 1999	Flood	Staten Island	Heavy rain falls on frozen ground with partially clogged storm drains Up to 2 feet of water collects in many streets in South Beach
August 26, 1999	Flood	Bronx, Manhattan, Queens	Flash flooding cripples public transit during the morning rush hour Subway service is severely disrupted as 3 to 5 feet of water collects at some subway stations 52 inches of water measured at the 6 station at Cypress Avenue in the Bronx A 10- to 20-foot section of the northbound platform for the 6 line at 28th Street crumbles and washes away Metro-North Railroad forced to close in Mott Haven in the Bronx
September 16, 1999	Flood	Citywide	Remnant of Hurricane Floyd Maximum rainfall rates of 1 to around 2 inches per hour for at least 3 consecutive hours 5.02 inches in Central Park
July 3, 2000	Inland flood	Brooklyn, Queens, Staten Island	Rainfall rates of up to an estimated 4 inches per hour for less than 1 hour Significant ponding of water traps people in two cars near the Verrazano-Narrows Bridge Significant low-lying and poor drainage flooding on Cross Island Parkway near Whitestone Bridge

Date	Event	Location(s)	Description
August 11, 2000	Inland flood	Bronx, Queens	Slow-moving thunderstorms produce rainfall rates estimated at around 2 inches per hour, causing significant flooding of low-lying and poor drainage areas In the Bronx, cars are submerged in rising water, trapping many people NWS radar estimates 2 to 3 inches of rainfall from 2:30 AM to 3:30 AM, with up to 5 inches during the preceding 24 hours
August 27, 2000	Inland flood	Staten Island	Heavy showers move very slowly east across northern Staten Island NWS radar estimates rainfall rates of 1.5 to 2 inches per hour for at least 2 consecutive hours Estimated rainfall of 3.5 to 4 inches results in serious widespread flooding of low-lying and poor drainage areas
August 28, 2000	Inland flood	Queens	NWS radar estimates rainfall rates of 1.5 to 2.0 inches per hour Total precipitation of 3.5 to 4 inches Serious widespread flooding on Cross Island Pkwy. in Whitestone Up to 5 feet of water ponds on streets in Bay Terrace
September 3, 2000	Inland flood	Queens	Nearly stationary thunderstorms produce torrential rain People have to be rescued from submerged cars on Northern Blvd. Several residential basements in poor drainage areas are flooded
June 17, 2001	Inland flood	Bronx, Brooklyn, Manhattan, Queens	Remnants of Tropical Storm Allison Rainfall rates of up to 3 inches per hour Numerous reports of street and highway flooding
June 23, 2001	Inland flood	Manhattan, Staten Island	Several people require rescue from their cars on Staten Island Large segment of West Side Highway between 100th and 120th Streets in Manhattan closed
August 13, 2001	Inland flood	Brooklyn, Manhattan, Queens	Rainfall rates of more than 2 inches per hour in portions of northern Queens Highly localized rainfall of 5 inches or more Several healthcare facilities flood, including one area hospital and seven area nursing homes
June 26, 2002	Flood	Bronx	Widespread flash floods with thunderstorm

Date	Event	Location(s)	Description
August 16, 2002	Flood	Bronx, Manhattan, Queens	3 feet of water on Major Deegan Expwy. at Cross Bronx Expwy. interchange, which requires police rescues Shutdown of the Henry Hudson Parkway from 96th Street to 125th Street Significant flooding in Far Rockaway
September 2, 2002	Inland flood	Brooklyn, Queens	Significant street flooding in Greenpoint, Brooklyn, and on Brooklyn-Queens Expy. Significant widespread street flooding in Woodside, Queens
July 22, 2003	Inland flood	Queens, Staten Island	Significant street flooding in Bayside Hills and Ridgewood Con Ed reports significant flooding that results in street closings near Richmond Avenue and Victory Blvd.
August 4, 2003	Inland flood	Brooklyn, Manhattan, Queens, Staten Island	Rainfall rates of 2 to 3 inches per hour N and R subway tunnels flood Basements in Brooklyn flood Sewers and septics back up onto streets in Annadale, Staten Island
August 17, 2003	Inland flood	Brooklyn	Isolated locations receive as much as 3 to 4 inches of rain in 2 hours OEM reports water levels up to car doors on the Belt Pkwy. near Pennsylvania Avenue
September 23, 2003	Inland flood	Bronx, Brooklyn, Manhattan, Queens	Several lanes close on the FDR and Harlem River Drives in Manhattan, the Van Wyck Expy. in Queens, Ocean Parkway in Brooklyn, and several local streets in Riverdale in the Bronx
June 17, 2004	Inland flood	Bronx, Brooklyn, Manhattan, Queens	Significant flash flooding on roadways results in the need for people to be rescued from cars
June 25, 2004	Inland flood	Queens, Staten Island	Several cars trapped in floodwaters
July 2, 2004	Inland flood	Bronx, Queens	179th Street and Major Deegan Expwy. in the Bronx flood Bell Blvd. and 208 Place intersection in Queens flood with 2 people requiring rescue from cars
September 8, 2004	Inland flood	Bronx, Brooklyn, Manhattan, Queens	Remnants of Hurricane Frances Rainfall of up to 6 inches Extensive flash flooding across the region, resulting in rescues of people from homes and cars

Date	Event	Location(s)	Description
September 18, 2004	Inland flood	Citywide	Remnants of Hurricane Ivan Torrential rains of up to 5 inches in some areas
September 28, 2004	Inland flood	Citywide	Remnants of Hurricane Jeane drop 3 to 6 inches of rain across southeastern New York State Numerous roads and highways are closed
July 6, 2005	Inland flood	Brooklyn	Slow-moving thunderstorms producing rainfall rates of around 2 inches per hour cause flash flooding of streets
October 14, 2005	Inland flood	Brooklyn, Queens	Flooding along Ocean Pkwy. and the Grand Central Pkwy. Several trees and power poles lean from soggy ground
June 1, 2006	Inland flood	Staten Island	Flash flooding on the West Shore Expwy.
June 2, 2006	Inland flood	Manhattan, Queens, Staten Island	Flash flooding on FDR in Manhattan Flash flooding of roads, submerged vehicles, and a few houses on Staten Island surrounded by 5 feet of water
July 12, 2006	Inland flood	Citywide	Flash flooding of the FDR service road at 34th Street in Manhattan, with thunderstorm Wall collapse in Washington Heights in Manhattan
July 21, 2006	Inland flood,	Citywide	Partial flooding from thunderstorm resulted in road closures on the Staten Island Expy., the Belt Pkwy., the Brooklyn-Queens Expwy., the Grand Central Pkwy. and Van Wyck Expwy. Subway service suspended in both directions on the R and W lines between Whitehall Street in Manhattan and Ditmars Blvd. in Queens
August 10, 2006	Inland flood	Manhattan, Queens	Flash flooding forces closure of subway lines 1, 2, 3, and 6.
August 25, 2006	Inland flood	Bronx, Queens	Flash flooding along many major roads results in road closures Most significant flooding along the Major Deegan Expwy. and Cross Bronx Expwy.
October 28, 2006	Inland flood	Bronx	Flash flooding along portions of the Bronx River Pkwy. and Bruckner Expwy.

Date	Event	Location(s)	Description
November 8, 2006	Inland flood	Staten Island	Heavy rain floods many basements and closes numerous streets Staten Island Railroad service is suspended because of flash flooding across tracks
April 15, 2007	Flood	Brooklyn, Manhattan, Queens	Nor'easter brings heavy rain and high winds. 8.41 inches of rain in Central Park Street flooding along the Belt Pkwy. in and FDR Drive in Manhattan
April 27, 2007	Inland flood	Bronx, Manhattan, Queens	Rainfall of 2 to 3 inches Flash flooding of the Jackie Robinson Pkwy. and West Side Hwy. In Manhattan
June 4, 2007	Inland flood	Bronx, Brooklyn, Manhattan, Queens	Heavy rain from the remnants of Tropical Storm Barry causes flash flooding in parts of southeast New York. Rainfall amounts of up to just under 4 inches in Central Park
June 27, 2007	Inland flood	Bronx, Queens	Severe thunderstorms produce flash flooding, hail, and high winds across parts of the region
July 11, 2007	Inland flood	Manhattan	Heavy rain
July 18, 2007	Inland flood	Bronx, Brooklyn, Manhattan, Queens	A cluster of heavy thunderstorms produces torrential rain that results in widespread and significant flash flooding across the region Maximum rainfall rates are estimated at 2 to 3 inches per hour Total rainfall of around 3 to 6 inches
August 8, 2007	Inland flood	Citywide	Storms produce copious amounts of rainfall, causing widespread, significant flash flooding, including of several subway lines Properties in Brooklyn experience damage from heavy rain and fallen trees Large closures due to flooding along several highways
October 11, 2007	Inland flood	Bronx, Brooklyn, Manhattan, Queens	A low-pressure system slowly moving north from the mid-Atlantic coast across New England produces flash flooding across parts of New York City
June 14, 2008	Inland flood	Citywide	Thunderstorm causes flash flooding
July 27, 2008	Inland flood	Staten Island	Caused by thunderstorms with torrential downpours

Date	Event	Location(s)	Description
August 11, 2008	Inland flood	Citywide	Numerous thunderstorms with torrential rainfall lead to flash flooding Reports of sinkholes and stranded cars
August 14, 2008	Inland flood	Queens	Thunderstorms producing torrential rainfall lead to flash flooding. Total rainfall of almost 1.5 inches reported
August 15, 2008	Inland flood	Bronx, Manhattan	Thunderstorms producing torrential rainfall lead to flash flooding Several highways closed
September 6, 2008	Inland flood	Citywide	Tropical Storm Hanna causes torrential rain from heavy showers and thunderstorms, resulting in flash flooding and some riverine flooding Closures due to flooding along several highways and roads
July 29, 2009	Inland flood	Citywide	Thunderstorms produce very heavy rain leading to flash flooding Several highways closed due to flooding
October 24, 2009	Flood	Staten Island	Rainfall over 18 to 24 hours causes isolated flooding
March 13, 2010	Coastal flood	Bronx, Manhattan, Queens	Automated Surface Observing System (ASOS) records 3.84 inches of rainfall in Central Park and 3.16 inches at LaGuardia Airport
March 28, 2010	Heavy rain	Manhattan, Queens	A Nor'easter causes widespread flooding Suspension of some subway lines reported Closure of highways and roads due to flooding
March 30, 2010	Heavy rain, flood	Bronx, Queens	A Nor'easter causes widespread flooding A mudslide on the MetroNorth railroad tracks Total rainfall of 4.38 inches recorded in Central Park
August 22, 2010	Inland flood	Queens	Heavy rain and training thunderstorms Several vehicles became stuck in floodwaters with occupants rescued by local fire department

Date	Event	Location(s)	Description
October 1, 2010	Flood, inland flood	Bronx, Brooklyn, Manhattan, Queens	Remnants of Tropical Storm Nicole result in heavy rain and flooding Suspension of some subway lines reported Closure of highways and roads due to flooding Total rainfall recorded by the ASOS at JFK Airport and LaGuardia Airports of 3.08 inches and 3.06 inches respectively
October 11, 2010	Inland flood	Brooklyn	A wave of low pressure along a cold front moving through the area causes heavy rain and flash flooding
August 14, 2011	Inland flood	Brooklyn, Queens, Staten Island	Heavy rain results in flash flooding
August 28, 2011	Coastal and tidal flooding	Bronx, Brooklyn, Manhattan, Queens	Hurricane Irene makes landfall locally as a tropical storm Copious amounts of moisture within the storm produce extended periods of heavy rainfall, resulting in widespread moderate to major flooding
June 22, 2012	, Inland flood	Staten Island	Showers and thunderstorms ahead of a cold front produce heavy rain, resulting in isolated flash flooding
July 18, 2012	Inland flood	Manhattan, Queens	Thunderstorms produce heavy rainfall and result in flash flooding Closure of highways entrance/exits ramps due to flooding
October 29, 2012	Coastal flood	Citywide	Post-tropical storm Sandy brings record-breaking tides and wave action, combined with high winds, to cause 43 deaths and untold number of injuries and inflict damages estimated at $19 billion 51 square miles of New York City flooded—17 percent of the city's total land mass
May 8, 2013	Inland flood	Brooklyn	Thunderstorms training over area produce heavy rain that coincides with high tide, resulting in flash flooding across parts of southern Brooklyn
May 9, 2013	Inland flood	Queens	Showers and thunderstorms produce heavy rain, leading to flash flooding

Date	Event	Location(s)	Description
May 23, 2013	Inland flood	Staten Island	Storms produce heavy rain, resulting in flash flooding
June 2, 2013	Inland flood	Manhattan	Showers and thunderstorms produce heavy rainfall, resulting in isolated flash flooding
June 6-8, 2013	Flood	Manhattan	The remnants of Tropical Storm Andrea tracking up the Eastern Seaboard result in a prolonged period of heavy rain Total rainfall of 4.77 inches over the course of 3 days recorded by the ASOS in Central Park 4.16 inches fell on June 7.

Table 3: Historical Occurrences of Flooding in New York City

B. Vulnerability Assessment

i. Social Environment

Socio-demographic characteristics can be important factors in determining vulnerability to a flood hazard; they can play a significant role in shaping risk perception and determining a population's capacity to take risk-reduction actions to minimize the impacts of a flood. In New York City, high-risk populations include children, seniors, low-income residents, those who do not speak English very well and thus are "linguistically isolated," those with disabilities or other pre-existing health conditions, and in-patient populations at hospitals and other healthcare facilities. For a detailed discussion of at-risk populations, see "Social Environment" in Risk Assessment Section 4: New York City's Hazard Environment. Here, a close examination of the potential impact of a flood hazard those over the age of 65 and those living below the poverty line to help illustrate the potential impact of a flood on at-risk populations.

	New York City		Bronx		Brooklyn		Manhattan		Queens		Staten Island	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Population	398,102	4.9	16,422	0.5	164,803	6.6	89,277	5.6	99,110	4.4	28,490	6.1%
Housing Units	174,842	5.2	5,826	1.1	71,311	7.1	43,695	5.2	43,043	5.2	10,967	6.2%

Table 4: Population and Households in 100-Year Floodplain (Source: US Census 2010)

Borough	Persons Per Acre
Bronx	5.9
Brooklyn	22.5
Manhattan	43.6
Queens	8.9
Staten Island	3.9
New York City	**13.0**

Table 5: Population Density in 100-Year Floodplain (Source: US Census 2010)

Population over the Age of 65

Age plays a central role in determining an individual's ability to take risk-reduction actions in an emergency. New Yorkers over the age of 65 are among the most vulnerable groups in a flood-related disaster. As a group, seniors are more likely to have health conditions and disabilities that require regular access to health services and medication. During flooding events, these services are often disrupted or severely restricted. Decreased mobility due to a disability or age-related fragility can prevent timely evacuation or movement to safer ground. In the aftermath of a flood, exposure to mold in flood-damaged buildings can have a greater impact on older populations, particularly those with respiratory infections, asthmatic symptoms, or other pre-existing health conditions.

15 percent of those living in the PWM 100-year floodplain—or approximately 60,600 people—are over the age of 65.

Flood risk vulnerability is acute among immigrant seniors. Almost 50 percent of New York City's older residents are foreign-born. As a group, older immigrants often earn lower wages, have less in retirement savings, and receive fewer benefits from traditional entitlement programs like Social Security and Medicare than native-born seniors. According to Center for Urban Futures, nearly two-thirds of immigrant residents age 65 and older have limited English proficiency and therefore may not be aware of critical city services and resources available during an emergency.

Hurricane Sandy tragically highlighted the vulnerability of seniors to flood hazards in New York City. Nearly half of the fatalities during Hurricane Sandy were among adults aged 65 or older, most due to drowning. The Mayor's Special Initiative for Rebuilding and Resiliency (SIRR) found that 27% of the households in the surge area included seniors, three percentage points higher than throughout New York City. Seniors living alone made up 12.1% of all households in the surge area. Since the city's elderly population is growing more rapidly than the overall population, this type of social vulnerability is likely to increase in the future.

	New York City		Bronx		Brooklyn		Manhattan		Queens		Staten Island	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Under 5	22,812	5.7	1,069	6.5	8,934	5.4	4,793	5.4	6,421	6.5	1,595	5.6
Under 18	80,463	20.2	3,629	22.1	32,572	19.8	15,130	16.9	23,157	23.4	5,975	21.0
Over 65	60,583	15.2	1771	10.8	29,157	17.7	11,024	12.3	15,280	15.4	3,351	11.8

Table 6: Population by Age Group within 100-Year Floodplain (Source: US Census 2010)

	Estimate of Population that Speak English less than "very well"	Estimate of Population for English Proficiency is determined	% Speak English less than "very well"
New York City	95,627	376,918	25.4%

Bronx	2,342	15,318	15.3%
Brooklyn	58,011	157,149	36.9%
Manhattan	17,983	85,022	21.2%
Queens	12,753	92,602	13.8%
Staten Island	4,538	26,827	16.9%

Table 7: New Yorkers Who Speak English Less than "Very Well" within the 100-Year Floodplain (Source: ACS 5YR 2007-2011)

Low-Income Population

Low-income communities are disproportionately affected by almost all disasters, including floods. A flood can damage and/or destroy housing, businesses, and inventory. Floods can also damage critical infrastructure and disrupt vital services (see Built Environment, below). Low-income households have fewer resources to prepare for and recover from such disasters and therefore face higher health and safety risks along with economic hardships. In New York City, a one-person household earning $11,500 or less and a four-person household earning $23,000 or less are designated as low-income (see Social Environment in New York City's Hazard Environment). Approximately 18% of those living in the 100-year floodplain according to the PWMs—or 70,000 people—is estimated to be below poverty level.

Moreover, a significant percentage of low-income households are renters and thus have little control over investment in post-flood repairs. With the high-cost of housing in New York City, finding alternative housing options—even temporarily, during an evacuation or immediately following a storm—can pose a serious challenge. As a consequence, many low-income individuals and families continue to occupy their damaged homes to avoid a greater allocation of income towards rent or even homelessness. Yet occupying uninhabitable residences can increase the vulnerability of low-income households in other ways, including increasing exposure to mold and other hazardous materials in flood-damaged buildings. Health problems, in turn, can result in lost wages or even loss of employment, further increasing economic vulnerability.

	Estimate of Population Below Poverty Level	Estimate of Population for whom poverty status is determined	% Below Poverty Level
New York City	70,706	390,756	18.1%
Bronx	3,159	15,617	20.2%
Brooklyn	30,768	163,669	18.8%
Manhattan	19,061	86,546	22.0%
Queens	15,671	96,546	16.2%
Staten Island	2,047	28,378	7.2%

Table 8: Population below Poverty Level within 100-Year Floodplain (Source: ACS 5YR 2007- 2011)

Hurricane Sandy offers data points that help illustrate vulnerability based on income and access to resources. Post-Sandy, low-income households—both renters and owners—were especially hard-pressed to cover losses, despite the availability of FEMA assistance. The median

household income reported by FEMA-registered New Yorkers was $82,000 for owners and $18,000 for renters. Nearly one-third of owners (29.9%) and two-thirds of renters (64.9%) have household incomes of less than $30,000 per year (roughly 60% of the median income in New York City). Given the extremely low incomes of the renters claiming damages, they are particularly at risk of being unable to locate new housing that is affordable to them. In normal times, the overall amount of housing affordable to these households earning less than $30,000 per year is limited to just 22% of rental units in New York City. Replacing lost housing for these families is likely to be a long-term challenge for New York City.

While low-income renters were particularly vulnerable to housing instability after Sandy, many homeowners affected by Sandy were already facing the threat of foreclosure when the storm hit. They may face an even tougher struggle to retain their homes. There were 1,800 owners of one- to four-family homes in the surge area who had had foreclosure proceedings started against them in the two years prior to the storm.

ii. Built Environment

New York City boasts one of the world's densest and most diverse agglomerations of infrastructure and built assets. However, much of this built environment is vulnerable to inundation and structural damage during a flood.

- Buildings
- Wastewater and Waste Management Infrastructure
- Transportation Infrastructure
- Energy Infrastructure
- Telecommunications
- Critical Assets

Buildings

Flood risk varies by building height, construction type, and age. In general, low-rise buildings (one to two stories) are more vulnerable to structural damage than mid-rise (three to six stories) and high-rise (seven stories or higher) buildings. Moreover, low-rise buildings tend to house primary uses on the ground floor and therefore face higher risks of experiencing substantial damage. Low-rise buildings also tend to be constructed of lighter, wood stud-frame materials, which are more prone to structural damage and fire from electrical shorts caused by flooding than steel, masonry, or concrete frames, which are more characteristic of more recent and denser building types. Although wood buildings are less expensive to repair, reconstruct, and elevate than masonry buildings, new wood-frame housing is generally not permitted in New York City.

Older buildings are more likely to sustain significant flood damage than newer buildings primarily due to the increasingly stringent building and zoning standards that have been put into effect over time. Adherence to flood-resistant construction standards greatly reduces

vulnerability to flood damage. While data on the elevation and floodproofing characteristics of buildings is limited, building age serves as a proxy indicator of structural vulnerability.

Not surprisingly, during Hurricane Sandy, older (constructed before 1961) one-story buildings sustained the most severe structural damage. High-rise buildings generally experienced less structural damage, but they did sustain damage to building systems (housed in basements or otherwise insufficiently elevated), which was in many cases costly and disruptive. While severe damage to small buildings clearly has adverse consequences for owners and occupants, damage to larger buildings can also have lasting economic consequences, particularly in coops or condominiums, or where lost or damaged space represents a significant share of the building's cash flow.

Single-story light-frame buildings constructed before 1961—such as bungalows erected for seasonal use in many coastal areas of the city—was the building type most vulnerable to Hurricane Sandy's effects. Buildings matching these characteristics represent 21% of the buildings in the PWM 100-year floodplain (see Table 9).

FEMA's 2013 PWMs define the 100-year floodplain as an area that encompasses 67,700 buildings, or over 534 million square feet of floor area. These buildings contain substantial value and house important functions such as housing, offices, schools, and hospitals. Approximately 196,700 residential units, home to almost 400,000 New Yorkers, are located within the 100-year floodplain.

	1 Floor		2 Floors		3-6 Floors		7 Floors or Higher	
	Combustible	Non-Combustible	Combustible	Non-Combustible	Combustible	Non-Combustible	Combustible	Non-Combustible
Pre-1961	21.0%	2.6%	35.4%	1.0%	7.4%	1.2%	0.1%	0.4%
Post-1961	2.8%	0.9%	18.8%	0.5%	6.7%	0.7%	0.1%	0.6%

Table 9: Building Type and Age within 100-Year Floodplain (Source: MapPluto 13V1; FEMA, Preliminary Working Maps)

Wastewater and Waste Management Infrastructure

Much of the city's critical wastewater and waste management infrastructure is located in the 100-year floodplain. These critical facilities are often sited along the waterfront out of operational necessity or were built there years ago during the development of the infrastructure network.

For example, all of the city's 14 wastewater treatment plants are located along the waterfront at low elevations because waterfront adjacency significantly reduces the cost and environmental impact of treating wastewater in New York City. All 14 of the city's wastewater treatment plants have assets in the PWM 100-year floodplain that are potentially vulnerable to inundation by storm surge. If not properly adapted, the majority of New York City's wastewater treatment infrastructure is at risk of being damaged in severe storms or floods, which can lead to combined sewer overflows and contamination of the waterways—as Hurricane Sandy

powerfully demonstrated. Floodwaters from a surge can cause significant damage not only to wastewater management facilities but to the critical equipment they house. The corrosive impact of seawaters on electrical systems creates disruptions in the power supply at these facilities, resulting in an overflow of partially treated or untreated sewage into waterways.

Additionally, a significant share of both municipal and private solid waste management facilities, as well as other industrial facilities that store and use hazardous materials, are located within the 100-year floodplain. Flooding at facilities that store hazardous materials and solid waste—but don't properly manage such materials—can cause dispersion of contaminants, with adverse effects on employees, nearby populations, and natural resources.

Transportation Infrastructure

Many parts of the New York's transportation system, such as ferry terminals, are located near the waterfront due to operational needs or demands of transportation networks. Some transportation assets are built in low-lying areas or even below sea level. For example, rail and vehicular tunnels and subway stations—which make up a significant portion of the city's transportation network—are all located underground. According to the PWMs, approximately 12% of the city's roadway networks, all of the major tunnel portals other than those for the Lincoln Tunnel, portions of both airports, a variety of commuter rail assets, all three heliports, and numerous subway entrances and vent structures (principally in Lower Manhattan) are located in the 100-year floodplain. These assets are vulnerable to flooding from both coastal surge and heavy downpour.

Hurricane Sandy illustrated the potential impact a storm surge can have on vehicular tunnels, subway stations, roads, and airports. The transportation outages that followed the storm impaired mobility and access to, from, and within the city and the region, affecting 8.5 million public transit riders, 4.2 million drivers, and 1 million travelers.

Locations where tunnel entrances are in low-lying areas or in areas with poor subsurface drainage are particularly vulnerable to flooding. Examples of infrastructure matching this flood profile include the F train on Hillside Avenue in Queens and several subway lines in Lower Manhattan.

Generally, heavy downpours pose only a moderate risk to roads and bridges, which may experience more frequent temporary flooding, but not more lasting damage. New York City's vast street network is also vulnerable to flooding from heavy precipitation, storm surge, or, as in the case of neighborhoods such as Hamilton Beach and Broad Channel in Queens, high tides.

Energy Infrastructure

Much of the city's underground electric and steam distribution systems and generating facilities are located near the coast, and are thus vulnerable to storm surge and floodwaters. Approximately, 88% of the city's steam generating capacity lies within the PWM 100-year floodplain. In the electric system, 53% of in-city electric generation capacity, 37% of

transmission substation capacity, and 12% of large distribution substation capacity are within the 100-year floodplain. Sea-level-rise projections indicate the numbers of at-risk facilities will continue to grow in the coming decades.

For the natural gas system, the biggest risk that storm surge poses is to the distribution infrastructure. Although flooding itself will not stop the flow of gas, service can be compromised if water enters pipes.

Moreover, the generation of much of the city's electricity and steam power is dependent on natural gas and liquid fuel. Any disruption to the fuel supply chains can result in a disruption in power and steam production. Given the location of key terminals, pipelines, and refineries—and the importance of waterfront access for the movement of fuels into New York City—the greatest risk to the liquid fuel supply is storm surge. Of the 39 terminals in the New York metropolitan area, nearly all lie within FEMA's 100-year floodplain as mapped on the 1983 FIRMs.

Telecommunication Infrastructure

New York City's telecommunication services – telephone, wireless, internet, and cable – are vulnerable to flooding, particularly from storm surge. Though telecommunications facilities are generally farther from the floodplain, almost 13% of the city's critical telecommunication facilities lie in the PWM 100-year floodplain. Also, the high dependency of telecommunications on the power network significantly increases risk of service interruption during a flood. Vulnerability is projected to increase with climate change. For example, by the 2020s, the number of critical facilities in the 100-year floodplain will grow to approximately 18%. By the 2050s, that number is expected to climb to 24%. With up to 2.5 feet of sea level rise expected by the 2050s, the risk to critical central offices, including the two largest central offices serving Southern Manhattan, is likely to increase.

Critical Assets in 100-year floodplain

Table 10 displays the vast number of critical assets located within the 100-year floodplain. These assets have a 1% chance of being flooded in any given year.

Critical Asset	#
Subway stations	27
Rail stations	8
Bridges and tunnels	32
Major roads (miles)	154
Airports	2
Ferry landings	33
Emergency services—police stations	18
Emergency services—fire stations	8
Emergency services—EMS stations	4
Educational—colleges	4
Educational—public schools	99
Educational—private schools	30
Healthcare—hospitals	5

Healthcare—nursing homes	16
Healthcare—hospice	1
Healthcare—adult day healthcare centers	6
Infrastructure—power plants	10
Infrastructure—wastewater treatment plants	7
Telecommunications	10

Table 10: Critical Assets in the 100-Year Floodplain

The vulnerability of New York City's critical assets to flooding was reinforced by the city's experience during Hurricane Sandy. Close to 2 million people lost power at some point during the storm, with almost a third of these customers in Manhattan. Six hospitals closed—four in Manhattan, one in Brooklyn, and one on Staten Island—requiring City and State health officials, co-located at the City's Office of Emergency Management, to coordinate the evacuation of nearly 2,000 patients. Many of the city's highways, roads, railroads, and airports flooded. For example, all six East River subway tunnels connecting Brooklyn and Manhattan were knocked out of service by flooding, along with the Steinway Tunnel that carries the 7 train between Queens and Manhattan, the G train tunnel under Newtown Creek, the Long Island Railroad and Amtrak tunnels under the East River and the PATH and Amtrak tunnels under the Hudson River.

However, the PWMs do not reflect the full flooding risk to New York City's building stock and critical infrastructure. That is because these maps are based on historical storm profiles and do not take into account potential changes in coastal storms or projected sea level rise. Based on recent high-end projections for sea level rise, the city's floodplain could expand to include, for example, more than 88,000 buildings by the 2020s and more than 114,000 buildings by the 2050s.

Potential Loss Estimates

HAZUS-MH flood scenarios were completed using HAZUS-MH v2.1 (with ArcGIS 10.0). The HAZUS-MH flood model provides damage estimates based on the depth of flooding for a given location. It is assumed that damages are a result of standing water (the model does not account for damage that may be inflicted by water moving at high speed). This methodology should not be treated as or confused with a storm surge model.

This analysis focused on the impacts of the 1% annual chance flooding event (a.k.a. the 100-year flood). At the time of the analysis, FEMA was in the process of completing updates to the FIRMs for New York City. Although the new maps were not in effect at the time of publication, FEMA had already produced PWMs, published in May 2013, which contained the best available data to date. In the case of the PWMs, the floodplain consists of flood zones AE, AO and VE.

As with the other hazards modeled, the focus was on damage to buildings (as quantified by building damage counts, damage states, and dollar losses). Damages are categorized by percent of total replacement cost. These determinations are based on the depth of flooding in relation to the height of the first finished floor of a building. The results of the analysis help shed light on the expected distribution and level of losses for different areas. Although building damage

counts may not always reflect exact conditions on the ground, especially when analyzing small areas, percentages of buildings damaged and losses over the entire study area should provide a relatively accurate picture of the level of damage that might be expected to occur.

Overall, 13,341 buildings are in the 100-year floodplain. Slightly less than half of these buildings are predicted to have damage based on the HAZUS-MH output; 2.5% of these buildings are predicted to have significant damage to more than 50% of the structure.

Borough	Percentage of Building Damage							
	None	1–10%	11–20%	21–30%	31–40%	41–50%	>50%	Total
Bronx	529	34	295	316	74	90	24	1,362
Brooklyn	2,280	271	450	271	44	46	11	3,373
Manhattan	211	70	70	111	10	1	4	477
Queens	2,512	346	594	655	181	130	89	4,507
Staten Island	1,961	78	478	497	250	148	210	3,622
Total	7,493	799	1,887	1,850	559	415	338	13,341

Table 11: HAZUS-MH Calculations for Building Damage from a 100-Year Flood

Table 12 and Figure 11 through Figure 15 highlight the key findings from the HAZUS-MH run of a 100-year flood in New York City. A 100-year flood affecting all five boroughs could cause more than $12 billion in damage. More than 60% of the total damage would be to contents such as furniture, supplies, and other possessions.

Borough	Building Damage	Contents Damage	Inventory	Total
Bronx	302,256	439,998	21,455	763,709
Brooklyn	903,775	2,025,808	148,686	3,078,269
Manhattan	1,737,769	2,639,381	49,764	4,426,914
Queens	1,053,671	2,323,539	72,530	3,449,740
Staten Island	224,797	268,275	10,232	503,304
Total	4,222,268	7,697,001	302,667	12,221,936

Table 12: HAZUS-MH Calculations for Capital Stock Losses for a 100-Year Flood

DRAFT

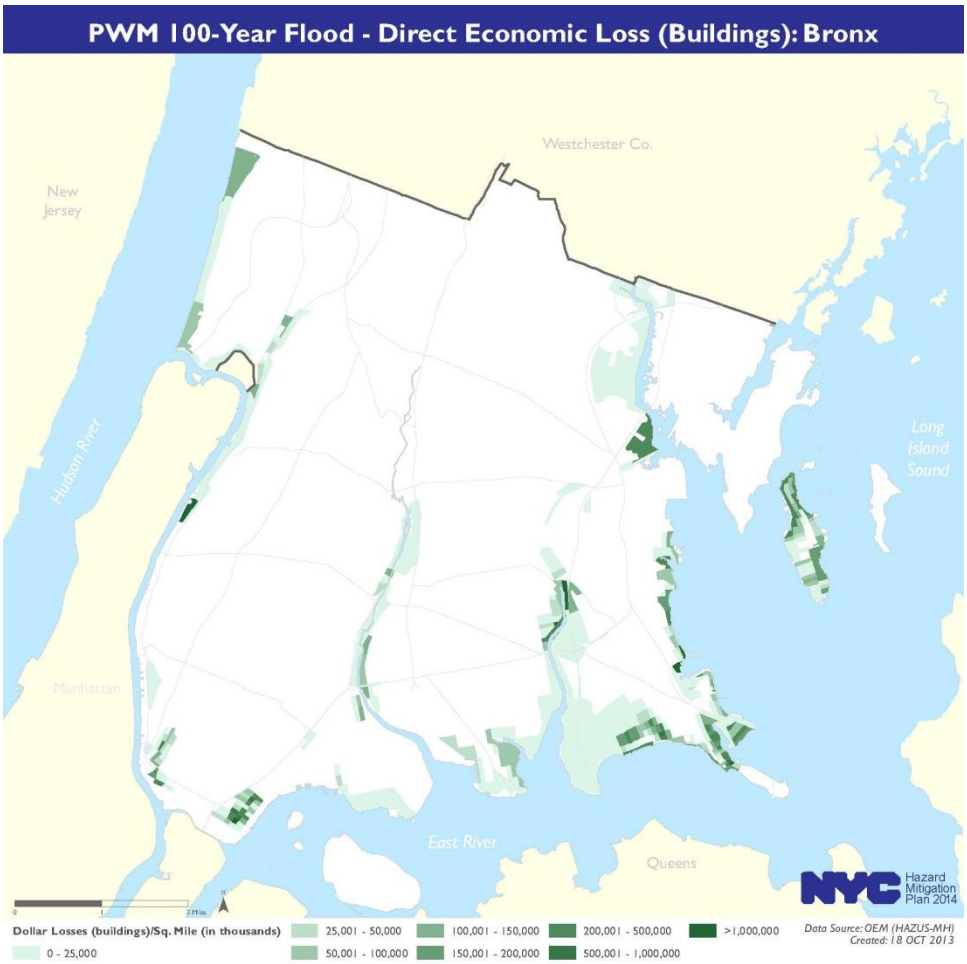

Figure 11: HAZUS-MH Results for Economic Losses from a 100-Year Flood in the Bronx

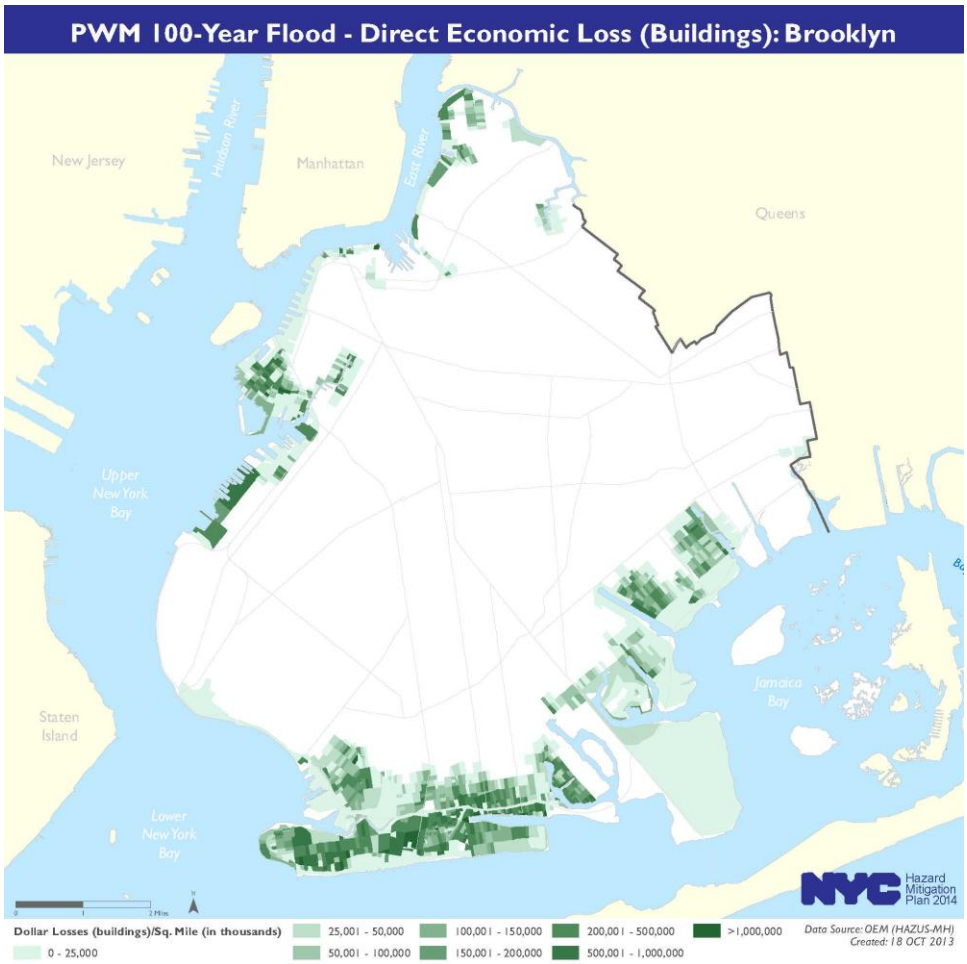

Figure 12: HAZUS-MH Results for Economic Losses from a 100-Year Flood in Brooklyn

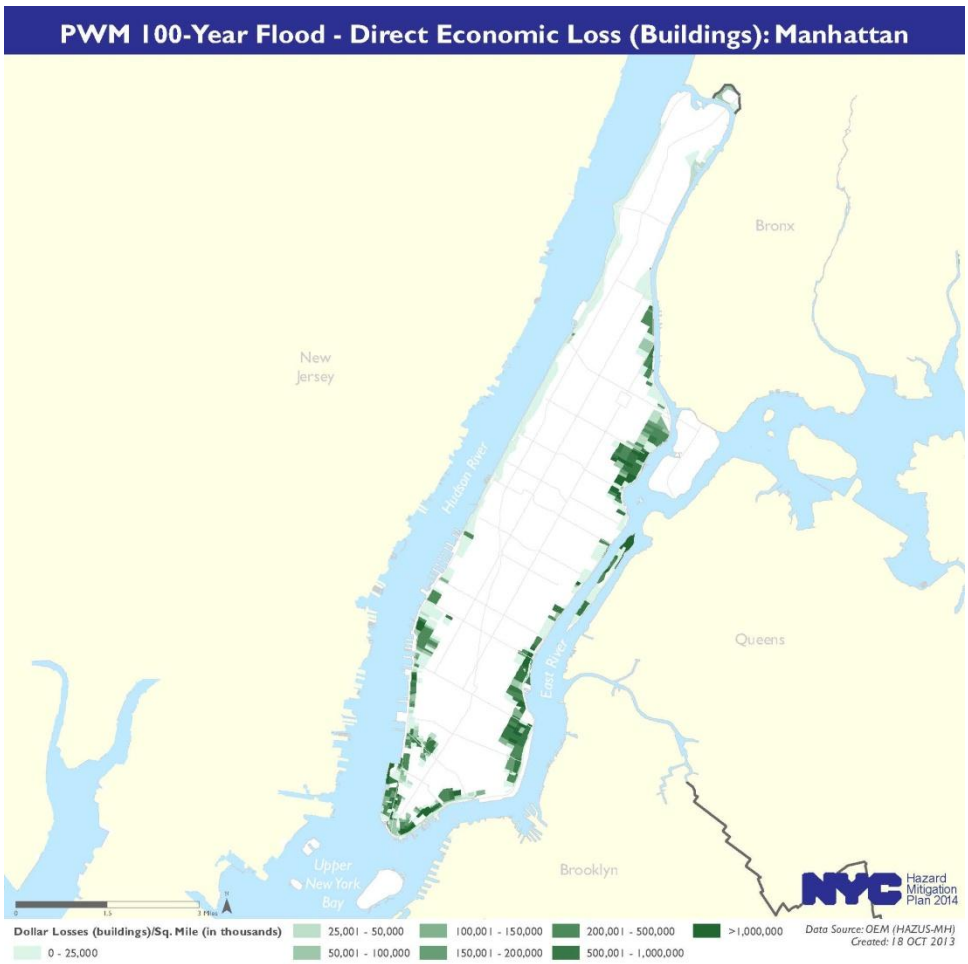

Figure 13: HAZUS-MH Results for Economic Losses from a 100-Year Flood in Manhattan

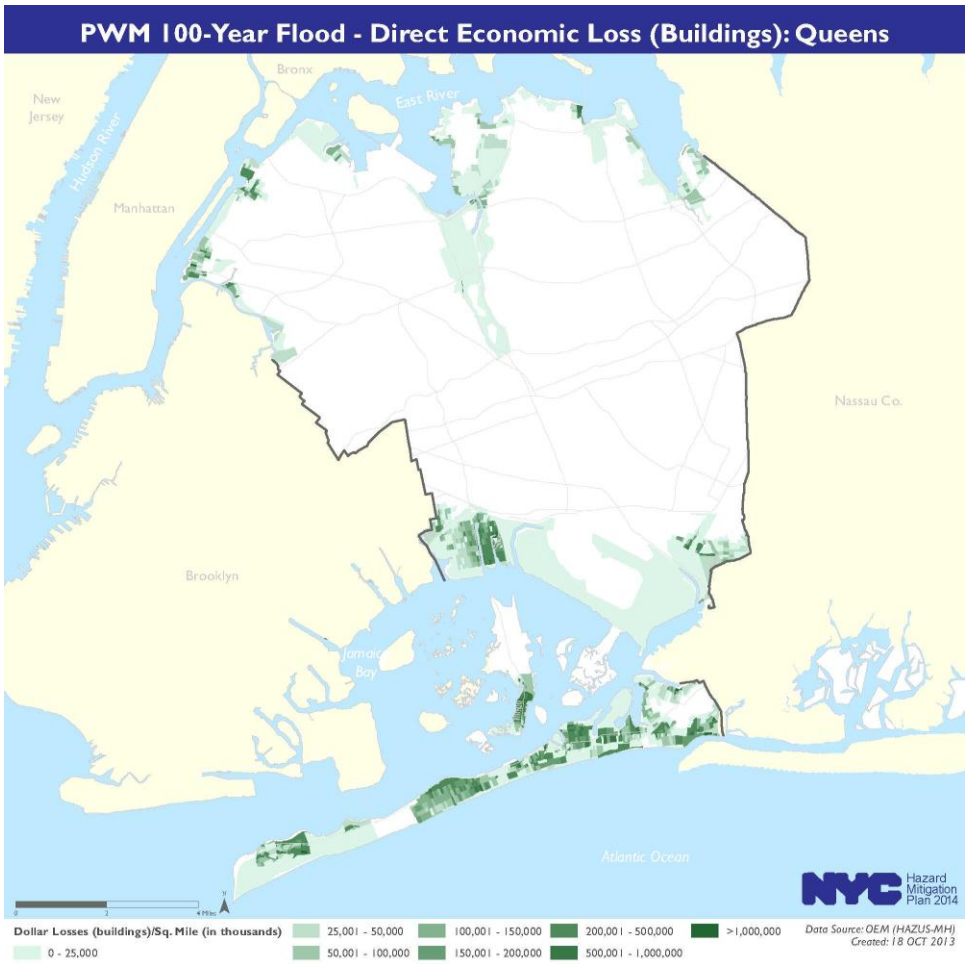

Figure 14: HAZUS-MH Results for Economic Losses from a 100-Year Flood in Queens

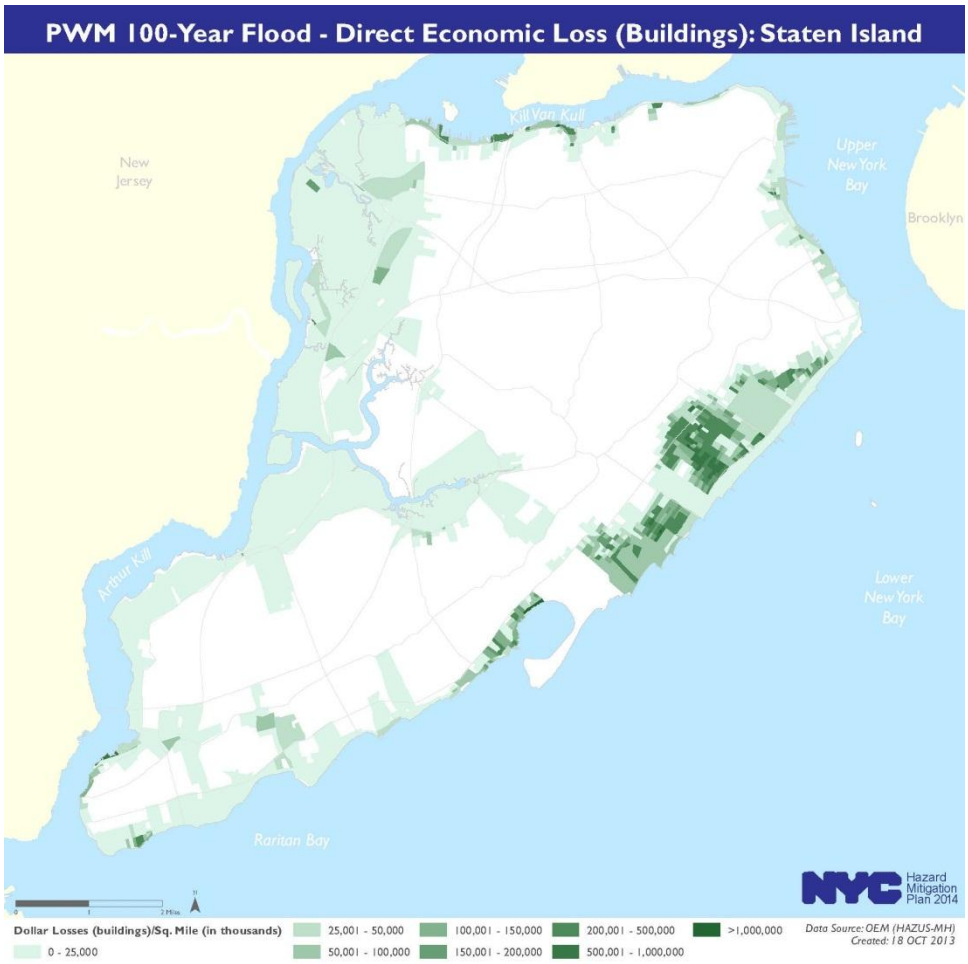

Figure 15: HAZUS-MH Results for Economic Losses from a 100-Year Flood in Staten Island

iii. Natural Environment

New York City's natural areas—its parks, trees, beaches, wetlands, and barrier islands—often act as the first line of defense against flooding. They are also among the city's most vulnerable assets to flooding hazards. According to FEMA's PWMs, more than 5,800 acres of the city's parkland—almost 24% of total parkland—are within the 100-year floodplain.

Some city parkland is composed of natural areas—such as wetlands, meadows, and dunes—that are able to withstand and recover from most storm events without significant repair costs. However, other parkland contains landscaped areas and facilities such as ballfields, recreation centers, pools, plazas, amphitheaters, and paths. Such areas and facilities are, not surprisingly, more vulnerable to structural damage (see Figure 16).

Flooding from coastal storm surge is the most significant risk to the city's parks. This was made evident during Sandy, when 5,700 acres of New York's park system were inundated by floodwaters, causing $800 million in damages.

The city's beaches bore the brunt of the storm's wave action, with significant impacts on the Rockaway Peninsula, Coney Island and adjacent areas of southern Brooklyn, and along the East and South Shores of Staten Island. On the Rockaway Peninsula, storm surge pounded whole sections of the boardwalk, scattering them into the neighboring communities. Meanwhile, erosion displaced up to 3 million cubic yards of sand and maybe more. In some places, beachfronts retreated by as much as 70 feet. Sandy also pushed water over bulkheads on waterfront sites, damaging these critical coastal defenses and allowing waters to flood parts of the Belt Parkway in Brooklyn. In addition, Sandy damaged beachfront infrastructure and facilities.

Flooding from storm surge also affected city marinas and piers, including the 79th Street Boat Basin in Manhattan, the World's Fair Marina in Queens, the Sheepshead Bay Piers in Brooklyn, and the Lemon Creek Marina on Staten Island. Docks, pilings, and piers were damaged, and buildings supporting these marinas were inundated, causing damage to equipment and electrical and plumbing systems.

In addition to storm surge, heavy downpours can threaten inland parks, natural areas, and preserves. Flooding resulting from heavy downpours can damage planted areas and surface materials without adequate drainage.

The city's tidal wetlands play a role in protecting against coastal floods, attenuating waves, and detaining some amount of storm surge. In general, wetlands are effective at protecting against smaller levels of storm surge and less significant waves than experienced during Hurricane Sandy. Wetlands also have the added benefit of sheltering a wide variety of plants that protect the quality of waterways by absorbing nutrients and filtering sediment and contaminants. In fact, during Sandy, salt marshes located in Jamaica Bay and its tributary systems remained largely clear of floating debris, with much of their vegetation surviving. Yet they are vulnerable to erosion from both coastal storm surge and intense rainfall events.

According to the New York City Panel on Climate Change (NPCC), sea levels are expected to rise around New York City. By the 2020s, under high-end sea-level-rise projections, 6,600 acres (27%) of the city's parkland could lie in the 100-year floodplain, increasing to over 7,400 acres (or 31%) by the 2050s. Sea level rise could result in a significant loss of tidal wetlands if wetlands do not receive an adequate supply of sediment to keep up with rising tides.

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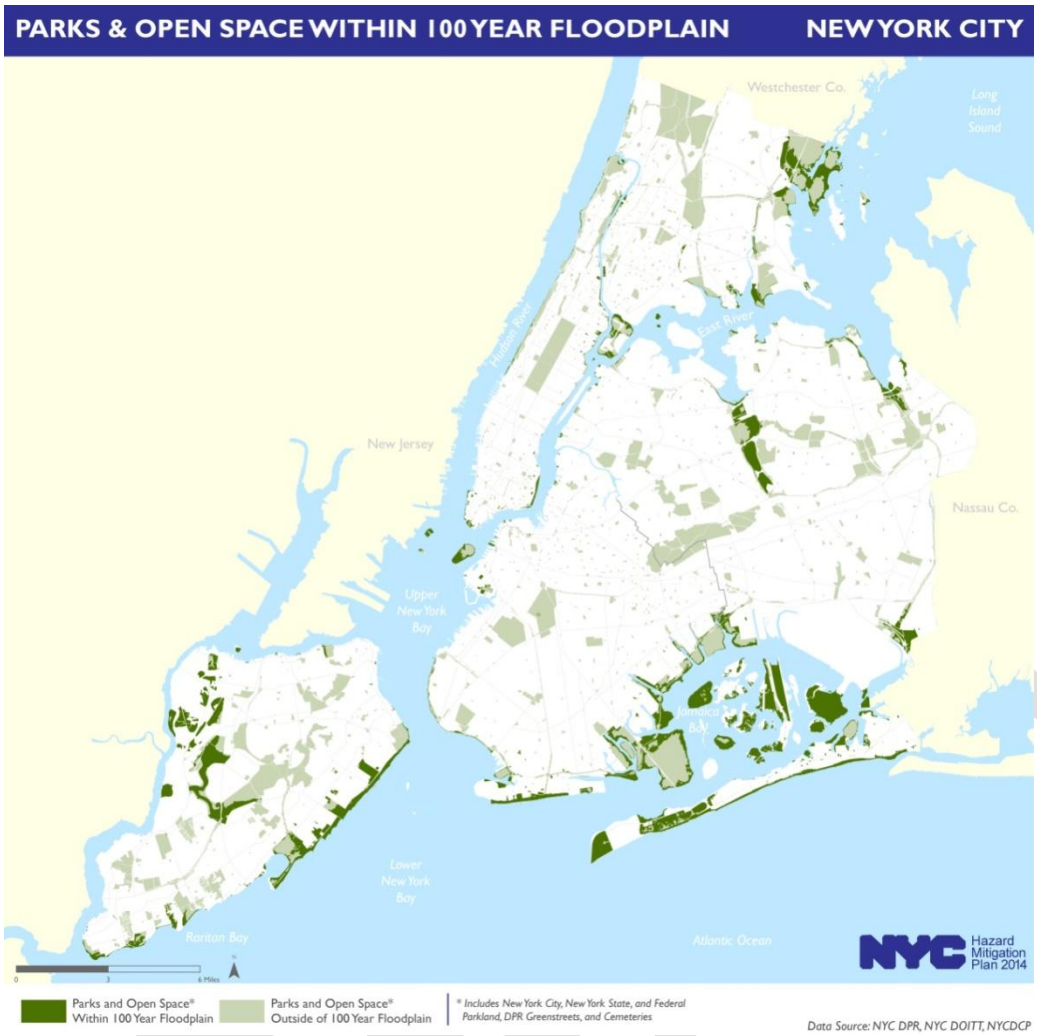

Figure 16: Parks and Open Space in the 100-year Floodplain

	Within Flood Zone	Overall	%
DPR Parks	6,654	28,380	23.4
Greenstreets	26	174	15.1
Schoolyard- playground	3	146	2.3
State Parks	263	752	34.9
Federal	4,225	6,513	64.9
Citywide	11,172	35,966	31.1

Table 13: Parks in the 100-year Floodplain

iv. Future Environment

Climate change is projected to exacerbate flooding hazards in the future. The rise in sea levels will create higher storm surges that will flood larger areas. Some low-lying areas of the city are already subject to coastal flooding at astronomical high tides. These areas will become more vulnerable to regular flooding from daily and monthly high tides. Additionally, changes in storm activity may lead to a greater number of the most intense coastal storms. (For more information on climate projections, see "Future Environment" in Risk Assessment Section 4: New York City's Hazard Environment.)

Sea Level Rise

The NPCC projects that by mid-century, sea levels could rise as much as 2.5 feet especially if the polar ice sheets melt at a more rapid rate than previously anticipated. That magnitude of sea level rise would threaten low-lying communities in New York City with regular and highly disruptive tidal flooding, and make flooding as severe as from today's 100-year storm at the Battery up to five times more likely. The NPCC also predicts that it is more likely than not (more than 50% probable) that there will be an increase in the most intense hurricanes in the North Atlantic Basin.

Sea Level Rise		2020s		2050s	
	Baseline	Middle Range (25th-75th percentile)	High End (90th percentile)	Middle Range (25th-75th percentile)	High End (90th percentile)
	0	+4 to 8 inches	+11 inches	+11 to 24 inches	+31 inches

Table 14: Sea Level Rise in 2020 and 2050

Future Flood Maps

The City worked with the NPCC to develop a series of "future flood maps" for New York that will help guide the city's resiliency and mitigation efforts. These forward-looking maps are created by using a simplified "bathtub model" approach of combining the NPCC's high-end sea level rise projections with FEMA's June 2013 PWMs. The future flood maps illustrate how the 100-year floodplain could increase over the next several decades with high-end projections for sea level rise. Because these maps were not developed using advanced coastal modeling, the accuracy of the flood projections is limited. Although they are not suitable for evaluating risks to individual properties, they are extremely useful for understanding the general extent of future flood risks.

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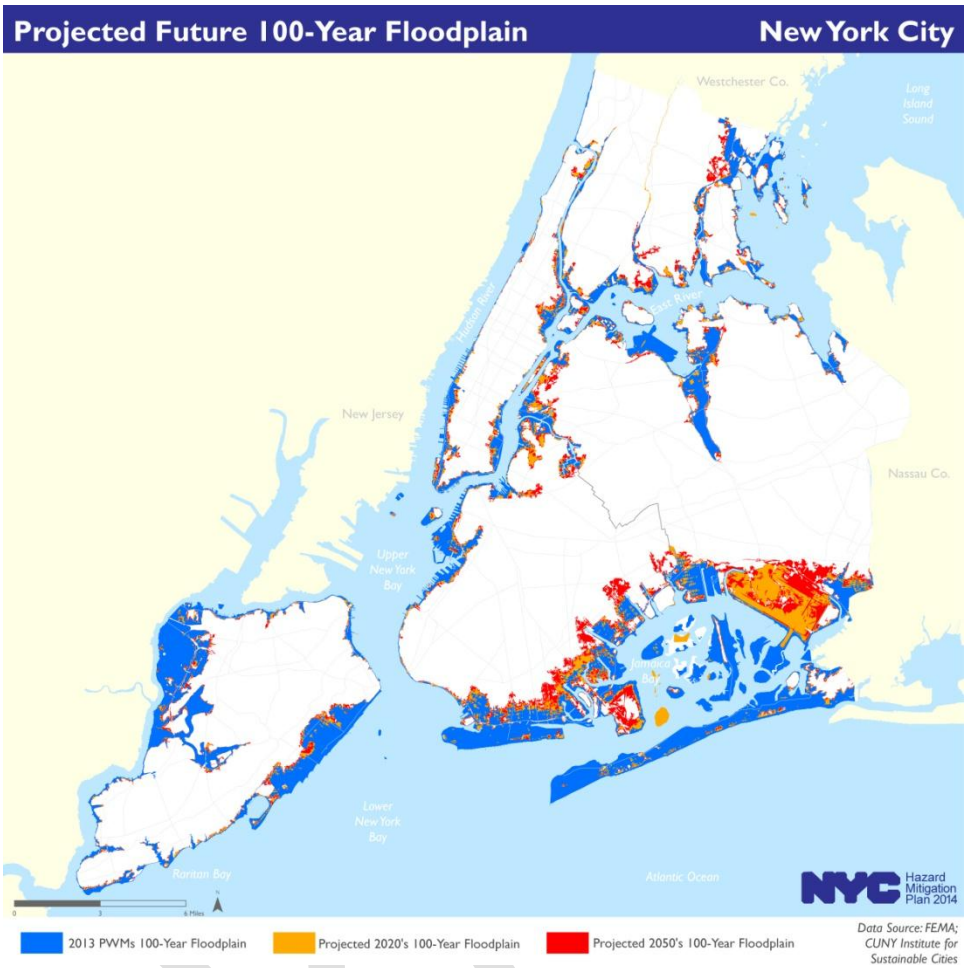

Figure 17: Projected Future 100-Year Floodplain

The future flood maps show that with a rise in sea level by the 2020s the area that could be flooded in a 100-year storm could expand to 59 square miles (up 23% from the PWMs) and encompass approximately 88,000 buildings (up 31%). With more than 2.5 feet of sea level rise by the 2050s, New York City's 100-year floodplain could be 72 square miles—a staggering 24% of the city—an area that today contains approximately 114,000 buildings (almost twice as many as encompassed by the PWMs). This area currently accounts for the infrastructure responsible for 97% of the city's power generation capacity, 20% of its hospital beds, and a large share of its public housing. Over 800,000 New Yorkers, or 10% of the city's current population, now live in the 100-year floodplain projected for the 2050s—a number of flood-vulnerable residents that is greater than the total number of people living in the entire city of Boston.

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