Chapter Four

The Impacts of Climate Change

"After learning about how climate change will impact Lower Manhattan, I am most concerned about how we as a city will adapt."

- Participant from the first open house

A truck is caught in a flooded Battery Park Underpass tunnel entrance following Hurricane Sandy (Photo Credit: Timothy Krause, https://bit.ly/3oPojmS)

How is Climate Change Already Impacting Lower Manhattan?

While Lower Manhattan's shoreline has transformed time and time again, it must once again be reimagined to respond to the impacts of climate change. **Numerous storms over the last decade have already exposed Lower Manhattan's vulnerabilities to the impacts of extreme weather, which are only expected to get worse.**

In 2012, Hurricane Sandy claimed 44 lives and caused $19 billion in damages and lost economic activity throughout the city.[1] The storm devastated Lower Manhattan, killing two people and damaging thousands of buildings. Hurricane Sandy damaged transportation assets, power lines, open space, and water and sewer infrastructure. Some of these damages had long-term implications, with repairs to Sandy-damaged subway tunnels continuing through to the time of writing this master plan. The combined volume of stormwater and wastewater during the hurricane overwhelmed the City's drainage system, and over five billion gallons of untreated or partially treated sewage were discharged into the City's waterways.[2]

In addition, thousands of jobs in Lower Manhattan were lost or displaced due to Hurricane Sandy's direct, indirect, and induced impacts. This job loss disproportionately affected low- to moderate-income households, as many of the jobs lost were in industries such as food services and retail that typically have fewer resources to reopen immediately after a disaster. Hurricane Sandy underscored not only Lower Manhattan's value as an economic, civic, and cultural heart of New York City, but also revealed how the impacts of climate change to Lower Manhattan are felt across the city and beyond.

In Summer 2021, New York City faced a whole different reality when record high temperatures hit the City and unprecedented rainfall rushed into homes and basements, resulting in significant loss of life and infrastructure damage across the city. Tropical Storm Henri and Hurricane Ida brought rainfall of record-breaking intensity to the region. Tropical Storm Henri produced New York City's heaviest hour of rainfall ever recorded (nearly two inches per hour), breaking a record set in 1888.[3]

Only two weeks later, Hurricane Ida surpassed Henri, when over three inches of rain fell in a single hour and triggered the first-ever flash flood emergency across the city.[4] The city also faced above-average heat, with 17 days breaking 90 degrees.[5] These events demonstrate how vulnerable both coastal and inland neighborhoods are to extreme storms, flooding, and heat, all likely to get worse with climate change.

As the City plans for the future, it must respond to a new normal. Sea levels in New York City have already risen by a foot since 1900 and are expected to rise up to six feet higher by the end of the century. Higher sea levels will produce higher tides, causing monthly and then daily flooding. Rising sea levels also increase the height of coastal storm surges and bring flooding further inland.[6] To estimate how high sea levels will be in the future, the City is using the New York City Panel on Climate Change (NPCC) high estimate (90th percentile) sea level rise projections for the 2020s through to 2100.[7]

Coastal storms, extreme precipitation, and extreme heat have all resulted in devastating impacts, and these impacts will only get worse in the future. Extreme heat is impacting the health of New Yorkers, storm surge is reaching further inland, extreme precipitation is stressing the city's sewer system and flooding streets, and now, rising sea levels also threaten to flood areas with high tides. Building on the findings of the *Lower Manhattan Climate Resilience Study,* the master plan responds to future tidal flooding and coastal storms along the shoreline between The Battery and the Brooklyn Bridge.

What are the Main Threats of Climate Change in Lower Manhattan?

Daily Tidal Flooding

Tidal flooding is the temporary inundation of low-lying areas as a result of high tides. Sea level rise will cause tides to be higher than they are today, resulting in higher water levels and tidal flooding in the Financial District and South Street Seaport.

The Lower Manhattan waterfront will experience frequent tidal flooding by the 2040s, putting critical infrastructure and jobs at risk. Tidal flooding will continue to become more frequent, occurring monthly by the 2050s and daily by the 2080s. By 2100, daily high tides will reach up to three blocks inland at Pearl Street.

Coastal Storms

Tropical storms, hurricanes, and nor'easters are major storm events that cause an abnormal rise in water levels along the coast, also known as storm surge. Flooding from coastal storms is more destructive than daily tidal flooding because of both the higher water levels as well as the forceful waves often associated with coastal storms.

As climate change progresses, warmer oceans will likely contribute to more frequent and intense storms with higher levels of flooding. By 2100, a 100-year (or one-percent annual chance) storm is projected to cause flooding over 15 feet deep above the existing East River Esplanade in parts of the Financial District and Seaport.

Extreme Precipitation

Extreme precipitation corresponds to heavy rainfall exceeding one inch of rain in one hour, or a total of three inches in a 24-hour period.

The New York City Panel on Climate Change (NPCC) anticipates that, by the end of the century, New York City could experience a 25-percent increase in annual rainfall, and one and a half times as many days with more than one inch of rain.[8] These events are already occurring more frequently, stressing the sewer system, and flooding inland streets.

Extreme Heat

Extreme heat events are defined as a period of three consecutive days with maximum temperatures at or above 90 degrees Fahrenheit.

Over the next 30 years, New York City could see an increase of 5.7 degrees in average annual temperatures and a doubling of the number of days above 90 degrees. Extreme heat has major health implications, including dehydration, heat exhaustion, heat stroke, and mortality.[9] In Lower Manhattan, the urban heat island effect causes an increase in temperature due to building density and high amounts of asphalt that absorb and emit heat, further amplifying the impacts of climate change.

How will Tidal Flooding Impact the Study Area?

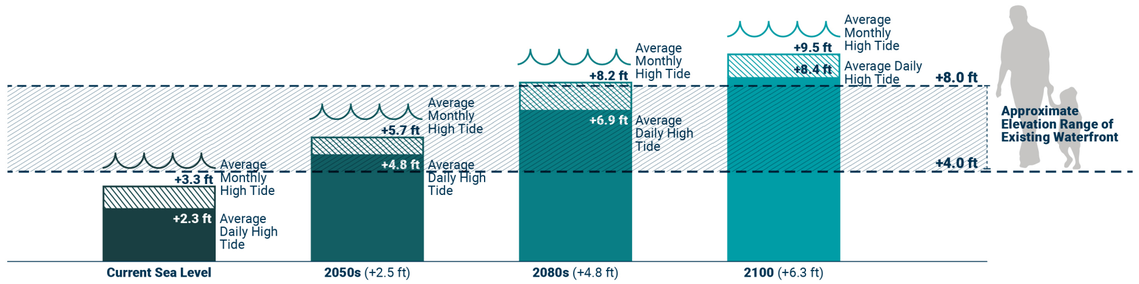
The waterfront in Lower Manhattan will experience frequent tidal flooding by the 2040s, monthly tidal flooding by the 2050s, and daily flooding by the 2080s. By 2100, daily high tides will reach up to three blocks inland at Pearl Street and be up to four feet higher than the esplanade today. By 2100, monthly high tides will be up to five and a half feet higher than the existing esplanade. Frequent tidal flooding in this area will damage streets, infrastructure, and critical maritime facilities, eventually rendering the area and its critical citywide uses nonfunctional, with vast negative consequences for the entire city.

As tidal flooding becomes more frequent, the NPCC uses the mean monthly high water (MMHW) – an event that is typically exceeded 25-35 times per year – as a useful threshold indicator of repeated flooding that is sufficient to justify large-scale adaptation investments. This is in comparison to mean higher high water (MHHW), or daily high tide, that is exceeded hundreds of times per year. In the Financial District and Seaport, MMHW is approximately a foot above the mean higher high water (MHHW), or daily high tide today. How the project team determined the design flood elevation (DFE)—the height of flood defense measures needed to protect the Financial District and Seaport from future tidal flooding—is further described in *Chapter 5* under Flood Defense.

Defining Key Terms

Mean Monthly High Water (MMHW): this is the average of all monthly maxima in predicted astronomical tide levels. This event is typically exceeded 25-35 times per year. Throughout this report, it is easily referred to as average monthly high tide.

Mean Higher High Water (MHHW): this is the average of the higher tides that occur each day. Throughout this report, it is easily referred to as average daily high tide.



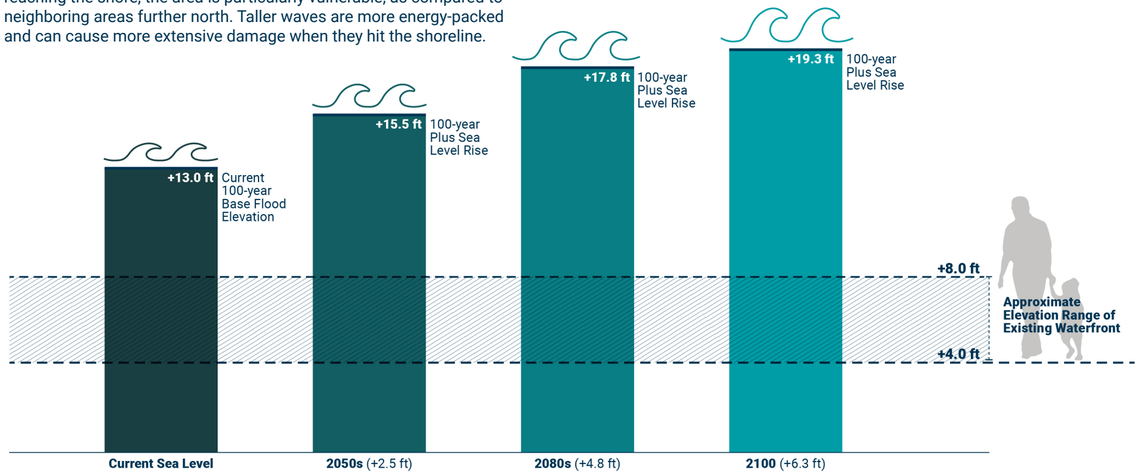
Projected Tidal Flooding Levels

How will Coastal Storm Flooding Impact the Study Area?

Tropical cyclones, such as tropical storms and hurricanes, and extratropical cyclones, such as nor'easters, cause substantial flooding in low-lying coastal areas, like the Financial District and Seaport. Sea level rise and rising tides will make the impacts of storm surge even greater, leading to substantial flooding. Climate change is also making these kinds of storms more intense and potentially more frequent.

Coastal storms also produce large waves that can crash over the existing shoreline and damage nearby buildings and structures. Because of the Financial District and Seaport's location in New York Harbor, where there is substantial space for waves to gain energy across open water before reaching the shore, the area is particularly vulnerable, as compared to neighboring areas further north. Taller waves are more energy-packed and can cause more extensive damage when they hit the shoreline.

Today, a 100-year storm could cause flooding up to nine feet deep.[1] By the 2050s, this depth will be up to 12 feet and by 2100, up to 15 feet. Currently, a coastal storm would reach inland about three city blocks; by 2100, flooding will reach inland more than five city blocks, past William Street. Flooding to this extent will significantly impact assets and buildings on the waterfront, including Pier 11, Whitehall Ferry Terminal, and the Battery Maritime Building.



Projected Coastal Flooding Levels

What Happens if Nothing is Done?

Failure to address the potential impacts of climate change in Lower Manhattan bears a steep cost and impacts all of New York City. **Inaction is not an option.** The Financial District and Seaport waterfront is critical to the economic development and identity of Lower Manhattan and damage to the area would have negative ripple effects throughout the tri-state region and the nation. From now through 2100, if no action is taken, repetitive flooding is projected to cause up to **$20.3 billion in estimated cumulative total losses** to the region. While this represents tremendous economic impacts, it still does not take into account many other costs that are challenging to quantify, including losses to citywide services from subway, electrical, and stormwater infrastructure.[ii]

Modeling suggests that if nothing is done to protect the area, estimated quantified losses would include:

- **$8.4 billion** in **direct economic impacts**[iii] to businesses in the study area
- **$6.7 billion** in **indirect and induced economic impacts** to businesses within the New York City Metropolitan Statistical Area (MSA)
- **$2.5 billion** in **building damages**
- **$1.7 billion** in **relocation costs**
- **$770 million** in **contents damage**
- **$264 million**[iv] in **social disruption**, including health costs from injuries and mental stress, and lost income due to health issues

Future Flooding from Daily Tides and Coastal Storms

- 2100 Daily High Tide
- 2015 100-Year Floodplain
- 2050s 100-Year Floodplain
- 2080s 100-Year Floodplain
- 2100 100-Year Floodplain
- +X Ground Elevation (NAVD88)

In addition to the losses quantified on the previous page, if no action is taken, the following impacts in the master plan study area will be felt across Lower Manhattan, the region, and even the country:

Roads and highways

- Flooding from major storms will impact over six miles of roadways by the 2050s and over seven miles by 2100. This will affect the movement of bikes and cars and could damage roadway infrastructure like traffic signals
- Flooding from major storms by the 2050s will impact 11 bus lines that have 59,000 daily riders

Critical community services and assets

- By 2100, an estimated 219 buildings in the Financial District and Seaport will experience monthly flooding, ultimately rendering them unusable. These buildings currently serve 86,000 workers and 6,200 residents as well as students, visitors and New Yorkers using public services in this area

Subway and rail infrastructure

- Fourteen of the city's 28 subway lines, serving 370,000 daily riders, run through Lower Manhattan. Seven of those lines (1, 4/5, R/W, and J/Z) have a combined four subway stations at risk of coastal storm flooding in the study area

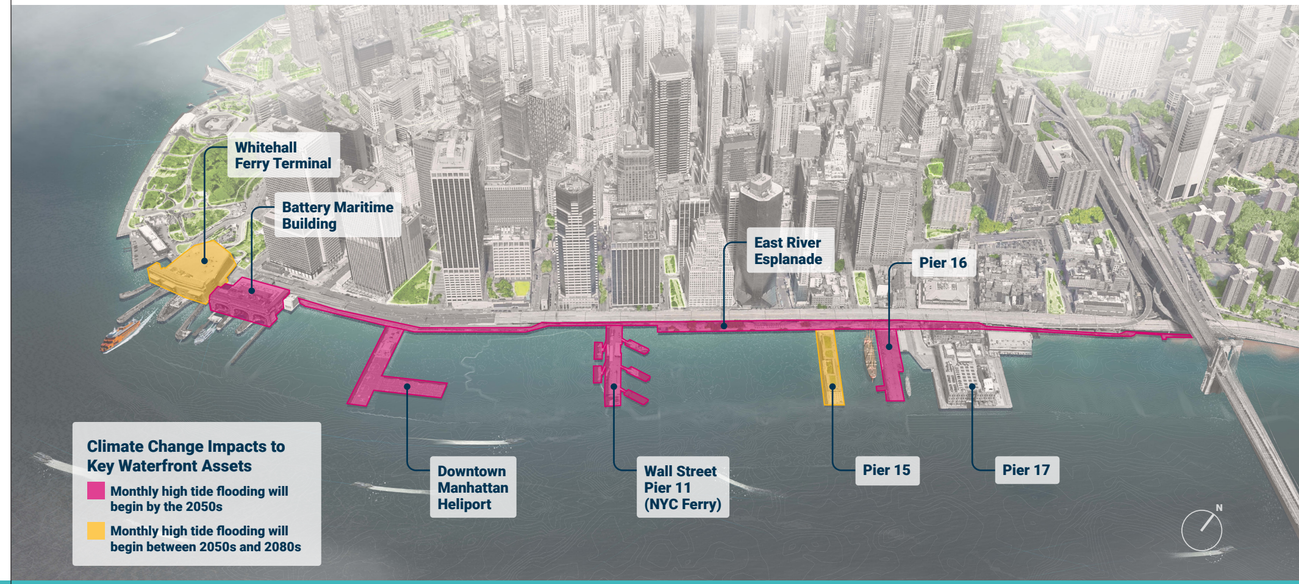
Electrical services and sewers

- Critical citywide electrical infrastructure would be impacted by coastal storm flooding in the study area, including Con Edison's oil-o-static line, an important piece of infrastructure that helps provide electricity throughout Lower Manhattan
- Flooding also puts stress on sewers, making them more likely to become overwhelmed and back up onto Lower Manhattan streets and basements

South Ferry Station in Lower Manhattan flooded to the mezzanine level after Hurricane Sandy (Photo Credit: MTA)

Ferries and piers

- Whitehall Ferry Terminal – home to the Staten Island ferry, the busiest passenger ferry route in the country with over 70,000 daily riders — will see operational impacts due to tidal flooding by the 2050s and will become significantly impaired by 2100
- The Battery Maritime Building, a historic structure that currently houses the Governors Island ferry and regional ferry service, will see operational impacts by the 2050s due to monthly tidal flooding
- Pier 11, which is the NYC Ferry Wall Street landing, will face monthly tidal flooding by the 2050s
- Pier 15, which has public open space, a restaurant, and the City Cruises line, will be impacted by monthly tidal flooding by the 2080s, though the portion closest to land will begin to experience monthly tidal flooding as early as the 2050s
- Pier 16, which provides docking space to historic ships, will face monthly tidal flooding by the 2050s
- Pier 17, which has retail space and a performance venue, will not be impacted by tidal flooding within this century because it was recently reconstructed at a higher elevation



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Notes

i. Reference point at Beekman and South Street

ii. Represents present value of direct, indirect, and induced losses with 6.25% discount rate. The region is defined as the New York City Metropolitan Statistical Area. Does not include any cost escalation and assumes existing building stock and business activity. In 2021 dollars, based on current property values and tax income.

iii. In the form of lost output.

iv. Does not account for potential population change.