NYC RISK LANDSCAPE:

A GUIDE TO THE NYC HAZARD MITIGATION PLAN

2024 EDITION

NYCEM
New York City Emergency Management

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ONE WAY
ONE WAY

RISK LANDSCAPE OVERVIEW

OVERVIEW

New York City (NYC) is no stranger to disasters. Throughout its history, NYC has been confronted with natural hazards including hurricanes, flooding, earthquakes, and snowstorms. This report builds upon insights from the last edition, reflecting both the ongoing progress and new understandings since then.

Each event offers lessons to make our city more resilient, emphasizing the importance of identifying and mitigating risk to break free from the cycle of response, recovery, and repeated damage. NYC is increasingly moving toward proactive mitigation, a fundamental shift that strengthens our preparedness and reduces future losses. For every dollar invested in hazard mitigation, an estimated six dollars are saved in long-term recovery costs.

This report serves as a companion to the 2024 NYC Hazard Mitigation Plan (HMP), with expanded strategies and findings from recent events, to guide future planning and enhance the city's resilience.

The HMP identifies natural hazard risks and vulnerabilities that are common to NYC. After identifying these risks, the HMP develops long-term strategies for reducing them. Mitigation plans are key to breaking the cycle of disaster damage and reconstruction. **This companion report summarizes the HMP and provides you with an overview of NYC's risk landscape.**

Prepared by NYC Emergency Management (NYCEM) in collaboration with a multitude of government agencies, organizations, private sector partners, and subject-matter experts, this guide includes:

- **Planning Process**: How the HMP was produced and all the stakeholders involved.
- **Hazard Environment**: Key features of the NYC's environment that make it vulnerable to natural hazards.
- **Hazard Profiles**: Profiles describing each hazard, its risk, and how to manage the risk.

Hazards addressed in this Guide are:


COASTAL EROSION


COASTAL STORMS


DROUGHT


EARTHQUAKES


EXTREME HEAT


FLOODING


HIGH WINDS


POOR AIR QUALITY


WINTER WEATHER

[1] K. Porter, et al., Natural Hazard Mitigation Saves: 2019 Report (Washington, DC: Multi-Hazard Mitigation Council, National Institute of Building Sciences, 2019).

HOW HAS MITIGATION EVOLVED IN NEW YORK CITY?

Historically, hazard events have led to the awareness and incentive to implement new mitigation strategies and capabilities. As displayed in the timeline, many changes to the Building Code and Zoning Resolution, and the creation of new laws and policies have come about due to major disasters. From the 1860s tenement fires, resulting in required fire escapes in the First Tenement House Act, to the destruction of Sandy leading to the adoption of the Flood Resilient Text Amendment, we frequently invest in mitigation strategies after major events. Our hope is that plans such as this Guide, will help shift NYC's mentality toward pre-disaster mitigation — thereby breaking the response, recovery, repeated damage cycle.

1860

TENEMENT FIRE TAKES 20 LIVES.

1860: The Building Code, the first comprehensive building regulations, was enacted for the city.

1867: The First Tenement House Act required fire escapes and one outhouse for every twenty occupants.

1897: The Second Tenement House Act ("Old Law") required that all rooms open onto a street, rear yard, or air shaft.

1899: The city enacted its first citywide Building Code. Previous laws were enacted by the State.

TENEMENT FIRE
1860

1870–1900

NEW YORKERS PROTESTED THE LOSS OF LIGHT AND AIR FROM THE CONSTRUCTION OF TALLER BUILDINGS.

NUMEROUS CHOLERA OUTBREAKS OCCURRED IN THE 1800S, WITH TUBERCULOSIS OUTBREAKS FOLLOWING FROM 1900 TO 1920.

1901: The Tenement House Act ("New Law") added height restrictions on residential buildings, replaced airshafts with courtyards, and required individual bathrooms in apartments.

1911

THE TRIANGLE SHIRTWAIST FACTORY FIRE KILLED 146 PEOPLE, SPURRING THE ADOPTION OF MANY BUILDING SAFETY CODES.

1913: The Labor Laws, strict fire safety and labor laws, were established for factories.

1916: First Zoning Resolution (the first in the nation) established rules for "land use and build" to separate residential, commercial, and manufacturing districts, and control building heights.

1929: Multiple Dwelling Law replaced Tenement House Act. Established additional fire and health safety requirements for multifamily buildings.

TRIANGLE SHIRTWAIST FACTORY FIRE
1912

1915

THE 42-STORY EQUITABLE BUILDING IS BUILT, BLOCKING LIGHT AND AIR FOR THE SURROUNDING ENVIRONMENT.

1916: Reactions to the Equitable Building completion, along with major shifts in population, transportation, technology, lifestyle changes, and government housing prompted the enactment of the Zoning Resolution. The Zoning Resolution used the concept of incentive zoning, involving granting extra floor area in exchange for public amenities.

1938: Revisions to the Building Code addressed wind loads for skyscrapers and standards for multifamily buildings.

1961: Second Zoning Resolution focused on reducing densities and requires open space. Introduces Floor Area Ratio, limiting building height based on size of lot.

1968: Building Codes of 1968 were created. Revisions incorporated new technology and building practices, including performance criteria for building construction and design requirements for wind pressure (including buildings lower than 100 feet).buildings lower than 100 feet).

42-STORY EQUITABLE BUILDING
1915

1860 1880 1900

1969

THE CUYAHOGA RIVER CATCHES ON FIRE IN CLEVELAND, OHIO AFTER CENTURIES OF POLLUTION FROM CLEVELAND'S STEEL MILLS AND FACTORIES.

1972: The Nixon administration passed the Clean Water Act.

1983: Revisions to the NYC Building Codes of 1968 incorporated FEMA floodplain maps and mandated flood-resistant construction standards (for new or substantially improved buildings) that residents must meet to be eligible for the National Flood Insurance Program.

1984

IN BHOPAL, INDIA, A PLASTICS MANUFACTURING PLANT, UNION CARBIDE, RELEASED 40 TONS OF METHYL ISOCYANATE AND KILLED 5,000 PEOPLE AND INJURED 50,000 PEOPLE.

1984: In reaction to the chemical release, the United States Congress passed the Emergency Planning and Community Right-to-Know Act.

1988

THE QUEBEC EARTHQUAKE AND 1989 LOMA PRIETA EARTHQUAKE IN CALIFORNIA WERE WIDELY FELT.

1988: Earthquakes prompted the adoption of federal seismic guidelines for bridges, NYC seismic Building Code provisions, and seismic Bridge Design guidelines.

1995: The Local Law 17/19 of the Building Code update contained the first seismic provisions that consider soil and foundation conditions for new construction (effective February 1996).

1998: Department of Transportation Seismic Criteria Guidelines for bridges were adopted by all local bridge owners. Guidelines are revisited every two to four years.

WORLD TRADE CENTER BEFORE 9/11 ATTACKS
2001

QUEBEC EARTHQUAKE
1988

2001

9/11 ATTACKS ON THE WORLD TRADE CENTER.

2001: Collapse of World Trade Center revealed safety issues related to outdated 1968 Building Code.

2008: The Building Code is comprehensively revised after updated and retitled "Construction Codes." Modeled after International Code Council codes, it addressed natural hazards and included additional safety and emergency provisions. Must be updated every three years.

2003

ON AUGUST 14, THE NORTHEAST REGIONAL BLACKOUT LEFT 50 MILLION PEOPLE WITHOUT POWER.

2003: City Council passed Executive Order 107 to implement Continuity of Operations planning and programming for City agencies.

2008: The NYC Panel on Climate Change, a body of leading climate and social scientists and risk management experts, convened to produce climate projections for NYC that would inform the public as well as the City's decision-making.

2013: Second NYC Panel on Climate Change convened.

NORTHEAST REGIONAL BLACKOUT
2003

1920 1940 1960

2012

HURRICANE SANDY

Hurricane Sandy struck on October 29, 2012 — the deadliest event of the 2012 Atlantic hurricane season — severely impacting the NYC area. Widespread flooding and extreme winds caused extensive damage, especially in Lower Manhattan, altered shorelines, created new inlets, and eroded soil. The storm highlighted vulnerabilities in older residential foundations and disrupted underground infrastructure, emphasizing the importance of resilient construction and emergency preparedness.

2013: Flood Resiliency Zoning Text Amendment encouraged flood-resilient building construction throughout designated flood zones. The update required that buildings be protected from flooding to a level 1 or 2 feet higher than the FEMA-designated flood elevation.

2014: 2014 Construction Codes: Effective Oct 1, 2014, they included new seismic standards for risk-based requirements and enhanced design requirements for soil liquefaction.

HURRICANE SANDY
2012

HURRICANE SANDY BLACKOUT
2012

2014–2015

A GAS EXPLOSION FROM A GAS LEAK AT AN APARTMENT BUILDING IN EAST HARLEM KILLED 8 AND INJURED 50.

A GAS EXPLOSION IN THE EAST VILLAGE, CAUSED BY AN ILLEGAL TAP INTO A GAS MAIN, KILLED 2 AND INJURED 22.

DURING THE SUMMER MONTHS, AN OUTBREAK OF LEGIONNAIRES' DISEASE RESULTED IN 133 CASES, WITH 16 FATALITIES.

2015: City Council enacted 10 bills to enhance gas safety. The first set of bills brought into effect legislation that required qualifications for those performing gas work and inspecting infrastructure, as well as institutionalized transparency between utility companies and property owners with the Department of Buildings. The second set of bills created requirements and penalties for home building owners concerning emergency alert systems and gas piping defects.

2015: The NYC Panel on Climate Change released the 2015 Report, stating that seven climate-change variables have the potential to affect the NYC area in the future.

2015: City Council passed a bill that required owners to register and quarterly inspect cooling towers. If a cooling tower tests positive for the bacteria that causes Legionnaires', the owner would have to follow Department of Health and Mental Hygiene (DOHMH) regulations to disinfect the system.

GAS EXPLOSION IN EAST HARLEM
2014

GAS EXPLOSION IN EAST VILLAGE
2015

1980 2000 2020

2016

DURING A WIND EVENT, AN UNSECURED CRANE BEING OPERATED BY AN UNTRAINED OPERATOR COLLAPSED IN MANHATTAN, INJURING 3 AND KILLING 1.

2016: As a result, City Council passed bills to require the Department of Buildings to notify the Federal Occupational Safety and Health Administration (OSHA) of any Construction Code violations; to increase the minimum and maximum fines for violations of the Building Code and Administration Code; to require that all cranes install anemometers; and to create an age limitation on cranes.

2020

THE FIRST CASE OF COVID-19 IN NYC WAS CONFIRMED ON MARCH 1, 2020, INITIATING AN OUTBREAK THAT MADE NYC THE MOST SEVERELY AFFECTED AREA IN THE U.S. BY LATE MARCH.

2020: In response, the City implemented several measures to curb the virus's spread, including mid-March school closures and a State executive order on March 20 to shut down all non-essential businesses. Public transit continued to operate for essential services, and face masks became mandatory in public spaces statewide. Low-income and vulnerable communities faced significant job losses.

2020: Targeted restrictions were placed in neighborhoods with infection rate spikes, leading to additional school closures and the suspension of indoor dining. In December, NYC began its vaccination campaign, shifting toward managing and eventually overcoming the pandemic phase.

CRANE COLLAPSE
2016

BETHESDA FOUNTAIN FLOODING
2021

WILDFIRE AIR POLLUTION OVER TRIBOROUGH BRIDGE
2023

2021

ON SEPTEMBER 1, 2021, THE REMNANTS OF HURRICANE IDA BROUGHT RECORD-BREAKING RAINFALL TO NYC, RESULTING IN SEVERE INLAND FLOODING AND OVER $100 MILLION IN DAMAGE.

2022: On March 22, 2022, the U.S. Department of Housing and Urban Development allocated approximately $188 million to NYC for long-term recovery efforts under the Disaster Relief Supplemental Appropriations Act, 2022. This funding aims to address the extensive damage and bolster the City's resilience against future severe weather incidents.

2022: Nearly 18 million vaccine doses were administered by mid-2022, highlighting the ongoing efforts to safeguard residents against future outbreaks of COVID-19.

2023

NYC FACED ITS WORST AIR QUALITY SINCE THE 1960S ON JUNE 6 DUE TO CANADIAN WILDFIRE SMOKE.

2024: On April 5, 2024, a magnitude 4.8 earthquake occurred, centered in Tewksbury Township, New Jersey, about 65 km west of NYC.

2024: Millions of people in the metropolitan area and anywhere from Virginia to Maine and beyond felt the ground shaking, resulting in the largest number (>180,000) of U.S. Geological Survey (USGS) "Did You Feel It?" reports of any earthquake. Despite its widespread reach, the earthquake resulted in no significant damage, marking it as a relatively minor seismic event.

2024: Mayor elevated NYC's drought watch to warning in November 2024, pausing the $2B Delaware Aqueduct repair due to a historic rainless streak. The order mandated that city agencies implement water-saving measures and New Yorkers conserve water. This was the first time the city declared a drought warning since 2002. The drought orders were lifted in early January 2025 due to increased rainfall contributing to a rise in water levels in the reservoirs.

2020 2021 2022 2023 2024

PLANNING PROCESS

The 2024 HMP update brought together a cross section of government agencies, community-based organizations, business consortia, cultural institutions, academics, universities, and the public. Some of these participants represent and serve communities neighboring NYC, including areas and counties within New York State, New Jersey, and Pennsylvania.

This diverse set of participants brought a full set of concerns, expertise, and solutions to the planning process.

Participants were placed in relevant cohorts and engaged in various ways including workshops, lectures, field trips, surveys, and content review.

HMP WORKSHOP, JAN 2023
SOURCE: NYCEM

PLANNING TEAM

The Planning Team served as the coordinating body of the HMP. It was composed of NYCEM staff, including planners, analysts, and executive support. The Planning Team facilitated development of the plan to ensure that the updated HMP met the requirements of the Disaster Mitigation Act (DMA) of 2000.

The Planning Team's responsibilities were to:

- Develop and implement the project workplan.
- Coordinate and engage with Planning Partners.
- Ensure adherence to requirements.
- Conduct an extensive analysis and literature review.
- Facilitate the plan's adoption.

HMP WORKSHOP, JUNE 2023
SOURCE: NYCEM

STEERING COMMITTEE

The Steering Committee is a group of 12 City agencies and two non-governmental organizations. They include agencies and organizations that were either involved in previous HMP steering committees or present a significant stake in the development and implementation of the HMP.

NYC Mayor's Office of Operations, NYC Mayor's Office of Management and Budget, NYC Mayor's Office of Climate and Environmental Justice, NYC Department of Housing Preservation & Development, NYC Department of Buildings, NYC Department of Health and Mental Hygiene, NYC Small Business Services, NYC Environmental Protection, NYC Department of Parks and Recreation, NYC Department of Economic Development Corporation, American Institute of Architects (New York), Regional Plan Association, NYC Department of City Planning, New York City Department of Transportation

PLANNING PARTNERS

The Planning Partners are a larger group of participants who have some stake in the development and implementation of the HMP. The following agencies and organizations participated throughout the Planning Process:

Columbia University, Con Edison, City University of New York, NYC Department of Design and Construction, Fire Department of the City of New York, NYC Housing Authority, NYC Department For The Aging, NYC Deputy Mayor of Operations, Port Authority of New York & New Jersey, NYC Department of Correction, NYC Department of Education, U.S. Army Corps of Engineers, NYC Office of Technology and Innovation, NYC Department of Sanitation, NYC Health + Hospitals, NYC Mayor's Office of Housing Recovery Operations, NYC Landmarks Preservation Commission, NYC Mayor's Office of Operations, Metropolitan Transportation Authority, National Weather Service, NYC Police Department, New York State Department of Environmental Conservation, New York State Office of Emergency Management , New York University, NYC Office of Chief Medical Examiner, NYC Office of Environmental Remediation, Pratt Institute, Public Service Enterprise Group, The Museum of Modern Art, Jen Munch Art Conservation, West Lake Conservators, Yale University Art Gallery, SUNY Buffalo State University, The Museum at FIT, Brooklyn Museum, OFMR, Center for Jewish History, Cooper Hewitt, Smithsonian Design Museum, Neue Galerie, Staten Island Museum, Center for Art, Research & Alliances (CARA), Brooklyn Public Library, New York Public Library, YIVO Institute for Jewish Research, NYU Wagner Graduate School of Public Service, SUNY University at Buffalo, CUNY Baruch College, CUNY Hunter College, Fordham University, Rebuild by Design, The New School Urban Systems Lab

PROCESS

Hazard Identification

The hazards outlined in the 2024 HMP were selected based on a series of criteria starting with continuing the use of existing hazard profiles from previous HMPs, incorporating hazards of relevance to City agencies, and categorizing the profiles based on the broadest shared denominator.

Workshops

The following workshops covered critical components of the HMP, including the Hazard Environment, Hazard Profiles, and Mitigation Strategy. Each session engaged participants in discussions and exercises to ensure a comprehensive understanding of the risks facing NYC and to identify actionable strategies for reducing vulnerabilities. The table below summarizes each session's focus, date, and participant engagement.

TABLE: SUMMARY OF HMP WORKSHOPS

SESSION	DATE	DESCRIPTION
Hazard Environment	January 2023	First workshop introduced and reviewed the NYC Hazard Environment with 23 participants from 12 agencies and organizations.
Hazard Profiles	March 2023	Second workshop focused on reviewing content of the Hazard Profiles with 17 participants from seven City agencies.
Mitigation Strategy	July 2023	Workshop included a visioning exercise for NYC across different time frames and an assessment of current mitigation strategies and actions.

Site Visits

The Planning Team organized a series of site visits with the purpose of providing a comprehensive and immersive understanding of the City's mitigation strategies and actions, as well as encouraging partners to contribute more precise and detailed information to the Mitigation Actions Database.

FRESHKILLS FIELD TRIP, MAY 2023
SOURCE: NYCEM

- Urban Post-Disaster Housing Prototype Program, NYCEM
- Interim Flood Protection Measures, NYCEM
- Blue Belt New Creek, NYC Department of Environmental Protection, NYC Department of Environmental Protection (DEP)
- East Side Coastal Resiliency Project, NYC Department of Design and Construction (DDC)
- Freshkills Park, Freshkills Park Alliance
- Parks Green Roofs, NYC Department of Parks and Recreation (Parks)
- Brooklyn Bridge Park, Brooklyn Bridge Park Conservancy

Through direct engagement, partners gained a deeper understanding of ongoing mitigation efforts and were better equipped to accurately document their actions in the database.

Lectures

A lecture series was organized with the primary objective of informing participants of the latest research and methodologies related to hazard mitigation. This series aligns with our commitment to knowledge sharing and informed decision-making. The series convened four distinct sessions, each offering unique insights into hazard mitigation.

- "Ida and the 'Right of Way' by the Regional Plan Association (RPA)
- "Hurricane Evacuation Zones" by NYCEM
- "Latest Climate Projections" by the NYC Panel on Climate Change (NPCC)
- "Hazard History and Consequence Tool" by NYCEM

Academic and Community Participation

To facilitate community participation in the hazard mitigation planning process, the Planning Team partnered with academics to develop community-focused hazard mitigation plans that address socially vulnerable and underrepresented communities. These efforts demonstrate a process in which communities will integrate the ideas, information, and strategy of the HMP.

HMP WORKSHOP, MAR 2023
SOURCE: NYCEM

MAINTENANCE

In developing the 2024 HMP, NYCEM is also committing to a formal plan maintenance process. The purpose is to ensure the 2024 HMP remains an active, viable document, and that the mitigation strategies it sets forth are updated and tracked. As mentioned in the Planning Participants section, the HMP is the result of a collaborative process involving the Planning Team, Steering Committee, and the Planning Partners. These bodies will continue to play a role in the HMP maintenance process, which includes efforts to:

- Monitor, evaluate, and update content and tools in the HMP.
- Codify annual mitigation actions and capability assessment updates.
- Incorporate the requirements of the HMP into existing planning mechanisms.
- Continue to engage communities by including them in the plan maintenance process.

Although the HMP update and publication of this Guide concluded in 2024, The Planning Team and HMP partners continue to implement strategies, assess their effectiveness, conduct research, confer, and adjust as required.

LEARN MORE ABOUT NYC

HAZARD ENVIRONMENT

To better understand the hazards in the HMP, an understanding of NYC's environment is essential. This section explores themes and topics necessary to assess the risks from natural hazards, vulnerabilities, and strategies for mitigation. As the most populous city in the U.S., NYC's role as a global hub, and its diverse population, neighborhoods, and infrastructure, emphasizes the vital need for comprehensive planning and risk mitigation.

NATURAL ENVIRONMENT

NYC's geographic position at the confluence of the Hudson River and the Atlantic Ocean has profoundly influenced its history and prosperity. Each borough, except the Bronx, features extensive shorelines, with Manhattan and Staten Island as islands, and Brooklyn and Queens as parts of Long Island. NYC not only borders the Hudson River and the Atlantic but also numerous bays, rivers, and tidal straits, including New York Harbor, Long Island Sound, the East River, Jamaica Bay, and the Harlem River. This unique relationship between land and water has significantly shaped the city.

TABLE: NYC'S RELATIONSHIP BETWEEN LAND AND WATER

TITLE	DESCRIPTION
Coastline Length	NYC features a 520-mile coastline bordering oceans, rivers, bays, inlets, harbors, and tidal straits.
Open Space/Parks Area	30,300 acres of open space and parks are managed by NYC Parks, covering 15 percent of the NYC's land area.
Open Space Buffer	Approximately 10,000 acres of open space serve as a buffer to inland areas, helping mitigate hazards from floods, high winds, and extreme weather.
Earthquake Vulnerability	Some areas in NYC are more vulnerable to the impacts of earthquakes due to their geology and the presence of artificial fill.
Ecological Habitats	NYC features 26 distinct, ecological habitats across its parks, with one-third of the parks' land dedicated to preserving environments like grasslands, wetlands, and streams.
Role of Natural Ecosystems	Natural ecosystems cover about 10,000 acres and are crucial in mitigating urban heat, absorbing stormwater, and providing protection during extreme weather events.

TOPOGRAPHY

NYC's topography varies significantly across its five boroughs. Elevations range from under 50 feet in much of Brooklyn, Manhattan, and Queens to nearly 300 feet in parts of northern Manhattan and the Bronx. The accompanying map highlights these variations, with Staten Island's Todt Hill being the NYC's highest point at 412 feet above sea level.

Human interventions, notably land reclamation along the waterfront, have notably reshaped the NYC's landscape. Lower Manhattan's extensive use of landfill, essential for developments like Battery Park City, has created areas prone to flooding. These low-lying, reclaimed lands heighten vulnerability in coastal neighborhoods, especially during severe weather events like coastal storms.

HISTORIC TOPO MAP OF NYC BOROUGHS
SOURCE: NYCEM

HISTORIC TOPO MAP OF MANHATTAN
SOURCE: NYCEM

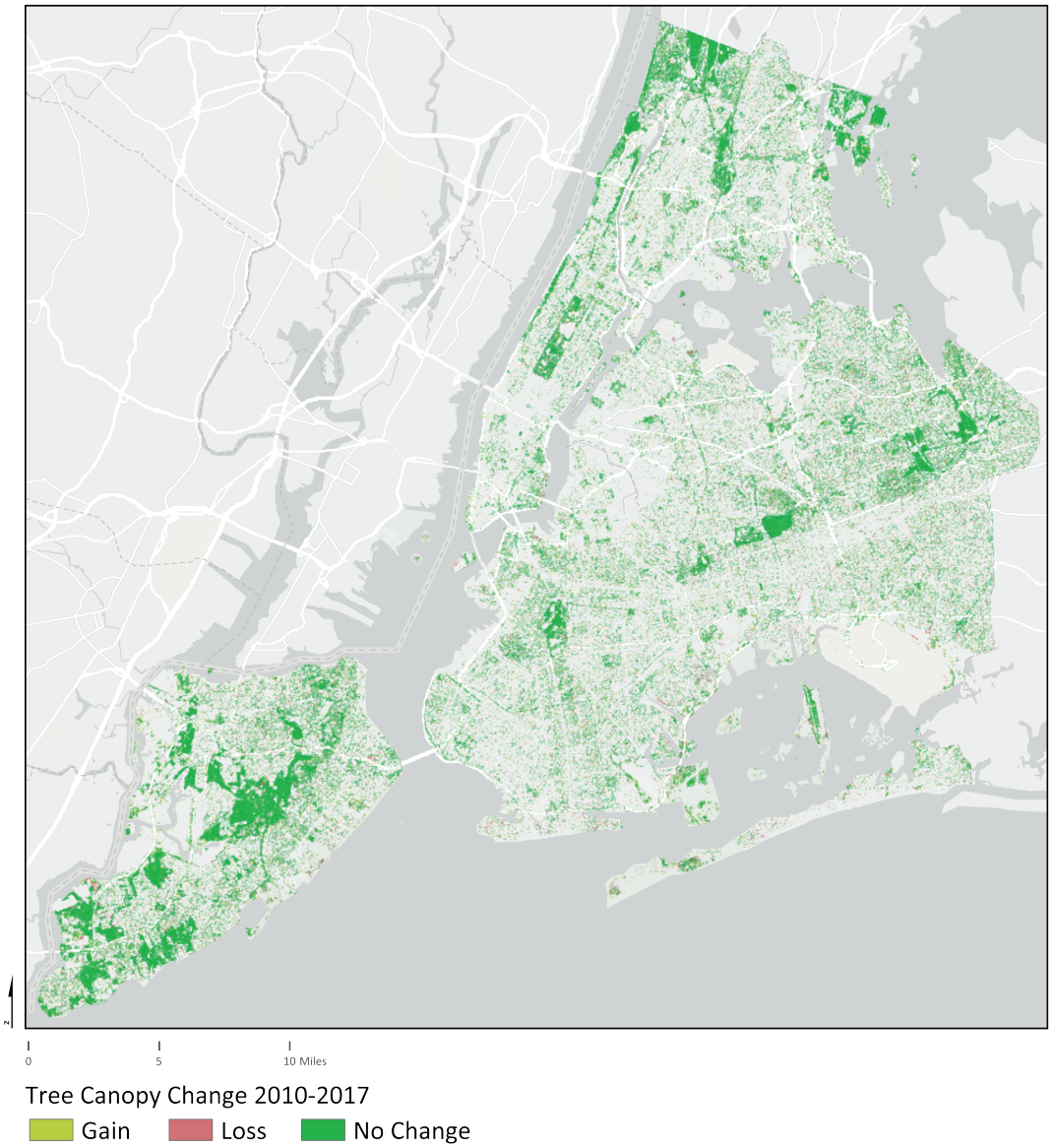
Open Space

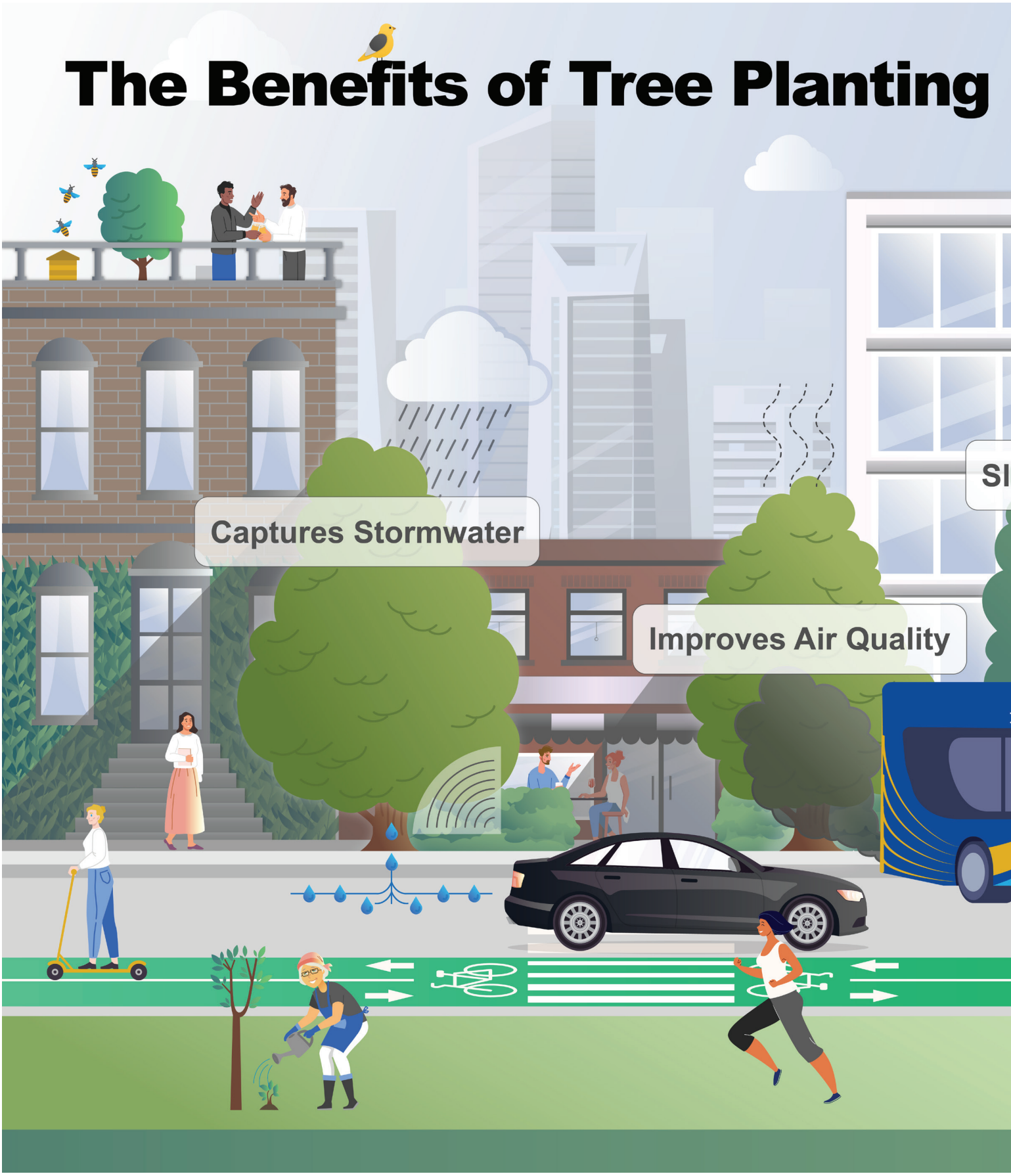
NYC includes a diverse array of open spaces, from natural areas to manicured parks, both shoreline and inland, spanning various sizes. Managed by NYC Department of Parks and Recreation, these spaces total over 30,300 acres — about 15 percent of NYC's land area, spread across more than 5,000 sites.

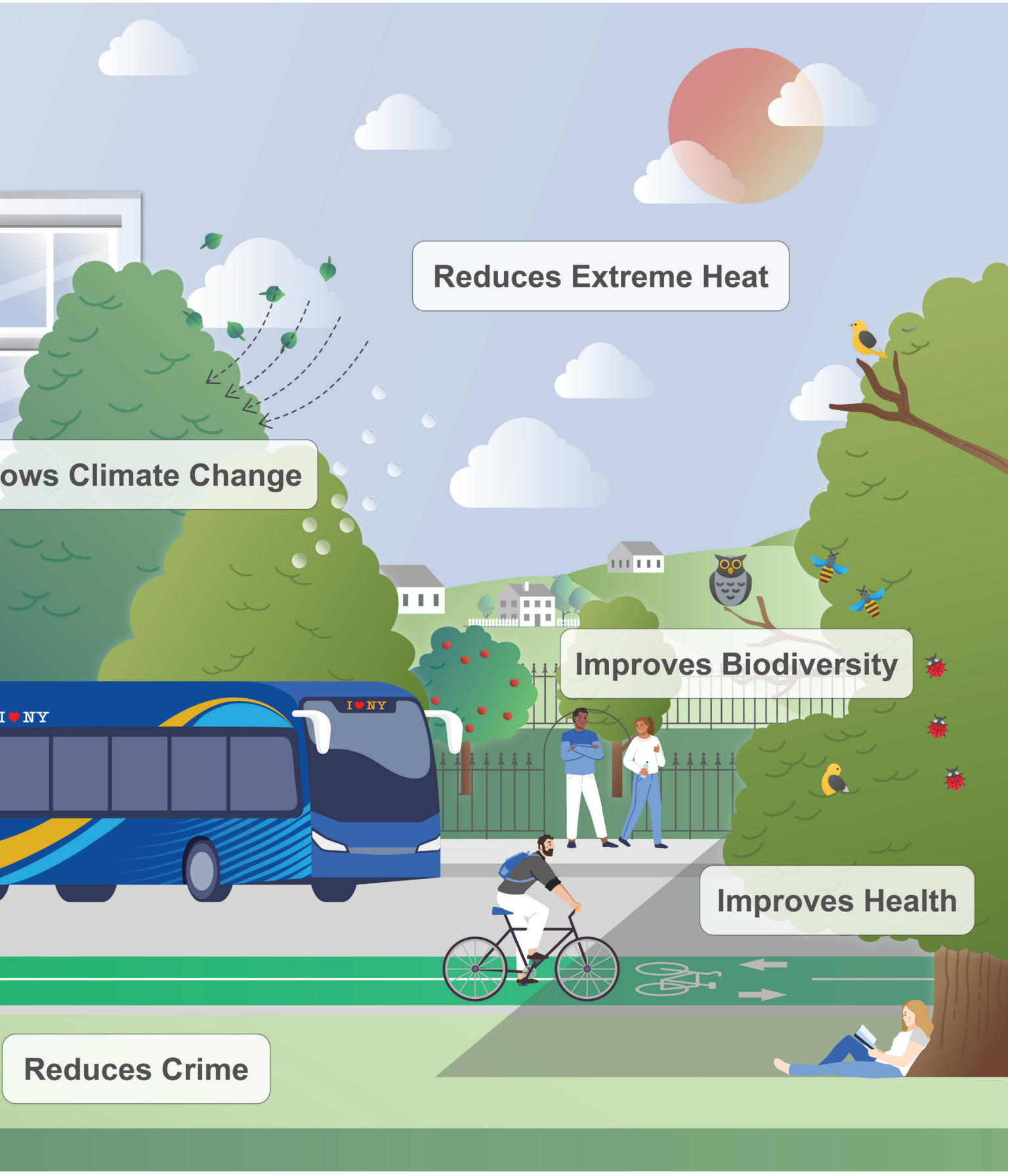
In 2016, NYC planted its one millionth tree through the MillionTreesNYC initiative, launched in 2007 as part of PlaNYC. Continuing these efforts, Local Law 148 of 2023 was passed that "sets goals to protect, care for, and expand the urban forest canopy with an overall goal of equitably expanding the urban forest canopy to cover 30 percent of land within the city."

NYC's parks and open spaces feature a diverse range of amenities such as playgrounds, esplanades, wetlands, trails, and more, contributing to the NYC's rich urban biodiversity. This diversity includes over 2,000 plant species, 200 tree species, and hundreds of bee and bird species, many of which are native and adapted to local conditions. However, urbanization and environmental changes are causing a decline in native species, replaced increasingly by invasive species. This shift is exacerbated by climate change and urban expansion, posing risks to about 140 rare species vulnerable to habitat degradation and the effects of international ports.

MAP: TREE CANOPY CHANGE 2010-2017




The Benefits of Tree Planting
Captures Stormwater
Improves Air Quality
Sl


Reduces Extreme Heat
ows Climate Change
Improves Biodiversity
Improves Health
Reduces Crime

GEOMORPHOLOGY AND TERRAIN

Geomorphology, which examines landforms and their shaping processes, is vital for assessing NYC's susceptibility to coastal storms and earthquakes. NYC's terrain was primarily sculpted by the Wisconsin Ice Sheet, a vast glacier that reached the area around 20,500 years ago. As it advanced, it transported and later deposited rock, gravel, and sand, forming a terminal moraine across Staten Island and central Brooklyn and Queens — around 18,000 years ago when the glacier began to melt. The subsequent melting also created outwash plains, now the low-lying areas vulnerable to storm surges and sea-level rise — particularly along Staten Island's east shore and in southern Brooklyn and Queens.

NYC's geological diversity, shown in the NYC Topography Map, reveals variations from solid bedrock to softer artificial fill, heightening the risk for seismic damage, especially in areas like Manhattan's Chinatown — which was developed on filled land. These characteristics underscore the increased earthquake risks detailed in the Earthquakes Hazard Profile of this report.

SOCIAL ENVIRONMENT

NYC, home to about 8.8 million people, has a population density of approximately 45 people per acre, making it the most populous and dense city in the United States. While all New Yorkers face potential risks from severe weather and other hazards, certain groups are more vulnerable. These include young children, seniors, people with disabilities or serious health conditions, people who are socially isolated, and households with limited English proficiency.

DEMOGRAPHICS

NYC is home to about 8.8 million people, averaging 45 people per acre. Manhattan, the most densely populated borough, has about 114 people per acre. In contrast, Staten Island is the least densely populated borough, with around 13 people per acre.

The demographic presented here identifies several populations particularly vulnerable to emergencies, including seniors, children, non-English speakers, and those with disabilities. Seniors often live alone, and many are foreign-born, potentially hindering their access to emergency services. Children in poverty and their families may lack resources for adequate disaster preparation and recovery. Additionally, a significant portion of the population with limited English proficiency and disabilities may face challenges in receiving and understanding emergency communications.

MAP: POPULATION DENSITY BY CENSUS TRACT

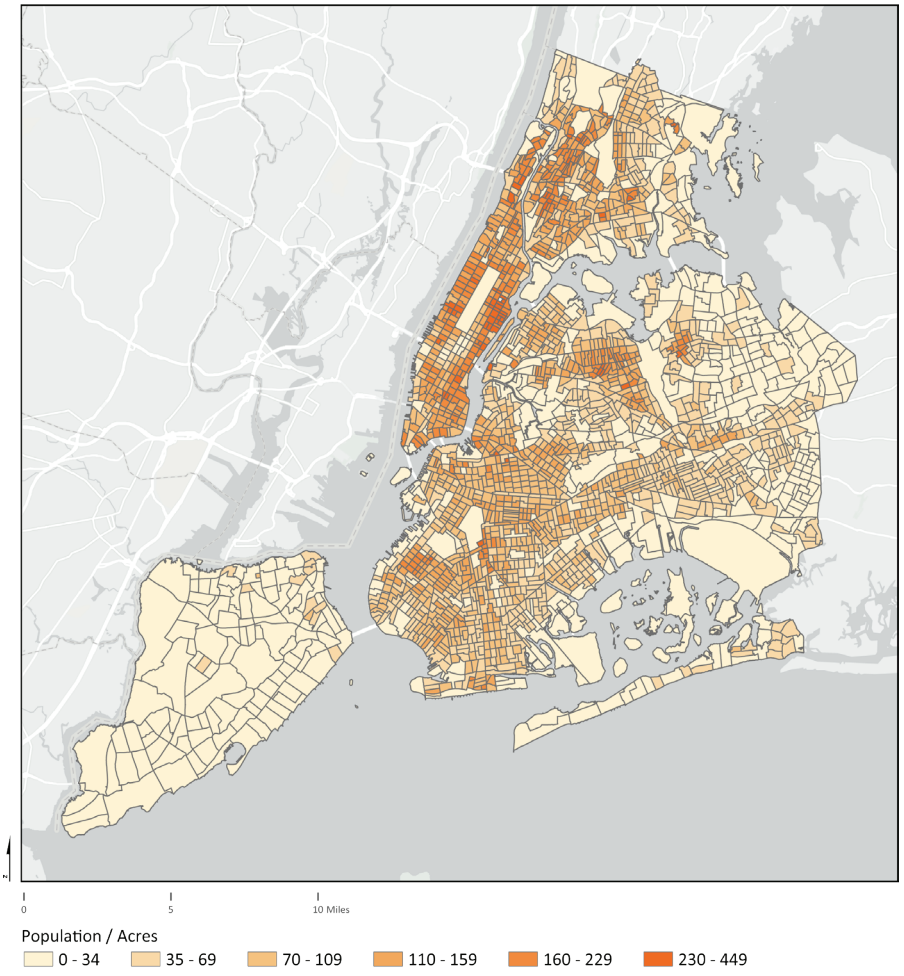


TABLE: VULNERABLE NYC DEMOGRAPHICS

Source: United States Census Bureau. American Community Survey (ACS) 2017–2021.

DEMOGRAPHIC	DETAILS
Seniors	• Population increased from 1.0 million (2010) to 1.3 million (2021) • 49% are foreign-born • 29% live alone
Children	• 20.9% of population under 18 years old • 6.2% under 5 years old • 48% of households have children under 18
Income & Poverty	• 17% live below the poverty line, totaling 1.5 million people • 29% of those under the poverty line are children under 18 • Highest concentrations in South Bronx, Upper Manhattan, and parts of Brooklyn
Language & Origin	• 3.1 million foreign-born residents • Over 200 languages spoken • Nearly 50% speak a language other than English at home • 22% have limited English-speaking proficiency
Disability	• 11% have at least one disability • 34% of those aged 65 and older have at least one type of disability

NEIGHBORHOOD KIDS PLAYING BASKETBALL
SOURCE: NYCEM

ENVIRONMENTAL JUSTICE

NYC's Environmental Justice (EJ) law defines Environmental Justice Areas as low-income, or minority communities located within the city. This definition enables City agencies to explore environmental and climate issues from a foundation of social vulnerability.

Low-income communities and communities of color are the most vulnerable to a rapidly changing climate. Disparities that are persistent in our society — from social, to economic and health inequities — can be exacerbated by the impacts of climate change and extreme weather events. For example, periods of extreme heat, winter storms, or floods can cause increases in utility and other costs that are not easily absorbed by low-income families. Preexisting underlying health conditions can make weathering a heatwave a life-threatening situation.

An EJ Area is an area that has been and continues to be more vulnerable to environmental injustices and climate catastrophe due to a history of systemic racism and economic inequality. This history has led to disparities in wealth, income, and education; the disproportionate concentration of other environmental hazards in low-income communities (for example, the siting of polluting infrastructure); unequal access to healthcare; and other factors.

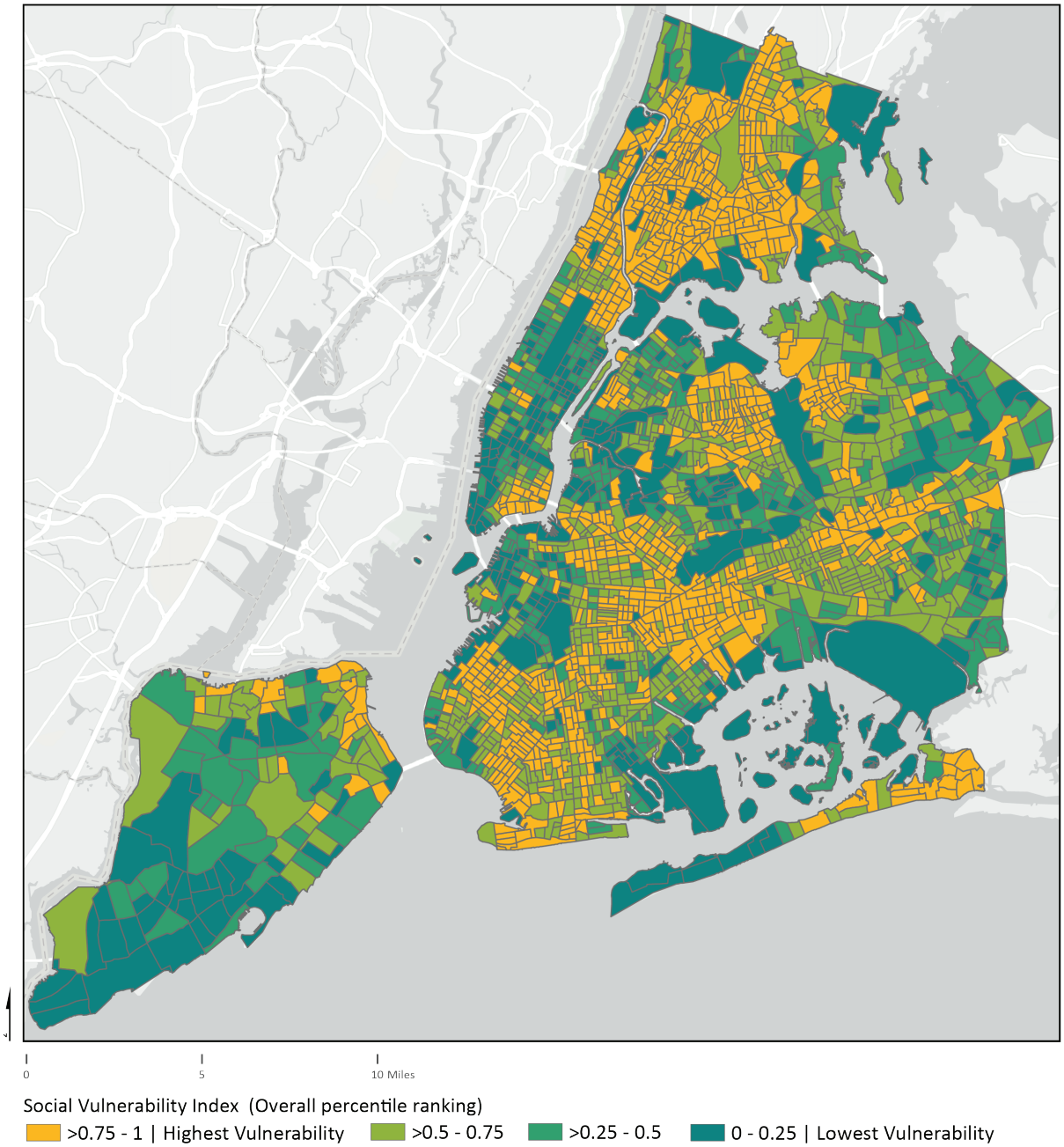
SOCIAL VULNERABILITY

Social vulnerability is the susceptibility of social groups to the adverse impacts of natural hazards, including disproportionate death, injury, loss, or disruption of livelihood.

The Centers for Disease Control and Prevention (CDC) created a Social Vulnerability Index (SVI) to help public health officials and emergency response planners identify and map the communities that will most likely need support before, during, and after a hazardous event.

Two areas with high social vulnerability include a large portion of The Bronx and East New York in Brooklyn, as seen in the map.

MAP: SOCIAL VULNERABILITY INDEX



ECONOMY

NYC is one of the global financial capitals of the world and serves as a center for national and regional economic activity. It is home to a wide range of industries and jobs — from finance and real estate, to high-tech and tourism, to manufacturing and the service sector. All this activity generates millions of regional jobs and economic activity. However, this activity is also vulnerable to the natural hazards profiled in this report.

HOUSING

Access to affordable housing can be a challenge in NYC, and disasters that result in property damage can further constrain the housing market. This may put pressure on the limited affordable supply and make recovery even harder.

Most New Yorkers (two-thirds) rent their homes, with a low vacancy rate and diverse housing typology, making housing recovery from disasters challenging. Further, some communities may already struggle with housing access due to historical discriminatory practices — including mortgage lending processes known as redlining — further exacerbating existing inequalities and access to housing.

HARLEM HOUSING COMPLEXES
SOURCE: ADOBE

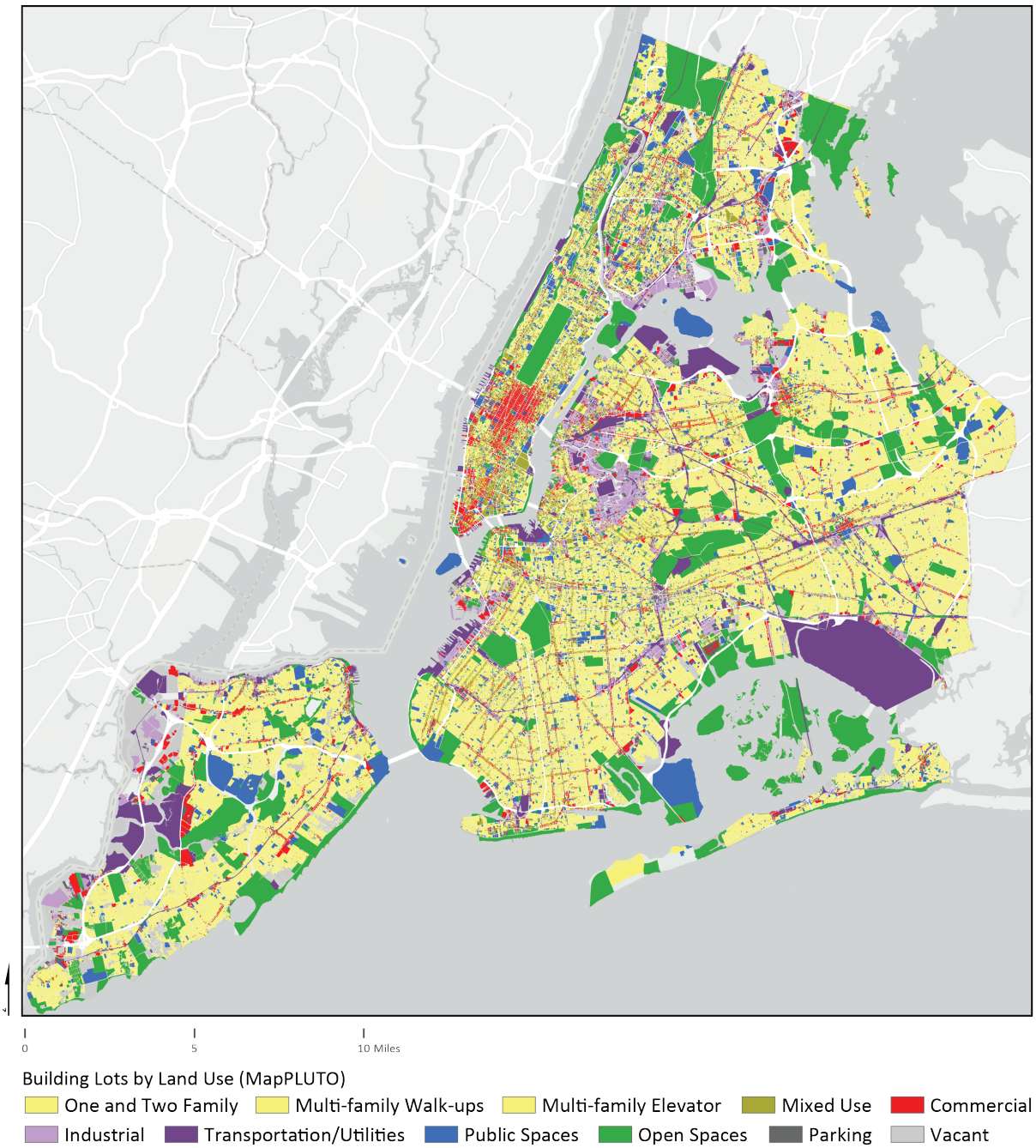
BUILT ENVIRONMENT

NYC's built environment is varied and immense, containing many characteristics that may amplify risks to hazards. Below NYC's streets and buildings is a vast network of critical underground transportation and infrastructure that enables millions of people to live in, work in, and visit the city — a factor that only adds to the complexity of NYC's unique built environment.

LAND USE

NYC's land area covers approximately 305 square miles. Excluding streets and major bodies of water, NYC's usable land, or lot area, totals approximately 145,000 acres (about 6.3 billion square feet).\

MAP: LAND USE



BUILDINGS

NYC's building stock encompasses approximately 1 million structures that vary by construction type, age, and use. Buildings reflect a wide variety of uses and construction types. These include single-family houses; freestanding wood-frame structures; attached masonry row houses; public housing projects; mid- and high-rise apartment complexes; low-rise retail districts; and massive commercial buildings and skyscrapers.

ENERGY SYSTEMS

NYC's energy infrastructure provides electric, natural gas, and steam to 8.8 million New Yorkers. It is one of the most complex and reliable services in the world. Power lines with robust, redundant networks link NYC to the broader regional electric grid.

TABLE: NYC ENERGY INFRASTRUCTURE

SYSTEM	DESCRIPTION
Electricity	Con Edison serves approximately 3.3 million customers within a 294-square mile area in NYC, operating 46 area substations. PSEG Long Island provides electricity to the Rockaways via three substations, serving about 32,757 customers through both overhead and underground cables.
Natural Gas	Con Edison distributes natural gas in Manhattan, the Bronx, and northern Queens, while National Grid handles Brooklyn, Staten Island, and southern Queens. Natural gas is crucial, meeting about 65 percent of NYC's heating needs, powering the majority of its "in-city" electricity production, and used extensively for cooking.
Steam	Con Edison operates five, steam-generating plants in NYC (four in Manhattan and one in Queens) and receives additional steam from a plant in Brooklyn Navy Yard. Their network of 105 miles of underground pipes supplies steam to over 1,650 customers in Manhattan below 96th Street on the East Side and below 89th Street on the West Side.

WATER SUPPLY

NYC's drinking water is renowned for its quality. Daily, the system delivers over 1 billion gallons to 10 million customers across New York State, including 8.8 million NYC residents. Additionally, about 110 million gallons are supplied daily to nearly 1 million people in Orange, Putnam, Westchester, and Ulster counties, serving nearly half of the state's population.

WASTERWATER TREATMENT

All 14 of NYC's wastewater plants are situated along the waterfront at low elevations, which reduces the cost and environmental impact of wastewater treatment. The waterfront locations facilitate gravity-driven flow and easy discharge of treated effluent into waterways. Additionally, these sites enable efficient boat transportation of sludge to DEP facilities for further treatment.

CROTON FALLS RESERVOIR
SOURCE: NYC DEP

TRANSPORTATION SYSTEMS

NYC's transportation system, a vast and complex network of rail, roadway, air, and waterway connections, is vital for daily travel and transport. Disruptions to this system can hinder commutes and interrupt the operations of businesses, government agencies, healthcare providers, and other institutions.

Rail Network

NYC's commuter and freight rail systems are among the nation's most complex, handling two-thirds of the U.S. rail riders. Daily, about 5.6 million riders use the subway. The Metropolitan Transportation Authority (MTA), operated by New York State, is the largest transit authority in the U.S. It manages major rail networks including NYC Transit (subway system), Long Island Rail Road at Penn Station and Grand Central Madison, and Metro-North Railroad at Grand Central Terminal. Additionally, the Port Authority of New York and New Jersey (PANYNJ) offers commuter rail via PATH trains between New Jersey and NYC, while Amtrak operates out of Penn Station, its busiest hub, connecting NYC to its national rail network.

Roadway Network

New York City Department of Transportation (DOT), MTA, New York State Department of Transportation (NYS DOT), and Port Authority of New York and New Jersey (PANYNJ) manage roadway travel in NYC. DOT manages approximately 800 bridges and four tunnels, and maintains over 6,300 miles of streets, 12,700 traffic signals, and numerous sidewalks and retaining walls.

MTA oversees seven bridges and two tunnels — used by more than 329 million vehicles each year — and operates 327 bus routes across NYC's roadways. PANYNJ manages four bridges and two tunnels between New York and New Jersey, as well as two bus terminals in NYC, whose networks transport commuters between these two states.

FOOD SUPPLY CHAIN

Most of the food consumed in NYC is produced outside its borders, with about 99 percent of the supply delivered by truck. Over half of NYC's food volume enters through its bridges and tunnels. The Hunts Point Food Distribution Center in the South Bronx, the world's largest produce market by revenue, is central to NYC's food network, distributing 12 percent of all food.

COUPLE AT PRODUCE MARKET
SOURCE: NYCEM

FUTURE ENVIRONMENT

NYC's future environment will be affected by climate change, population growth, and land-use development trends.

CLIMATE CHANGE

Climate change presents multiple risks to NYC by altering the frequency and patterns of hazardous weather, including heatwaves, torrential rains, high winds, and increasingly severe snowstorms and storm surges.

The fourth convening of the New York Panel on Climate Change (NPCC4) was led by experts from diverse disciplines including climate science, engineering, and urban planning. The panel, selected for its broad expertise, produced a comprehensive report with chapters on health, energy, equity, and more. The 2024 NPCC4 report reaffirms the 2015 climate projections. These projections, derived from extensive climate analysis and scientific literature, inform the City's resiliency planning and adaptation strategies for climate change.

The NPCC4 findings are integrated throughout the hazard profiles to highlight how climate change will shape NYC's future environment. Key projections include more frequent heat waves, rising sea levels, heavier precipitation, and fewer days with freezing temperatures. These changes are expected to intensify risks across natural, built, and social systems, requiring adaptive strategies to mitigate cascading impacts on public health, infrastructure, and the economy.

POPULATION PROJECTIONS

NYC's population is dynamic, with several hundred thousand people moving in and out annually. Since 1990, the population has consistently grown with each decade's census. According to recent forecasts by the NYC Department of City Planning (DCP), this trend is expected to continue. By 2040, NYC's population is projected to grow by almost 10 percent, reaching over 9 million residents for the first time.

CROWD IN GRAND CENTRAL STATION
SOURCE: NYC MAYOR'S OFFICE

01

COASTAL EROSION

LEARN ABOUT COASTAL EROSION

What is the Hazard?
What is the Risk?
How to Manage the Risk?

Coastal erosion plays a significant role in the retreat of NYC's coastlines. It also amplifies the NYC's vulnerability to coastal storms, leaving it more at risk for natural resource depletion, infrastructure damage, physical and mental harm, and economic hardship.

WHAT IS THE HAZARD?

Coastal erosion is the loss or displacement of coastline land from the interaction of oceans, waves, and beaches, often coupled with the impact of human activity. Coastal erosion occurs when wind, waves, longshore currents, tides, runoff of surface water, or groundwater seepage, move sand and sediment from a shoreline location. This displaced sand and sediment shift from place to place and do not disappear from the overall system unless human activities, such as dredging, permanently remove them. In NYC, seasonal patterns may influence erosion. Winters are typically more erosive, while summers typically bring sediments back to the shoreline.

While coastal erosion is a natural process, human activity can worsen it through poor land-use methods. For example, built structures that do not consider coastal erosion cycles or hydrodynamics can increase erosion or shift sediments to nearby areas. Some coastal-control structures along the coast are built to prevent erosion in a specific location. However, if they are not constructed carefully, these structures can increase erosion in adjacent areas.

Coastal erosion poses many challenges to coastal communities — the loss of valuable real estate and personal property, as well as the loss of recreational areas, wildlife habitat, and vital natural flood protection. Coastal communities require the best methods for controlling beach erosion and restoring land.

COASTAL EROSION IN BROOKLYN'S SEAGATE 1996–2018

These aerial photos of Seagate in Brooklyn display how certain hardened structures can alter the shoreline. Since its construction in 1995, the groin (extending into the water perpendicular to the shore) has worsened erosion on the western side, exposing property, while the beach on the east side has remained intact. Interestingly, the Seagate shoreline has changed again since the photo was taken in 2012; the USACE completed construction of groins in the Seagate area in 2017.

LEFT TO RIGHT:
Brooklyn Seagate, 1996–2018
Source: NYCEM, DoITT (imagery)

SEVERITY

Coastal erosion can be rapid or can occur gradually. However, measuring gradual (or long-term) erosion is often difficult because the extent of natural erosion in a specific shoreline varies significantly from year to year. If choices are made to dredge or nourish beaches along particular parts of the coast, it can be difficult to determine how much beach is being lost or gained through natural processes and how much is being affected by human activities.

PROBABILITY

Gradual coastal erosion is essentially a given, because it is a continuous natural process that affects coastlines in NYC and around the world. Rapid coastal erosion is likely to occur, but the extent of any such erosion is hard to predict because it is based on several factors, including the unknown probability of coastal storms.

LOCATION

Along NYC's 520 miles of coastline, long-term erosion rates vary significantly because of geology and the physical nature of different locations along the shoreline.

Areas along NYC's southern shore is at greatest risk, since they are exposed to wave action from the Atlantic Ocean and to the waters of many bays, including Gravesend, Jamaica, Lower New York, and Raritan.

To protect against the effects of coastal erosion, the New York State Department of Environmental Conservation (NYS DEC) developed the Coastal Erosion Hazard Area (CEHA) construction permit program and has delineated hazard area boundaries on CEHA maps.

There are two separate categories that make up CEHAs.

- **Natural Protective Feature Areas**: Such as nearshore areas, beaches, bluffs, and dunes, Natural Protective Feature Areas make up New York's natural features that protect against erosion. Alterations to these areas may reduce or eliminate their protective capabilities and diminish the reserves of sand or other natural materials that naturally replenish shores following storms. Landward limits of the Natural Protective Feature Area are delineated on the CEHA maps.
- **Structural Hazard Areas**: These are regulated areas landward of the Natural Protective Feature Areas. They are designated only along shorelines that are receding at an average rate of one foot or more per year.

SHORELINE CHANGE FOR ANNADALE, STATEN ISLAND: 1924–2018
SOURCE: NYS DEC, NYCEM GIS, 2018

NYS DEC has identified three distinct CEHAs for NYC.6 Together, these comprise approximately 1,428 acres and represent 0.7 percent of NYC's land area:

- Coney Island, Brooklyn
- Plumb Beach, Brooklyn
- Rockaway Peninsula, Queens
- South Shore, Staten Island

HISTORIC OCCURRENCES

Coastal erosion is an ongoing natural process frequently exacerbated by human activity. Throughout NYC's history, however, the combined impact of high winds and storm tides during significant coastal storms, such as nor'easters or hurricanes, have caused large-scale, event-driven erosion.

US Army Corps of Engineers (USACE) Rockaway Coastal Storm Protection

USACE is actively enhancing the storm risk management measures around the NYC coastal area to protect over 850,000 residents and critical infrastructure. Key initiatives include a composite seawall with a reinforced dune system, groin construction, and a Storm Surge Barrier for Jamaica Bay. Construction of the reinforced dune system began on July 5, 2022, and the Storm Surge Barrier's final design is still under review.

WHAT IS THE RISK?

Coastal erosion poses many challenges to coastal communities — the loss of valuable real estate, personal property, recreational areas, and vital natural flood protection. Controlling beach erosion and restoring land are major concerns in NYC's coastal communities.

SOCIAL ENVIRONMENT

Coastal erosion can happen rapidly or gradually. When coastal erosion occurs rapidly, in association with harsh coastal storms, it has the potential for structural damage and financial loss.

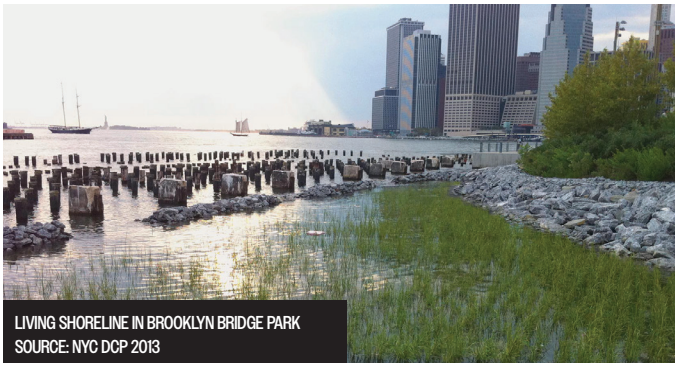
Gradual coastal erosion may also pose a financial risk. If businesses and residents relocate from waterfront property, the low availability and high cost of housing in NYC may present a challenge. However, if residents with waterfront property remain to protect their property, they may be required to make structural changes or construct bulkheads or riprap. The cost of these interventions may financially stress lower- or middle-income residents.

People with disabilities and access and functional needs may also face similar issues. Relocating may be difficult because of the expenses and the availability of accessible housing, or the time needed to make housing accessible. Structural improvements may not be possible because doing so could render the housing inaccessible.

BUILT ENVIRONMENT

As coastal erosion continues, built structures become closer to the water's edge, thereby increasing the risk of damage to public and private property.

NYC has 197 buildings with a footprint that intersects a CEHA. The table indicates that 106 buildings are completely or mostly within the hazard area, while another 91 at least touch the perimeter.[2]



LIVING SHORELINE IN BROOKLYN BRIDGE PARK
SOURCE: NYC DCP 2013

NATURAL ENVIRONMENT

Under natural conditions, beaches (particularly barrier islands or spits like the Rockaway Peninsula) are dynamic features of the landscape. The shape and location of NYC's coastline change over time, due to coastal erosion and other processes. Left in a natural state, some beaches and shoreline areas erode while others increase. Overall, however, these processes are balanced.

Although human activity can potentially exacerbate coastal erosion, built infrastructure can also help to mitigate it. For example, shoreline stabilization structures keep beaches and shorelines intact for public use. These structures can prevent longshore drift (where waves approach the shoreline in such a way that results in sediment being moved north along the beach in a zigzag motion) and help to protect public amenities and recreational assets. However, constructing hardened structures along the coast may accelerate erosion by inhibiting the migration of natural beach sediment. Implementing and managing nature-based protection measures in coastal areas, such as the restoration of marshland or development of living shorelines, can enhance shoreline stabilization and work with natural coastal processes to lessen their impact.

FUTURE ENVIRONMENT

The NPCC4 report anticipates sea-level rise to accelerate in NYC in the next century and remain above the global average rate. The report projects sea-level rise of 14 to 19 inches by the 2050s and 25 to 39 inches by the 2080s. This rise in sea level will exacerbate coastal erosion, especially during coastal storms that could hit NYC with increased frequency and ferocity.

Exactly how much erosion is directly attributable to sea-level rise is unclear. When viewed in terms of 30- to 50-year periods, the effect of sea-level rise is less significant than that of other contributors to shoreline change.

Future erosion rates are difficult to predict, underscoring the need to increase baseline data collection and build monitoring stations along the coast to assess annual shoreline changes.

[2] NYC Department of Buildings, "Coastal Erosion Hazard Map," City of New York.

HOW TO MANAGE THE RISK?

STRUCTURAL

To protect the urban environment, NYC has built robust erosion-control structures throughout the five boroughs. Engineered structures on shore or in the water, that are properly sited and sized according to building codes, play a crucial role in mitigating coastal erosion. Adhering to American Society of Civil Engineers (ASCE) standards, like ASCE 7, is essential in this context as it provides comprehensive guidelines for designing structures to withstand various environmental loads. This includes forces caused by natural disasters such as floods and tsunamis, ensuring that these structures effectively counteract the impacts of coastal erosion and maintain the integrity of the shoreline.[3]

Choosing the most effective erosion-control structure depends on the specific features of the coastal location:

TABLE: COASTAL LOCATION DESCRIPTIONS

TITLE	DESCRIPTION
Seawalls	Massive structures built parallel to the shoreline, often made of stone, rock, or concrete, designed to resist wave forces and prevent erosion by holding the shoreline in place.
Revetments	Sloped structures made typically of stone or concrete blocks to protect underlying soil from erosion and minimize wave energy. Riprap and gabions are common materials used in revetments.
Bulkheads	Vertical retaining walls, usually made of wood or sheet steel, designed to hold soil in place and stabilize the shoreline.
Groins	Structures extending perpendicular from the shore into the water, constructed from durable materials like rock, concrete, wood, or steel to trap sand, prevent erosion, and break waves, ensuring effectiveness in coastal protection.
Jetties	Larger structures compared to groins, primarily designed for sediment management and typically located at river mouths.
Breakwaters	Offshore structures, usually made of rock, positioned parallel to the shoreline to break waves and reduce shoreline erosion.
Artificial Reefs	Structures, either fully or partially submerged, made from materials like rock or concrete to break waves, reduce shoreline erosion, and provide marine habitats.

GROINS ALONG THE ROCKAWAY PENINSULA
SOURCE: NYC DCP, 2013

[3] American Society of Civil Engineers, "Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ACSE/SCI 7-11)," American Society of Civil Engineers.

THE JAMAICA BAY OYSTER RESTORATION PROJECT. SOURCE: NYC DEP

NATURE-BASED STRATEGIES

Placing natural and nature-based buffers and protective features on the shore or in the water can help maintain the shoreline in place. Environmental control measures include the following:

TABLE: ENVIRONMENTAL CONTROL MEASURES

TITLE	DESCRIPTION
Beach Nourishment	The process of adding sand, typically dredged from nearby ocean bottoms, to beaches to enhance elevation and distance between upland areas and the shoreline. This creates a buffer that absorbs storm and wave energy, reducing flood risk and dune erosion.
Vegetation	Often used on beaches, dunes, and unstable shorelines to anchor sand or soil, helping to stabilize these areas and prevent erosion.
Living Shorelines	Combinations of natural elements — like plants with sand or soil and hard structures such as stone, riprap, or eco-friendly concrete blocks — stabilize shorelines, prevent erosion, and support wildlife and marine habitats.
Constructed Wetlands	New or restored tidal wetlands utilize plants to anchor the soil, prevent erosion, and create habitats for wildlife.
Vegetated Islands	Fixed or floating offshore structures, such as anchored mats or infill islands, provide ecological benefits and help minimize shoreline erosion by breaking waves.

NYC's development into a major seaport and coastal city, renowned for its extensive waterfront, has deep historical roots stretching back well before the early twentieth century. This flourishing center of commerce and activity owes its origins to the times preceding colonial settlement, with the Lenape people being the original inhabitants of this region.[4] Their presence and interaction with the area's natural resources set the foundation for what would become one of the world's most dynamic and significant urban waterfronts.

Today, approximately 30 percent of the City's coastline is under NYC Department of Parks and Recreation (NYC Parks) jurisdictions, including more than 14 miles of beaches that NYC protects and manages for public use and enjoyment as well as diverse habitats for plants and animals.[5] Since 1975, NYC has facilitated placement of an estimated 20 million cubic yards of sand on popular Rockaway Peninsula beaches. From the inception of its Natural Resources Group in 1984, NYC Parks has restored acres of forest and of wetland on its properties. The NYC Department of Environmental Protection (DEP), NYS DEC, NPS, and the New York State Office of Parks, Recreation and Historic Preservation (NYS Parks) have also contributed significantly to the restoration of coastal natural areas.

[4] National Museum of the American Indian, *Manahatta to Manhattan: Native Americans in Lower Manhattan* (Smithsonian Institution, 2010).
[5] NYC Parks, "About the New York City Department of Parks & Recreation," New York City Department of Parks and Recreation.

POLICY AND REGULATION

Limiting development in CEHAs and other protective land-use methods can reduce the risk of coastal erosion. The NYC Waterfront Revitalization Program (WRP), which is overseen by the NYC Department of City Planning (DCP), creates policies for waterfront planning, preservation, and development projects in the city and ensures they are implemented consistently over the long term.

The WRP is authorized by New York State's Waterfront Revitalization of Coastal Areas and Inland Waterways Act, which was enacted in response to the Federal Coastal Zone Management Act. The NYS Waterfront Revitalization Act allows each municipality to participate in the State's Coastal Management Program by preparing and adopting its own local contribution to the WRP.

The New York State Department of Environmental Conservation enforces regulations within all state-designated CEHAs, as described earlier. The State's Environmental Conservation Law, which limits coastal development to protect areas sensitive to erosion at risk, regulates properties in all CEHAs.[6]

In addition, the Water Resources Development Act (WRDA) of 2022 has introduced several provisions that aim to improve coastal erosion management and enhance shoreline resiliency in New York. Section 8106 provides a legislative framework for comprehensive coastal erosion management in New York. It allows for the expansion of feasibility studies to explore various risks, including coastal erosion, and introduces measures for shoreline restoration, flood risk reduction, and the use of advanced mapping tools for effective coastal management.[7]

Other types of regulatory measures include the following:

- **Construction Permits:** Often required to construct or modify existing structures, incorporate coastal erosion management regulations to ensure that any type of building activity will not accelerate shoreline erosion.
- **Setbacks or Buffers:** Specify the minimum distance required from the erosion hazard area for certain types of land use or new development. Regulatory setbacks, which are identified on the State's CEHA maps, are only marked in areas having a long-term average erosion rate of one foot or greater per year.
- **Development Restrictions:** Change the types of zoning allowed in coastal areas or restrict the types of expenditures allowed. For example, the Coastal Barrier Resource Act (CBRA) created federal regulations applicable to different categories of private and public land units along the shore.[8] CBRA provisions restrict use of federal expenditures, such as federal flood insurance, that might otherwise encourage development in at-risk shoreline environments. Areas within the private land units can be developed, provided private developers or other nonfederal parties bear the full cost.

BEACH RENOURISHMENT AT ROCKAWAY BEACH
SOURCE: USACE

[6] Coastal Management, "Coastal Development: Protecting New York Coastlines," New York State.
[7] Nicole T. Carter and Anna E. Normand, "Water Resources Development Act of 2022," Congressional Research Service, 2022.
[8] U.S. Fish and Wildlife Service. "Coastal Barrier Resources Act," U.S. Fish and Wildlife Service.

02

COASTAL STORMS

LEARN ABOUT COASTAL EROSION

What is the Hazard?
What is the Risk?
How to Manage the Risk?

In the future, climate change and rising sea levels are likely to increase the frequency, severity, and impact of coastal storms in NYC.

WHAT IS THE HAZARD?

Coastal storms happen when different meteorological conditions converge. Coastal storms are organized systems that have unique characteristics, but each type can turn deadly due to their hazardous consequences — sustained destructive winds, heavy rainfall, storm surge, coastal flooding, and erosion. NYC experiences hazards from two types of coastal storm systems:

CHARACTERISTICS OF COASTAL STORMS

TROPICAL CYCLONE

- Forms in tropics or subtropics
- Derives energy from warm ocean water
- New York City is most at risk between August and October
- Often associated with bands of severe thunderstorms and possibly tornadoes
- Forms over water
- Not associated with wintry precipitation (snow, sleet, freezing rain)

NOR'EASTER

- Forms outside of the tropics
- Derives energy from temperature contrasts between cold and warm air masses in the atmosphere
- New York City most at risk between October and April
- Rarely associated with severe thunderstorms and tornadoes
- Forms and maintains strength over either land or water
- Often associated with wintry precipitation (snow, sleet, freezing rain)

TROPICAL CYCLONES

Tropical cyclones are organized systems of thunderstorms that form over warm tropical ocean waters. These systems rotate counterclockwise in the northern hemisphere around a low-pressure center and are classified into three types:

- **Tropical Depression**: An organized system of clouds and thunderstorms with a defined surface circulation and maximum sustained winds of 38 miles per hour (mph) or fewer.
- **Tropical Storm**: An organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds of 39 to 73 mph.
- **Hurricane**: An intense tropical weather system of strong thunderstorms with a well-defined low-pressure center ("eye") and maximum sustained winds of 74 mph or greater.[9]

Several conditions must be in place for tropical cyclones to form and maintain their intensity. For a tropical cyclone to form, generally, water temperatures at the ocean's surface must be greater than 80°F at the point of origin. Tropical cyclones that affect NYC originate in the North Atlantic Basin. Conditions that cause tropical cyclones to form are most likely to occur off the western coast of Africa, in the Caribbean Sea, and in the Gulf of Mexico.

The North Atlantic Basin has an average of 14 named tropical storms, seven hurricanes, and three major hurricanes per year.[10] NYC is at highest risk between August and October, when water temperatures are warmest and meteorological conditions in the North Atlantic Basin favor storm formation.

When tropical systems make landfall, the primary hazards are heavy rain, high winds, tornadoes, and storm surge. The most dangerous conditions arise in two specific areas of a hurricane — near the center of circulation, or eye wall (the region surrounding the eye), and in the right-front quadrant of the storm, where the hurricane's high-speed forward motion accelerates the impact of high winds and storm surge.

Heavy rain from tropical systems can occur throughout the duration of a storm. The heaviest rain typically falls on the left side of the storm's eye. The amount of rainfall depends upon the storm's speed, size, and the geography of the area it traverses, not on its classification.

[9] National Oceanic and Atmospheric Administration, "Tropical Cyclone Climatology," National Hurricane Center.
[10] National Hurricane Center and Central Pacific Hurricane Center, "Tropical Cyclone Climatology," National Oceanic and Atmospheric Administration.

LIGHTNING AROUND THE VERRAZZANO-NARROWS BRIDGE
SOURCE: METROPOLITAN TRANSPORTATION AUTHORITY

NOR'EASTERS

A nor'easter is a type of coastal storm that primarily affects the mid-Atlantic and New England states between October and April. Like tropical cyclones, nor'easters are associated with heavy precipitation and a counterclockwise rotation around a center of low pressure. The following chart summarizes the differences between tropical cyclones and nor'easters.[11]

TABLE: TROPICAL CYCLONE AND NOR'EASTER CHARACTERISTICS

TROPICAL CYCLONE	NOR'EASTER
• Forms in tropics or subtropics. • Forms over water. • Derives energy from warm ocean water. • Occurs between June and November. • Often associated with bands of severe thunderstorms and possibly tornadoes. • Not associated with wintery precipitation (snow, sleet, freezing rain).	• Forms outside of the tropics. • Forms and maintains strength over either land or water. • Derives energy from temperature contrasts in the atmosphere. • Occurs between October and April. • Rarely associated with severe thunderstorms and tornadoes. • Often associated with wintry precipitation (snow, sleet, freezing rain).

When these storms reach the Northeast or mid-Atlantic coast, the counterclockwise circulation brings winds from a northeasterly direction — hence the name nor'easters. Although nor'easters are typically weaker than hurricanes, they may be larger and have durations lasting multiple tide cycles, creating the risk of more widespread impact. Nor'easters occur more frequently than hurricanes in the NYC area. Due to their frequency, the risk posed by hazards from nor'easters could be considered cumulatively greater than those from hurricanes.

The hazards posed by nor'easters are heavy precipitation, inland flooding, and winds typically strong enough to knock down trees and power lines, causing widespread disruption and structural damage to buildings. Nor'easters may also create coastal flooding from storm surge and large waves.

The hazards of heavy snowfall, sleet, and freezing rain are often associated with nor'easters. When a wintertime nor'easter moves up the Atlantic coast and follows a track west of NYC, precipitation often changes from snow or sleet to rain. If a nor'easter maintains a track just off the coast of the city, snow or mixed precipitation likely occurs.

[11] National Weather Service, "What Is a Nor'easter?," National Oceanic and Atmospheric Administration.

SEVERITY

Tropical Cyclones

The severity of a tropical cyclone depends on multiple factors and is primarily related to potential, expected, or experienced impacts. However, the intensity of tropical storms is formally categorized based on wind speed as measured by the Saffir-Simpson Hurricane Wind Scale. This scale categorizes a hurricane's intensity on a scale ranging from 1 to 5 based on the storm's maximum sustained wind speed. Levels of potential property damage are associated with each of the five categories. Hurricanes categorized 3 or higher are considered major hurricanes. This scale does not indicate the amount of surge or rain expected from a hurricane, only wind.[12]

Although the Saffir-Simpson Hurricane Wind scale is a practical way of measuring hurricane strength, other factors contribute to a hurricane's impact on a given location — including the storm's size (proportional to the radius of maximum winds) and speed of its forward motion. A larger, slower-moving storm, for example, may cause greater damage than a smaller, faster-moving storm with high winds because a single location might be battered by winds from a slower-moving hurricane for a longer period.

Nor'easters

Nor'easters do not have a universally recognized classification system, but their strength and severity are influenced by factors like those discussed regarding the severity of tropical storms.

When a nor'easter produces a heavy snowfall, the Northeast Snowfall Impact Scale (NESIS) is used to measure the intensity of wintry precipitation. The NESIS characterizes and ranks high-impact Northeast snowstorms — those with large areas of snowfall accumulations of 10 inches and greater — on a scale of 1 to 5.

The National Climatic Data Center developed this scale to indicate the degree to which Northeast snowstorms might affect the transportation systems and economy of the region — and thereby impact the rest of the country. The NESIS index incorporates population data and meteorological measurements to gauge a nor'easter storm's overall impact.

PROBABILITY

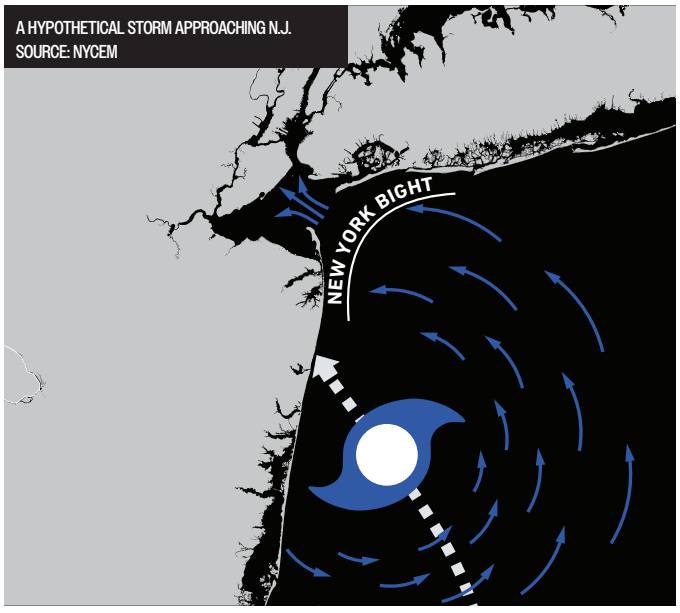
Tropical Cyclones

National Hurricane Center (NHC) forecasts storm tide heights for tropical storms and hurricanes on a probabilistic basis (a range of likely storm tide levels) and updates its forecasts regularly as specific storms approach landfall.

The NHC calculates return periods for hurricanes for various locations along the East Coast of the United States. These return period calculations represent the average amount of time between the passage of two hurricane eyes within a 50-nautical-mile (57.54-mile) radius of a given location.[13]

Nor'easters

The National Oceanic and Atmospheric Administration (NOAA) provides timely storm tide forecasts for nontropical storms (including nor'easters) on a deterministic basis (a single value for each tide gauge location). NYC typically experiences several nor'easters of different intensity every year. Most of these nor'easters are relatively weak but retain the potential to produce significant rainfall or snowfall hazards that can cause minor-to-moderate damage across the area. The probability of severe nor'easters affecting NYC is low, but they do strike occasionally.



A HYPOTHETICAL STORM APPROACHING N.J.
SOURCE: NYCEM

[12] National Hurricane Center and Central Pacific Hurricane Center, "Saffir-Simpson Hurricane Wind Scale," National Oceanic and Atmospheric Administration. [13] National Hurricane Center and Central Pacific Hurricane Center, "Tropical Cyclone Climatology," National Oceanic and Atmospheric Administration.

LOCATION

Tropical Cyclones

The vulnerability of different neighborhoods and areas of NYC to hazards associated with tropical storms varies significantly. To predict storm surge and to guide the City's planning for coastal storms, NYCEM utilizes outputs from an NHC computer model called SLOSH (Sea, Lake, and Overland Surges from Hurricanes). The model estimates surge heights for storms of varying strengths and directions and generates a worst-case scenario for specific locations.

The NYC Hurricane Evacuation Zones map shows areas of the city likely to experience inundation from different categories and direction of storms, based on the SLOSH model calculations. The extent of inundation and storm-surge depths indicated on the map reflect the worst-case scenario for Category 1–4 hurricanes in different parts of NYC.

Nor'easters

The National Weather Service (NWS) provides water level forecast ranges, referenced to several different data points that reference water levels, by a phase of the tide. The two most common tidal data references that are used for tidal gauges around the NYC metro region ahead of an impending coastal flood event include Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW).

HISTORIC OCCURRENCES

There have been several notable tropical or tropical-connected systems that have affected NYC since the last HMP in 2019. Each produced a different impact:

TABLE: NOTABLE STORM IMPACTS

STORM NAME	DATE	DESCRIPTION
Tropical Storm Isaias	August 4, 2020	Impacted the Tri-state area with winds being the most damaging element of the storm. Peak gusts reached 70 mph at JFK Airport.
Tropical Storm Henri	August 21, 2021	Intense rainfall in NYC, resulting in signif-icant subway flooding and infrastructure challenges. The storm produced two rounds of flash flooding spanning two days.
Post-Tropical Cyclone (PTC) Ida	September 1, 2021	The remnants of Hurricane Ida brought devastating rains to the Northeast, inun-dating NYC's subways, washing away ve-hicles, and halting flights. The cata-strophic flooding resulted in at least 44 deaths across four states, including 13 in NYC.

THE ROCKAWAYS AFTER HURRICANE SANDY
SOURCE: NYC DEP

WHAT IS THE RISK?

Many factors make NYC particularly vulnerable to major coastal storms and their secondary impacts. Based on the SLOSH modeling, storm-surge inundation areas of the city have nearly 2.8 million city residents, a significant amount of extremely valuable real estate, and a vast network of critical, interconnected infrastructure.

SOCIAL ENVIRONMENT

While storm surge and rainfall flooding remain significant risks to life safety during coastal storms, recent findings from the NHC indicate a decrease in storm surge-related fatalities. This trend is largely attributed to improved preparedness messaging and response strategies. Despite this progress, indirect fatalities still pose substantial risks:

Indirect Fatalities in the United States

TRAFFIC ACCIDENT RISK	POST-EVENT CLEANUP RISK	CARBON MONOXIDE POISONING RISK	LACK OF MEDICAL CARE RISK	POWER-RELATED ISSUES RISK
16%	15%	12%	11%	11%

Notably, 57 percent of the victims of storm surge-related deaths were over the age of 60, highlighting a vulnerable demographic that requires focused attention in our mitigation efforts.[14]

NYC residents, particularly at-risk populations such as seniors, people who are physically or mentally disabled, people with underlying health conditions, or others who require access or functional assistance, could be exposed to significant safety and health risks during a storm and after it has passed. Health risks could result from direct exposure to the impact of the storm — people may drown in rising waters, get struck by flying debris and falling trees, or be electrocuted by fallen power lines.

People may also be forced to shelter in inadequate housing that lacks heat or hot water. They may be exposed to contaminated floodwaters, spoiled food, or mold. Further, they may experience the complete disruption of basic services. Rain, wind, and runoff may also contribute to high levels of turbidity (suspended pollutants) in local reservoirs, which interferes with the disinfection of drinking water.[15]

Risk factors that increase people's vulnerability to coastal storms include lack of mobility, language barriers, and lack of access to medical resources. Seniors are highly likely to be physically disabled or have preexisting medical conditions that make evacuation more difficult — particularly in elevator buildings during utility outages. People who rely on life-sustaining equipment in their homes are at increased risk if coastal storms create power outages — and otherwise.

People who do not evacuate during a coastal storm and choose to shelter in place are also at increased risk for several reasons. Those sheltering in place may experience delayed responses from medical personnel due to lack of transportation, limited access to certain areas, nonfunctioning medical facilities, or high volumes of emergency calls. Power outages may disable systems that use electric pumps to distribute water to upper floors of high-rise buildings, stranding people without potable water or water for washing and flushing. Residents living in high-rise buildings also risk being stranded if they live on higher floors and lose the power that runs their elevators.

If storms knock out or damage essential utilities or building systems — and if extremely hot or cold weather follows — people are exposed to greater risk by the lack of air-conditioning or heat. If residents are stranded in flooded or damaged homes after the storm passes, they risk being exposed to secondary health hazards, such as contaminated drinking water or growth of toxic mold. If people are without power for an extended period after a storm, the health risks associated with food spoilage increase.

Following a major storm or other disaster, people who are directly, significantly affected may also experience (or experience exacerbated) mental health problems, such as post-traumatic stress disorder, anxiety, and mood disorders.

[14] Michael Brennan, Daniel Brown, and Leah Pope, "Recent Trends in Tropical Cyclone Fatalities in the United States," *The Front Page* (blog) of The American Meteorological Society, August 8, 2023.
[15] Char Adams, "Women in New York Prisons Complain of Contaminated Water after Hurricane Ida," NBC News, September 14, 2021.

These mental health impacts are most common in the months immediately following a storm but can potentially last much longer depending upon the severity of the storm, the nature of their exposure, chronic stress factors related to the storm (such as prolonged displacement or power disruption), preexisting mental health issues, and access to adequate care and assistance.

BUILT ENVIRONMENT

Buildings and infrastructure in NYC are vulnerable to significant damage during coastal storms. This section discusses the risk to NYC's built environment, including its building stock, the potential risk to buildings due to coastal storms, and infrastructure.

Building Stock

The vulnerability of buildings to storm surge and storm damage in NYC varies according to the height of the building, its type of construction, the building's age, the residential subsurface space, and its location.

Low-rise buildings situated in inundation areas in NYC are more vulnerable to coastal storm damage and destruction than mid-rise and high-rise buildings for several reasons. Because low-rise buildings have more floor area closer to the ground than other types, a larger proportion of these buildings will be damaged by the storm surge. Low-rise buildings are often built from lightweight materials, so they are more susceptible to structural damage than high-rise buildings with steel, masonry, or concrete frames.

As buildings rise higher, their facades are more vulnerable to damage from extreme winds. Wind speed could be equivalent to speeds of one storm category stronger for every 30 stories of a building's height. For older buildings not designed to modern standards, the higher wind speed associated with the higher floors of tall buildings could lead to broken windows and falling debris that puts people below and inside the building at risk. Despite containing proportionally less combustible material than other building types, high-rise buildings are vulnerable because of a different set of fire hazards, such as the difficulties associated with a complex vertical response and evacuation operations due to the building's height.

The susceptibility of the built environment to flood damage depends on the specific characteristics of the storm and the location of buildings. For example, buildings situated along the open coast are not only subject to higher wind speeds but also to the destructive force of wave action. This may cause more serious damage than would be suffered by buildings away from the coast that are subject only to stillwater flooding. Buildings with basements or subsurface spaces are also at risk of flooding during tropical cyclones that produce heavy rainfall. That vulnerability is amplified when the area is used as residential space.

Infrastructure

Much of NYC's aging transportation and utility infrastructure is also highly vulnerable to significant damage from coastal storms. Within the transportation sector, subway tunnels, subway stations, passenger car tunnels, and bus depots in low-lying, flood-prone areas are at particular risk. For example, during Hurricane Sandy, NYC suffered extensive flooding of subway, PATH, commuter train, and Amtrak tunnels, as well as the Hugh Carey Brooklyn-Battery and Queens-Midtown vehicular tunnels. Disruptions in the commodity supply chain could result in shortages of liquid fuels throughout NYC. Physical damage or loss of power to key distribution terminals, as was experienced during Hurricane Sandy, is also a significant risk.

Vulnerable utilities include above-ground telecommunications and power-distribution infrastructure (power lines and electric substations) that are directly exposed to wind, flooding, falling trees, and flying debris. Underground power and telecommunications are less exposed but are still subject to flooding in vulnerable locations. An inflow of saltwater can corrode and damage underground electric distribution equipment and transportation infrastructure.[17]

Hurricane winds can impact trees and bring down power lines, causing power outages. In 2020, Tropical Storm Isaias brought down many power lines, causing 257,000 customer outages (NYC and Westchester County). The outages were mostly caused by the high winds downing trees on overhead power lines. This event caused the second largest outage in Con Edison's history, preceded by Hurricane Sandy, which caused 1.1 million customer outages.[18]

[17] Con Edison Media Relations, "Storm Isaias Outage Is Second Largest in Con Edison's Long History," Con Edison, August 4, 2020. [18] Division of Reliability and Security, *Review and Assessment of Electric Utility Performance*, New Jersey Board of Public Utilities, State of New Jersey, November 18, 2020.

FLOODED SUBWAY TUNNEL FROM HURRICANE SANDY
SOURCE: NYCEM

NATURAL ENVIRONMENT

Coastal storms can have large impacts on natural areas and coastal ecosystems. Significant coastal storms have the potential to erode and harm wetlands and cause barrier islands to narrow or split. Coastal storms can also cause beach and dune erosion, wetland loss, and barrier island breaching. These can damage or destroy coastal habitats and disrupt migration patterns of terrestrial animals. The loss of natural storm barriers also exposes wooded areas and parks farther inland to the impacts of wind and storm surge. For example, saltwater inundation — as result of storm surge — on wooded areas leads to tree mortality and lessened health for years following an exposure event. Coastal storms can directly affect the health of the natural environment by contributing to the release of hazardous materials (HAZMAT) or causing overflow from sewers and wastewater treatment plants. Throughout the history of NYC, many industrial facilities have been built along or near the waterfront to facilitate maritime transportation. Even today, many of these low-lying areas are dominated by industrial use.

Coastal storms and related flooding raise the risk of HAZMAT releases from these industrial sites, which could contaminate underground water and soil, which discharge into and further contaminate nearby bodies of water. Certain chemicals may be toxic to species of plants, animals, and invertebrates. Uncontained spills, especially those that impact surface water, can kill or injure plants, fish, and wildlife and cause damage to their habitats and food sources. The remediation of the natural environment after a toxic chemical release poses its own unique challenges and often involves lengthy, costly processes. Large volumes of debris in local waterways, resulting from coastal storms, can also be hazardous to local species. Cumulative impacts from coastal storms can lead to large-scale changes in the population, distribution, and migrations of marine and aquatic species over the long term.

FUTURE ENVIRONMENT

In planning for the potential impacts of future coastal storms, planners and emergency managers must understand how climate change will affect the probability and severity of these storms in or near NYC. When considering the risk from coastal storms, impacts from three potential changes need to be considered: an increase in coastal storm surge as the sea level rises, an increase in extreme hurricane winds, and an increase in the frequency of storms.

Ocean surface temperatures are projected to increase as the global climate continues to warm, causing storms to intensify. It is unclear exactly how changes to all the climatic variables will affect the behavior of hurricanes in the future. However, climate scientists predict that the frequency of the most intense hurricanes (but not the frequency of hurricanes in general) could increase globally, particularly in the North Atlantic Basin.

Although uncertainty exists as to the exact nature of the change affecting coastal storm systems, scientists predict that the impacts of coastal storms will worsen in the future when combined with the impact of rises in sea level due to climate change. First, as ocean water warms, it expands and increases in volume, causing sea levels to rise. Second, increased average temperatures by climate change cause land glaciers and polar ice caps to melt at a faster rate, which increases the amount of water in the oceans. The sea level is up to 9 inches higher than it was in 1950 in NYC due to a combination of warming climate and local factors such as land subsidence (sinking).[19]

[19] SeaLevelRise.org, “New York’s Sea Level Has Risen 9” Since 1950,” SeaLevelRise.org.

HOW TO MANAGE THE RISK?

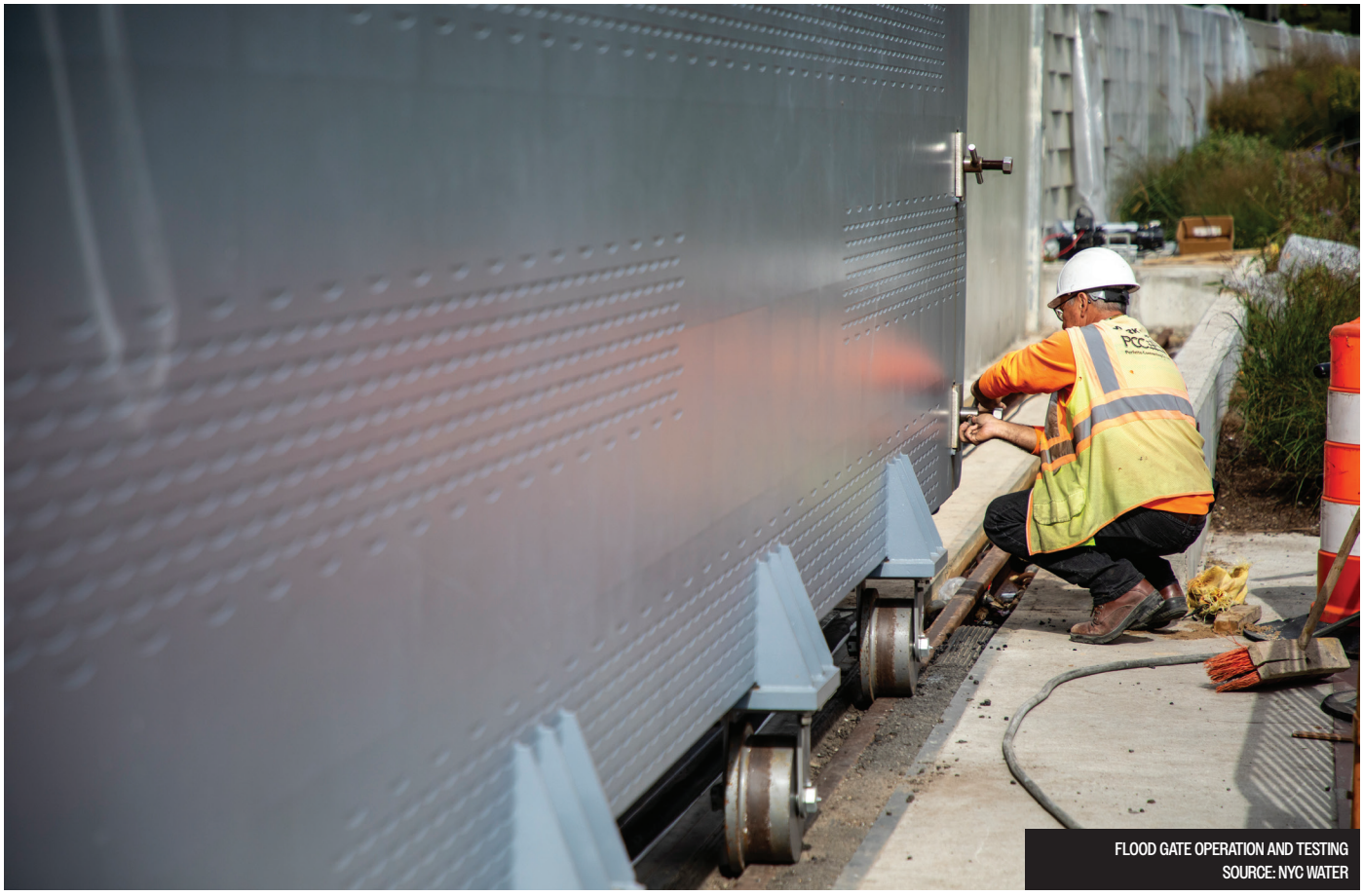
NYC takes an integrated approach to managing risk associated with coastal storms. This approach involves a comprehensive plan that includes regulatory, water management, land management, and environmental policies in addition to public education initiatives.

Public-private partnerships and other collaborative efforts have been underway for several years to protect buildings and infrastructure in NYC from the high winds associated with coastal storms. NYC also focuses on increasing public awareness of risks from high winds and flooding during coastal storms, particularly among people living in flood zones and areas of greatest risk.

NYC has formed the new Coastal Resiliency Bureau at the DEP. The new bureau at DEP establishes central coordination for flood resilience projects and provides New Yorkers with a central repository of information on local flooding events.[20]

NYC's Climate Resiliency Design Guidelines (CRDG), currently being applied in a five-year pilot program across 23 City agencies, help inform design and construction of City assets based on exposure to current and future coastal flood risk. Mandated by Local Law 41 (2021), scoring based on the CRDG will be required of all City capital projects beginning in 2027.

A wide range of coordinated strategies are employed to cope with and recover from the multiple, varied, social and structural consequences of these cyclical coastal natural phenomena. NYC provides a complete, detailed database on the ongoing and planned mitigation activities and projects of dozens of City agencies.



FLOOD GATE OPERATION AND TESTING
SOURCE: NYC WATER

[20] City of New York, *PlaNYC: Getting Sustainability Done*, City of New York, April 2023

03

DROUGHT

LEARN ABOUT DROUGHT

What is the Hazard?
What is the Risk?
How to Manage the Risk?

WHAT IS THE HAZARD?

Drought differs from other hazards in many ways. Its effects take considerable time to develop, and the extent of the hazard can linger for prolonged periods after the drought itself has ceased. For example, most definitions of socioeconomic drought associate the hazard with supply, demand, and economic goods. The absence of a definitive and universally accepted definition complicates the determination of whether a drought is occurring and the level of its severity. Compared to other natural hazards, the geographical area, impacts, and duration of drought are difficult to quantify. This is especially true in NYC because its water comes from three upstate sources.

NYC's complex water supply system is a remarkable feat of engineering. It originates in upstate reservoirs in the greater Catskills area and extends over 125 miles to supply New Yorkers with high-quality water.[21] A water shortage can be caused by a drought, which can affect reservoir water levels. Droughts have occurred in the past and may occur again in a future shaped by climate change.

The NYC Department of Environmental Protection (DEP) manages our water supply system, ensuring the steady flow of water from large upstate watersheds through a complex network of reservoirs, aqueducts, tunnels, and neighborhood water mains (or distribution water mains).

SEVERITY

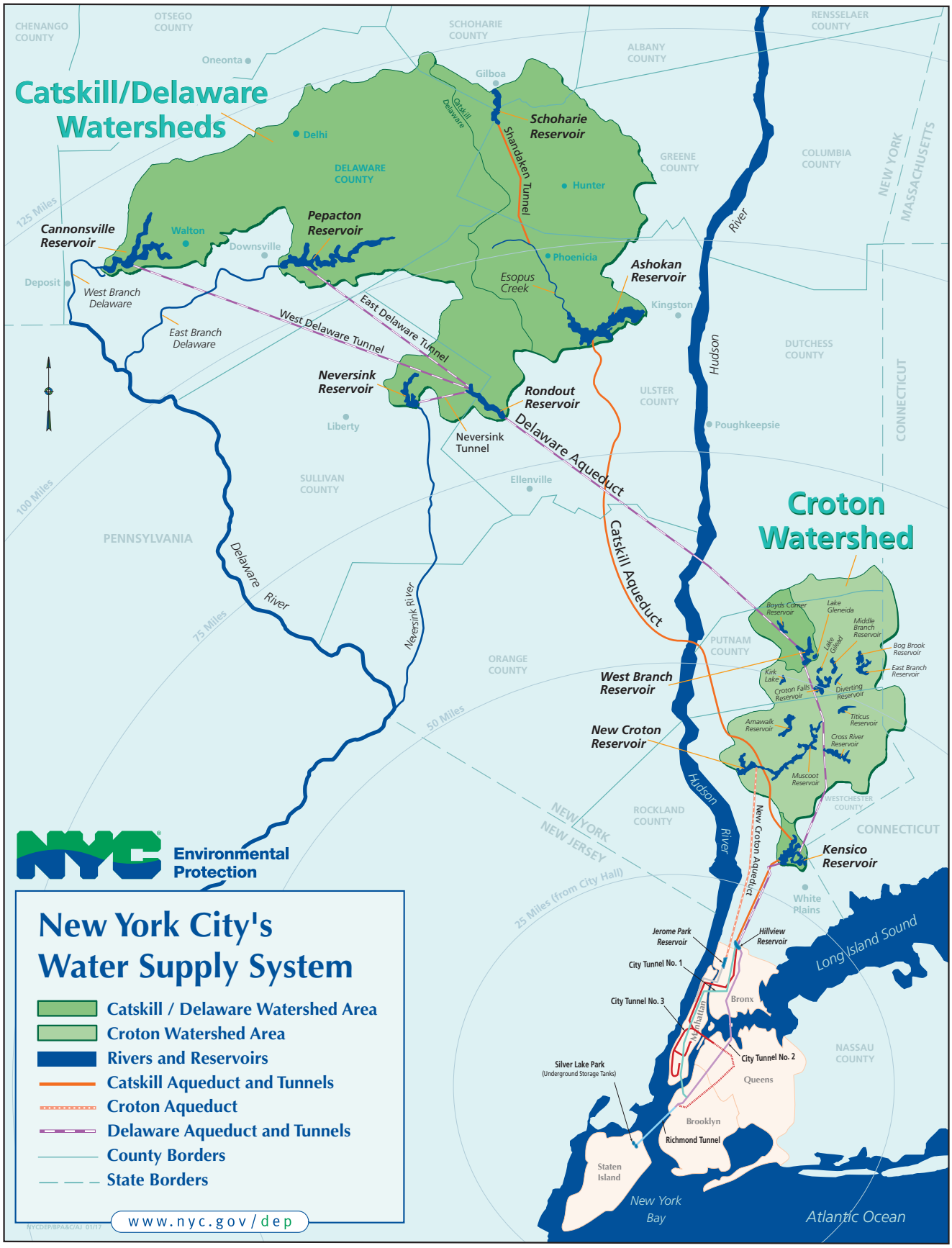
DEP developed the Water Shortage Emergency Rules to guide the City's response to drought. The current Water Shortage Emergency Rules, updated recently in May 2022 in preparation for the Delaware Aqueduct shutdown, has three phases: drought watch, drought warning, and drought emergency.[22] Drought emergencies are subdivided into three stages, each with increasingly severe mandated water-use restrictions. Factors such as prevailing hydrological and meteorological conditions inform the guidelines. DEP declares a drought watch when there is less than a 50 percent probability that either of the two largest reservoir systems — the Delaware (Cannonsville, Neversink, Pepacton, and Rondout reservoirs) or the Catskill (Ashokan and Schoharie reservoirs) — will fill by the following June 1, the start of the water year. DEP declares a drought warning when there is less than a 33 percent probability that the Delaware or the Catskill system will fill by the start of the water year.[23]

Each day, more than one billion gallons of water is delivered to NYC, almost all by gravity.[24] We use water daily for our basic needs — drinking, bathing, cooking, and laundry. Therefore, it comes as no surprise that residential buildings are our largest water consumers, accounting for 86 percent of total water usage.[25] Water is also used for institutional, commercial, and manufacturing purposes. For example, hospitals use steam to sanitize medical equipment, and water is also used in some manufacturing processes, including bottling plants in NYC.

A DROUGHT IS A DEFICIENCY OF PRECIPITATION OVER AN EXTENDED PERIOD RESULTING IN A WATER SHORTAGE.

THE NATIONAL WEATHER SERVICE (NWS) DESCRIBES FIVE TYPES OF DROUGHTS: METEOROLOGICAL, AGRICULTURAL, HYDROLOGICAL, SOCIOECONOMIC, AND ECOLOGICAL — MOST OF WHICH CAN SIGNIFICANTLY AFFECT NEW YORK CITY.

[21] NYC Department of Environmental Protection, "Final Environmental Impact Statement," in Water for the Future: Upstate Water Supply Resiliency, NYC Department of Environmental Protection. [22] NYC Law Department, "Chapter 21: Water Shortage Emergency Rules," in The Rules of the City of New York, American Legal Publishing. [23] NYC Department of Environmental Protection, Water Demand Management Plan, City of New York. [24] Greg Moyer, "A Marvel of Engineering Meets the Needs of a Thirsty New York," New York Times, October 16, 2014. [25] Urban Green Council, *New York City's Energy and Water Use 2014 and 2015 Report*, Urban Green Council, October 2017.


Catskill/Delaware Watersheds
Croton Watershed
Schoharie Reservoir
Shandaken Tunnel
Pepacton Reservoir
Cannonsville Reservoir
Ashokan Reservoir
Esopus Creek
West Delaware Tunnel
East Delaware Tunnel
Neversink Reservoir
Rondout Reservoir
Neversink Tunnel
Delaware Aqueduct
Catskill Aqueduct
West Branch Reservoir
New Croton Reservoir
Kensico Reservoir
New Croton Aqueduct
Jerome Park Reservoir
Hillview Reservoir
City Tunnel No. 1
City Tunnel No. 3
City Tunnel No. 2
Silver Lake Park
(Underground Storage Tanks)
Richmond Tunnel
Boyds Corner Reservoir
Lake Gleneida
Middle Branch Reservoir
Lake Gilead
Bog Brook Reservoir
East Branch Reservoir
Kirk Lake
Croton Falls Reservoir
Diverting Reservoir
Titicus Reservoir
Amawalk Reservoir
Cross River Reservoir
Muscoot Reservoir
Delaware River
Neversink River
Hudson River
Long Island Sound
New York Bay
Atlantic Ocean
Oneonta
Gilboa
Delhi
Hunter
Walton
Downsville
Deposit
Phoenicia
Kingston
Poughkeepsie
Liberty
Ellenville
White Plains
West Branch Delaware
East Branch Delaware
Esopus Creek
Catskill Delaware
Bronx
Manhattan
Queens
Brooklyn
Staten Island
OTSEGO COUNTY
CHENANGO COUNTY
SCHOHARIE COUNTY
ALBANY COUNTY
RENSSELAER COUNTY
DELAWARE COUNTY
GREENE COUNTY
COLUMBIA COUNTY
DUTCHESS COUNTY
ULSTER COUNTY
SULLIVAN COUNTY
ORANGE COUNTY
PUTNAM COUNTY
ROCKLAND COUNTY
WESTCHESTER COUNTY
NASSAU COUNTY
PENNSYLVANIA
NEW YORK
NEW JERSEY
CONNECTICUT
MASSACHUSETTS
125 Miles
100 Miles
75 Miles
50 Miles
25 Miles (from City Hall)
NYC Environmental Protection
New York City's Water Supply System
Catskill / Delaware Watershed Area
Croton Watershed Area
Rivers and Reservoirs
Catskill Aqueduct and Tunnels
Croton Aqueduct
Delaware Aqueduct and Tunnels
County Borders
State Borders
www.nyc.gov/dep
NYCDEP/BPA&C/AJ 01/17

PROBABILITY

Occasional drought is a normal, recurrent feature of our regional environment. According to the New York State Department of Environmental Conservation (NYS DEC), New York's Average Annual Precipitation ranges from 60 inches in the Catskills to 28 inches in the Lake Champlain Valley.[26]

Even with a temperate, moist climate, normal fluctuations in regional weather patterns can lead to periods of dry weather. The last severe droughts in New York State occurred in the mid-1960s, again in the early and mid-1980s, in the early 2000s, and as recently as 2024.

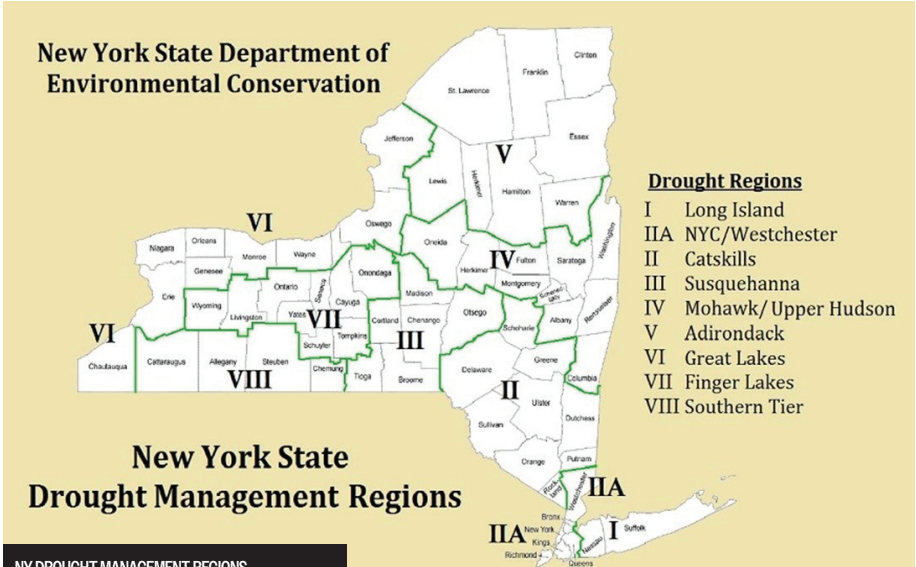
Water Shortage Caused by Drought

Water shortages due to a drought affect NYC on a citywide basis. Because the reservoirs that supply our water are upstate, rainfall in that region, not within our city, is what determines how adequate our water supply is.

A 2011 study by the Lamont-Doherty Earth Observatory (referencing tree-ring historical record evidence) predicts that a severe drought similar to the one in the 1960s could easily return to the greater Catskills region without warning, and its duration cannot be forecast.[28] That is, the wetter conditions that have prevailed since the 1970s may not persist in the future.

Water Shortage Caused by Infrastructure Failure

While this hazard profile focuses on drought and the potential water shortages it may cause, it is important to acknowledge that such droughts can also be the result from water systems infrastructure failure. Due to its age and complexity, parts of the system are prone to malfunctions that could disrupt water distribution, such as leaks in the Delaware Aqueduct, which currently loses up to 35 million gallons per day. Planned repairs and inspections, scheduled for the aqueduct and City Water Tunnels No. 1 and 2, aim to mitigate these risks by enhancing the system's reliability and capacity.[29] [30] [31]



NY DROUGHT MANAGEMENT REGIONS
SOURCE: NYS DEC, 2022

LOCATION

Droughts tend to affect NYC on a citywide basis. As described in NYC's Hazard Environment, major components of the NYC's water supply system are located upstate in the greater Catskills area, making the system vulnerable to weather conditions to that region. As part of its New York State Drought Plan, NYS DEC subdivided the state into drought management regions. NYC is in Drought Region IIA; however, most of its watershed lies to the north in Region II, as shown in the map titled New York State Drought Management Regions.[32]

[26] NYS Department of Environmental Conservation, "Drought," New York State. [28] Richard Seager, "Persistent Drought in North America: A Climate Modeling and Paleoclimate Perspective," Lamont-Doherty Earth Observatory, The Earth Institute at Columbia University. [29] City of New York, "Mayor Bloomberg, Deputy Mayor Holloway and Environmental Protection Commissioner Strickland Visit Upstate Construction Site as Critical Repairs to the Delaware Aqueduct Begin," City of New York, November 4, 2013. [30] City of New York, "Mayor Bloomberg, Deputy Mayor Holloway and Environmental Protection Commissioner Strickland Visit Upstate Construction Site as Critical Repairs to the Delaware Aqueduct Begin," City of New York, November 4, 2013. [31] Water Technology, "New York City Tunnel No. 3," Water Technology. [32] NYS Department of Environmental Conservation, "Drought," New York State.

HISTORIC OCCURRENCES

TABLE: HISTORIC NYC DROUGHTS

NAME	DATE	DESCRIPTION
1963-1965	November 1, 1963	A conservation campaign escalating to an intense campaign by April 1, 1965.
1980-1982	October 16, 1980	Starting with a drought watch and escalating to an emergency with water supply at 33%. Spanned just over two years.
1985	February 25, 1985	A drought watch at 50% water supply progressed to an emergency. Spanned one year.
1989	January 17, 1989	A drought watch at 58% water supply quickly hit emergency stages with levels at 55%-71%, recovering to 90% normal. Spanned about 118 days.
1991	September 25, 1991	A drought watch at 53% water supply led to a warning
1995	July 05, 1995	A drought watch at 84% water supply progressed to a warning at 58%. Spanned 132 days.
2002	December 23, 2001	A drought watch at 44.4% water supply progressed to an emergency at 57.5. Spanned 376 days.
2024	November 2, 2024	A drought watch at 65.6% water supply progressed to a warning at 60.1%. Spanned 62 days.

CROTON FALLS RESERVOIR IN 2014
SOURCE: NYC DEP

WHAT IS THE RISK?

Each drought produces a unique set of impacts on NYC, depending on its severity, duration, and spatial extent and on ever-changing social conditions. Drought can directly or indirectly affect NYC's social, economic, built, natural, and future environments.

SOCIAL ENVIRONMENT

Drought can negatively affect the population of NYC in many ways. The harmful effects of this hazard may be particularly acute among vulnerable populations, including the very young, seniors, low-income populations, and those with preexisting or chronic health conditions.

Severe droughts can adversely affect public health. They can lead to a diminished quantity and quality of potable water, which can increase the likelihood of dehydration, compromise sanitation and hygiene, and lead to an increase in illness and disease. According to the Centers for Disease Control (CDC), decreased rainfall can cause groundwater and surface water to become polluted with viruses, protozoa, and bacteria, increasing the risk of disease outbreaks.

It should be noted that, because NYC imports most of its food, a prolonged severe drought in any region of the world that supplies a significant quantity of the food supply could produce some shortages and higher prices. Higher prices may create further hardships for low-income households and strain the budgets of commercial and institutional kitchens.

Droughts may also affect the population by compromising food and nutrition availability. Limits on growing season, low crop yields, and increasing food prices could result in food shortages. This could adversely affect low-income populations, which may lack the resources to contend with these drought impacts.

BUILT ENVIRONMENT

In general, drought does not cause structural damage and does not affect infrastructure such as highways, bridges, and electric conveyance systems. Drought can, however, affect the functioning of the energy and steam supply systems in NYC. Several power-generation plants rely on potable water to produce power. The ability to cool equipment and buildings that use water-dependent cooling systems may be disrupted during a water shortage.

Drought can also pose a risk, albeit very low, of aggravating "soil shrinkage," — the reduction in soil volume that occurs as soil loses moisture.[34] The condition can compromise the foundations on which infrastructure stands, including retaining walls and bulkheads, affecting their stability. However, soil shrinkage only causes real damage if soils shrink and swell as the moisture content decreases and increases. According to the U.S. Geological Survey, NYC soils typically are not high swelling in nature. Therefore, there is a very low risk of structural damage associated with drought.[35]

Droughts can also affect green roofs. In NYC, green roofs contain vegetation that provides insulation, combats the urban heat island effect, and improves air quality. Droughts impair plants on green roofs, disrupting their ability to reduce air pollution and provide other benefits.

NATURAL ENVIRONMENT

Drought has a much more severe impact on the natural environment than on the built environment. Effects may include loss of wetlands, damage to plant species, and reduction in biodiversity. For example, NYC's waterfront mainly consists of wetlands that range from approximately 5,600 acres to just over 10,000 acres, located in Jamaica Bay, on Staten Island, and along the Long Island Sound.[36]

[34] North Dakota State University Agriculture Communication, "Dry Soil May Cause Building Problems," North Dakota State University.
[35] NYC Soil & Water Conservation District, "NYC Urban Soils Institute & NYC Soil Survey," City of New York. [36] NYC Office of Long-Term Planning and Sustainability, *New York City: Wetlands Strategy*, City of New York, May 2012.

These wetlands provide wildlife protection, protect coastal communities, provide recreation, reduce the impact of the urban heat island effect, and improve water quality.

Droughts can threaten community gardens. There are nearly 500 community gardens in NYC. Like green roofs, these gardens help reduce air pollution, combat the urban heat island effect, and increase access to fresh produce.[37]

FUTURE ENVIRONMENT

The NYC Panel on Climate Change (NPCC) projects future disruptions in precipitation patterns and rising temperatures for NYC. While annual rainfall is predicted to increase here, along with the intensity of severe storms, the frequency of drought will approximately double by the 2050s and will be five times greater by the 2080s.[38]

HOW TO MANAGE THE RISK?

PROTECTING INFRASTRUCTURE

Maintaining the water supply system, repairing leaks and cracks, and creating redundancy are crucial to ensuring the system's continued performance under normal conditions, and to reducing the impacts of any water shortages.

DEP's largest and longest-running project — one of the country's largest infrastructure projects — is City Water Tunnel No. 3. Initiated in 1970, it was activated in 2013, with the final portions to be completed sometime this decade, at an estimated total cost of $5 billion.[39] The tunnel is a critical piece of infrastructure. When it is completed, it will add capacity to the system, deliver water to customers, and allow DEP to inspect and repair City Water Tunnels No. 1 and No. 2 as needed.

DEP's Water for the Future program addresses the leak in the Delaware Aqueduct. In 2013, DEP began building a three-mile tunnel, the Delaware Bypass Tunnel, to bypass the section of the aqueduct that is leaking in Orange County.[40] To connect this tunnel, the Aqueduct was shut down in fall 2023, during which time DEP augmented available supply and minimized demand.[41]

DEP completed construction that increased the capacity of the Catskill Water System in 2021.[42] Workers cleaned 59 miles of the aqueduct's concrete lining and repaired structural defects and leaks at several locations. One of the major shutdowns during the construction process included a special effort to reconstruct much of the Catskill Influent Weir — the structure that discharges water from the aqueduct into Kensico Reservoir. The inside of the weir was cleaned and the piers that hold the weir together were completely reconstructed with new concrete.

Additional projects to increase resiliency include: Kensico Eastview Connection, CDIS4-Delware Connection, upgrades to Croton Falls and Cross River Pump Stations, the Catskill-Delaware Interconnection, and the planned tunnel between Kensico Reservoir and the Catskill-Delaware Disinfection facility.[43]

Water Conservation Regulations and Programs' long-term water conservation strategies help reduce water demand and thus extend how long water remains available during a prolonged water shortage. They also help to meet the demands of a growing population. They take the form of regulatory controls and programs that encourage conservation.

Both building design and the equipment used in buildings can reduce water use. The DOB Construction Codes encourage water conservation strategies in new buildings as part of an approved water conservation plan.

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[37] Grow NYC, "Community Gardens," City of New York. [38] Jorge E. González, Luis Ortiz, Brianne K. Smith, Naresh Devineni, Brian Colle, James F. Booth, Arun Ravindranath, et al., "New York City Panel on Climate Change 2019 Report Chapter 2: New Methods for Assessing Extreme Temperatures, Heavy Downpours, and Drought," *Annals of the New York Academy of Sciences 1439*, no. 1 (March 2019): 30–70. [39] Jim Dwyer, "De Blasio Postpones Work on Crucial Water Tunnel," *New York Times*, April 5, 2016. [40] Water Technology, "Delaware Aqueduct Rondout-West Branch Bypass Tunnel Project," Water Technology. [41] NYC Department of Environmental Protection, "Delaware Aqueduct Repairs: Delaware Aqueduct Shutdown, October 1, 2023," City of New York, June 29, 2022. [42] NYC Water Staff, "Catskill Aqueduct Rehab Reaches the Finish Line," Medium, March 23, 2022. [43] NYC Department of Environmental Protection, *Delaware Aqueduct Repair Project: Final Connection and Water Supply Management Plan*, presentation by John Milgram, New York, NY, n.d.

DEP's water conservation initiatives include:

TABLE: DEP WATER CONSERVATION INITIATIVES

TITLE	DESCRIPTION
Toilet Replacement Program	Targets residential buildings, the major consumers of water, offering discounts to replace old toilets with high-efficiency models that use only 1.28 gallons per flush as opposed to the conventional 5 gallons.
Municipal Water Efficiency Program	Retrofits City-owned properties to save up to 9 million gallons of water daily.
Residential Water Efficiency Program	Provides free water-use surveys to residential buildings, identifying opportunities for savings, like leak detection.
Non-Residential Water Efficiency Program	Promotes water efficiency among major water users such as hospitals and hotels.
Online Resources and Pilot Programs	Features DEP's website tools for customers to monitor water use and detect leaks, supported by a pilot program for monthly billing to aid in managing and reducing water demand.

Reservoir Monitoring and Water Shortage Protocols Monitoring

DEP closely measures and monitors reservoir levels. Its Operations Support Tool is a collection of predictive modeling and data tools that help the agency monitor reservoir levels. The tool automatically delivers continuous, real-time projections. Improved forecasts from the National Weather Service (NWS) have recently been incorporated into it. DEP also closely monitors the condition of the in-city water distribution system.

Alternative Water Supplies

NYC has alternative drinking water sources. While these alternative supplies do exist, they would require substantial time and resources to make them usable. The Queens system is not usable because of water quality issues and disuse. Chelsea's can only be used in the most extreme conditions (e.g., to maintain pressure for firefighting). There are also water quality issues and a need to filter water before use.

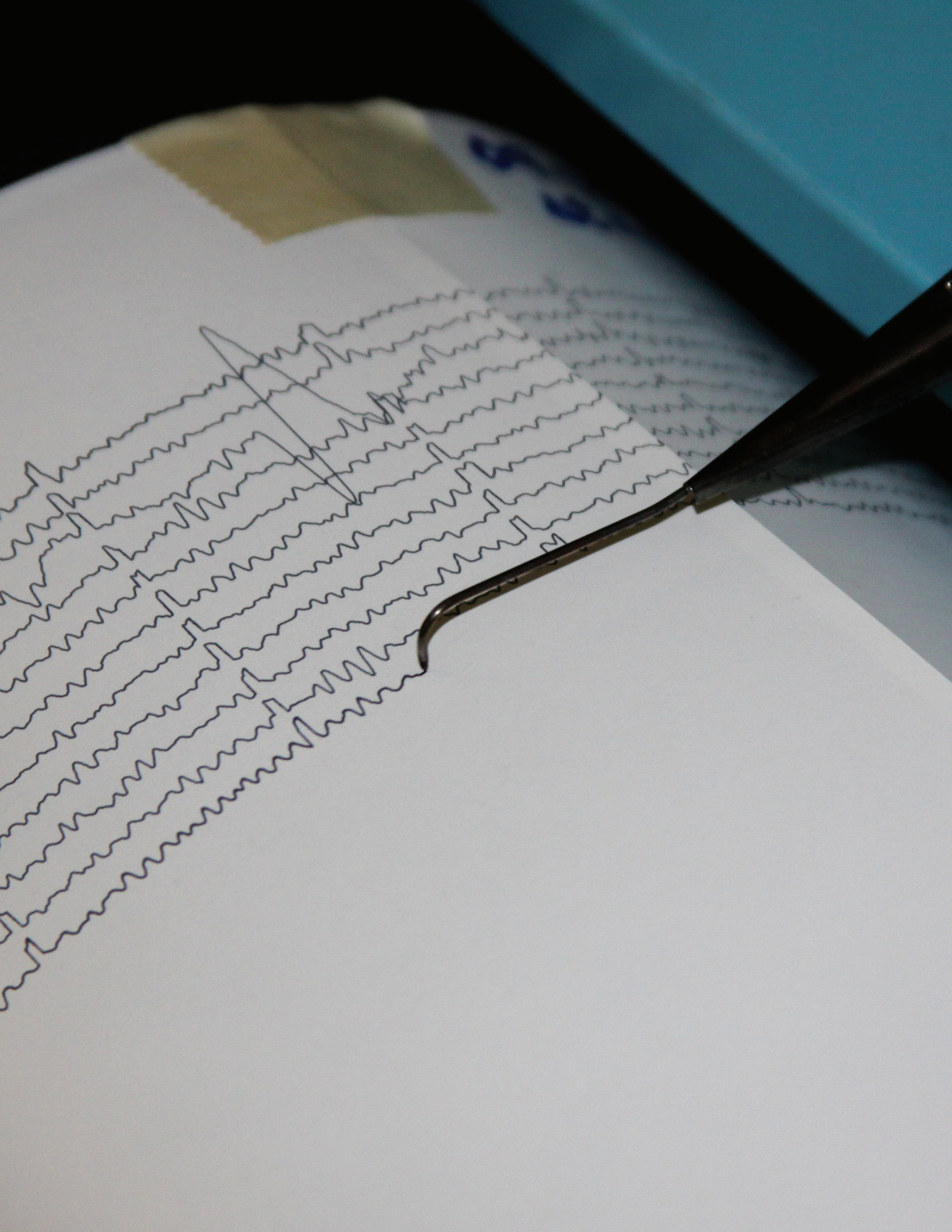
Water Shortage Protocols

During a planned or unplanned water shortage, reducing the amount of water we consume is imperative. DEP's Water Demand Management Plan describes formal operational phases (the phases are defined in the Water Shortage Emergency Rules and soon-to-be-revised Drought Management and Contingency Plan) for managing a water shortage and actions for each phase.

Communication

As a water shortage initially develops, clear communication with water users is essential. They must be informed about the potential seriousness of the situation and about steps they can take to curtail their water use.

Since water shortages can vary in duration, location, and severity, messaging may have to be tailored. For situations where the water shortage is localized, such as a water main break, messaging is targeted to the affected customers.



04

EARTHQUAKES

LEARN ABOUT EARTHQUAKES

What is the Hazard?
What is the Risk?
How to Manage the Risk?

Although NYC does not sit on a major fault system that has been recently active, like the San Andreas Fault in California, earthquakes are possible here.

The likelihood that a strong earthquake will occur is moderate, but the risk is heightened by NYC's population density, the scale of its built environment, the interdependencies of its critical infrastructure systems, the age of its infrastructure, and the high proportion of buildings that were built before seismic design provisions were adopted in building codes in 1995.

WHAT IS THE HAZARD?

An earthquake is caused by sudden slip on a fault that releases energy in seismic waves. As rocks and the Earth's plates are strained by these tremendous geological processes from plate tectonics, energy builds up under the Earth's surface. Eventually, accumulated strain deep underground becomes so great that it is abruptly released in an earthquake, which generates seismic waves that cause shaking.[44]

An earthquake has the potential to damage and destroy buildings and a city's infrastructure and take lives. Under certain conditions, earthquakes can trigger landslides and cause soil liquefaction. The latter occurs when shaking and ground vibration during an earthquake cause unconsolidated, water-saturated soils to soften and turn fluid. Ground shaking, landslides, and liquefaction together can damage or destroy buildings, disrupt utilities, trigger fires, and endanger public safety.

SEVERITY

Earthquake size is classified according to a magnitude scale that can be related to the energy released at the earthquake's source. Seismographs and other scientific tools are used to measure and record data to understand the severity of each tremor in the Earth and the severity of each earthquake event. In the past, earthquake tremors were ranked according to the Richter scale, but in the 1970s, the scientific community began to use the more accurate Moment Magnitude scale. The Moment Magnitude scale measures the size of an earthquake at its source in relation to the size of the fault and the degree to which the fault is displaced. It is a logarithmic scale — each point that an earthquake's magnitude increases on the scale represents an energy release that is 32 times larger than the point that precedes it.[45]

THE EARTHQUAKE MAGNITUDE SCALE

A single step in the magnitude scale represents an increase of about 32 times the amount of energy released.

Magnitude 9	Extreme Damage Expected
Magnitude 8	Significant Damage Expected
Magnitude 7	Damage Expected
Magnitude 6	Damage May Occur
Magnitude 5	Minor Damage May Occur

[44] U.S. Geological Survey, "What Is An Earthquake and What Causes Them to Happen?," U.S. Geological Survey.
[45] U.S. Geological Survey, "Earthquake Magnitude, Energy Release, and Shaking Intensity," U.S. Geological Survey.

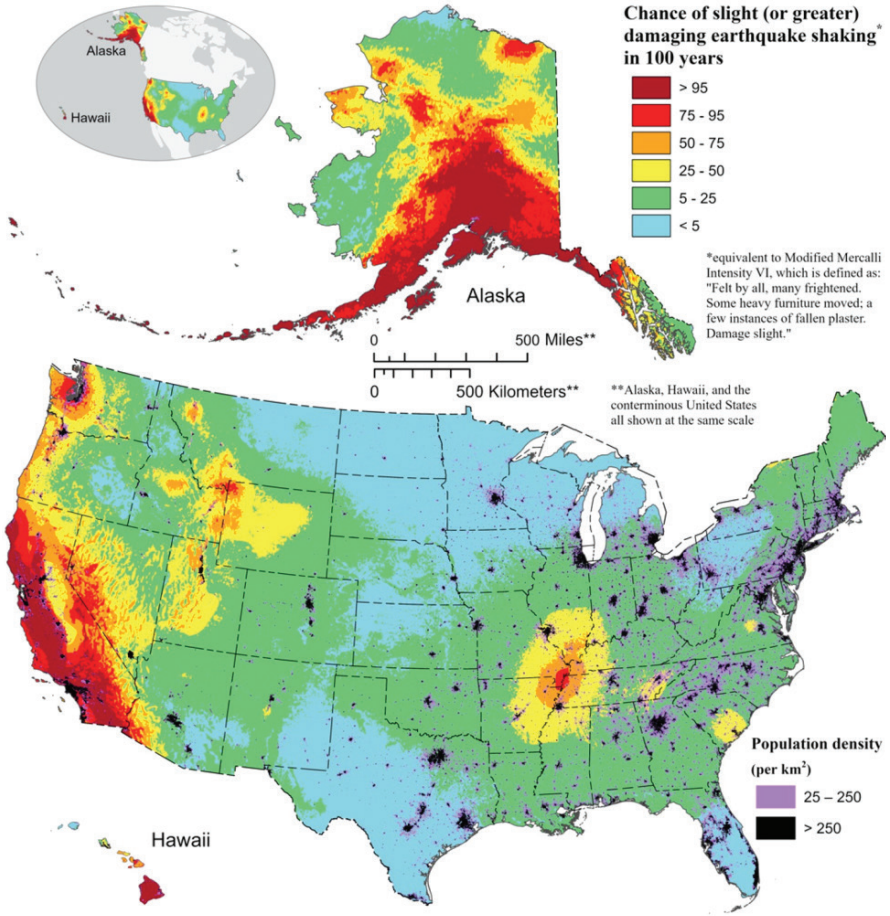
On August 10, 1884, NYC experienced its most severe earthquake, which was estimated to have a magnitude of 5.2 on the Richter scale.[46]

Experts also measure earthquake severity using methods like Peak Ground Acceleration (PGA), which quantifies how much the ground shakes during an earthquake. PGA, critical for seismic building codes, helps dictate construction standards to ensure buildings can withstand significant shakes without severe damage. While PGA remains relevant, Spectral Acceleration (SA) is now more commonly used in modern building codes, as it provides a more precise assessment of how different types of buildings respond to earthquake shaking.

PROBABILITY

PGA is also used to understand more about the types of earthquake hazards that are likely. The U.S. Geological Survey (USGS), which studies seismic conditions nationally, produces maps that indicate where future earthquakes are most likely to occur, how frequently they might occur, and how hard the ground may shake (PGA).[47]

The National Seismic Hazard Model Map displays the likelihood of damaging earthquake shaking in the United States over the next 100 years. The latest USGS maps, released in 2023, show that there is a 5 to 25 percent chance of a slight or damaging earthquake occurring in the NYC area over a 100-year period.



[46] Bob Groves, "N.J. Is Not Immune to Quakes," *The Record, Bergen County*, March 2, 2001. [47] Mark D. Petersen, Morgan P. Moschetti, Peter M. Powers, Charles S. Mueller, Kathleen M. Haller, Arthur D. Frankel, Yuehua Zeng, et al., *Documentation for the 2014 Update of the United States National Seismic Hazard Maps* (U.S. Geological Survey, August 5, 2014).

LOCATION

Strong earthquakes in NYC have not been registered, but moderate-magnitude earthquakes are possible and have occurred (as in 1884). Even if an earthquake's epicenter is far from NYC, the geology underlying the northeast United States can cause some ground shaking to be felt in the NYC.[48]

When an earthquake occurs, the older, harder bedrock of the Northeast transmits high-frequency motions that can travel long distances before they subside. For example, tremors from the 2011 earthquake in east-central Virginia and the 2013 earthquake along Canada's Ottawa River were felt by many people in the eastern United States, including in NYC. The 2011 Virginia earthquake caused extensive damage 87 miles away in Washington, DC.

If an earthquake occurs beneath NYC, the unique geologic characteristics of the metropolitan area could result in significant effects due to soil amplification. The two main factors contributing to soil amplification here are the sharp contrast between softer soils and very hard bedrock, and the bedrock motions, which could be relatively short and shake with high frequency.

For centuries, large areas of NYC have been filled to cover soft sediments and marshes in order to create new space for building development.[49] For example, Manhattan's present-day Chinatown is on land created by filling in a large pond; the World's Fair Park site in Flushing, Queens, was built on an ash dump; and JFK Airport on Brooklyn's south shore was built atop a hydraulic sand fill. These areas are like the Marina district in San Francisco, which suffered extensive damage in the 1989 Loma Prieta earthquake because of amplification of seismic waves by the soft soils.

HISTORIC OCCURRENCES

TABLE: HISTORIC NYC EARTHQUAKES

NAME	DATE	DESCRIPTION
1884 Brooklyn-Sandy Hook Earthquake	August 10, 1884	A significant earthquake estimated at magnitude 5.2 occurred between Brooklyn and Sandy Hook, NJ. It caused damage from Virginia to Maine, affecting buildings in NJ and NYC.
Damaging Earthquakes	1973 & 2012	Only two damaging earthquakes with a magnitude of 5.0 and above recorded in New York State, showing longer "return periods" for larger earthquakes in the region.[50]
2011 Virgina Earthquake	August 23, 2011	A magnitude 5.8 earthquake caused widespread shaking across the East Coast, triggering landslides and structural damage. Tremors were felt in NYC, with minor building damage reported.
2024 Tewksbury Earthquake	April 5, 2024	A magnitude 4.8 earthquake centered in Tewksbury Township, NJ, about 65 km west of NYC. Felt widely, it generated over 180,000 USGS "Did You Feel It?" reports but no significant damage.

[48] S. Nikolaou, "Local Geology of New York City and Its Effect on Seismic Ground Motions," proceedings from the Fifth International Conference on Case Histories in Geotechnical Engineering, New York, NY, April 13–17, 2004. [49] Michael Kimmelman, "When Manhattan Was Mannahatta: A Stroll through the Centuries," *New York Times*, May 13, 2020. [50]Jagtar S. Khinda, "New York City's New Seismic Design Criteria Guidelines for the New Millennium and an Update on the Seismic Retrofit for New York City Bridges," proceedings from International Bridge Conference, Pittsburgh, PA, June 14–16, 1999.

CASE STUDY: 2024 Tewksbury Earthquake

On April 5, 2024, a magnitude 4.8 earthquake, centered in Tewksbury Township, New Jersey, occurred about 65 km west of New York City. Millions of people in the metropolitan area and anywhere from Virginia to Maine and beyond felt the ground shaking, resulting in the largest number (>180,000) of U.S. Geological Survey (USGS) “Did You Feel It?” reports of any earthquake. Despite its widespread reach, the earthquake resulted in no significant damage, marking it as a relatively minor seismic event.

This earthquake was notable as the strongest to affect New Jersey since the more substantial 5.3 magnitude quake in 1783, and the most intense in NYC since the estimated 5.0 magnitude tremor on August 10, 1884. The occurrence of dozens of aftershocks in the days following the initial quake kept the region on alert, although these too did not lead to any reported major damage.

The event serves as a reminder of the geological activity that can affect even areas not typically associated with frequent seismic activity, emphasizing the importance of preparedness and monitoring in these regions.

TAYLOR'S MILL, NJ BEFORE 2024 EARTHQUAKE
SOURCE: WIKIPEDIA COMMONS

TAYLOR'S MILL, NJ AFTER 2024 EARTHQUAKE
SOURCE: GEER-NIST

WHAT IS THE RISK?

Although the seismic hazard in NYC is moderate, because of the potential occurrence of a unique set of factors, summarized by the high seismic risk equation, the risk to the area could be high due to the high cost of dealing with the repercussions of any earthquake damage in a congested city environment.

SOCIAL ENVIRONMENT

Unlike other natural hazards, earthquakes occur with little to no warning — a situation that places the local population at immediate risk. Since New Yorkers experience earthquakes less frequently than other natural hazard events, people might be at higher risk, because they are less likely to be prepared to respond to this type of emergency.

A moderate (magnitude 5.5 to 6) earthquake could cause significant injuries and casualties. Mortality and injury typically peak within the first 72 hours following an earthquake. In a study of 1,100 fatal earthquakes around the globe, 75 percent of fatalities were caused by collapsing buildings.

BUILT ENVIRONMENT

Although earthquakes in NYC have a low probability of occurrence, any potential damage here could be catastrophic due to the density and age of buildings and the interdependencies of complex layers of infrastructure.

Buildings

NYC's built environment consists of a unique concentration of commercial and residential high-rise skyscrapers and low-rise buildings that are largely made of unreinforced brick. Each building type has a very different risk profile according to its height, material, location, and foundation.

High-Rise and Low-Rise Buildings

The structural systems of NYC's high-rise buildings are less vulnerable to earthquake damage than low-rise buildings. Large earthquakes with long-period waves tend to damage tall buildings; however, these categories of earthquake events are less likely to occur in NYC. Large-magnitude earthquakes that occur farther away from NYC, such as in Canada or the Midwest, can create low-frequency (slow-moving) shaking in the city that can affect tall buildings.

Unreinforced Masonry and Wood Buildings

Structures in New York that were not designed for earthquake loads are inherently vulnerable should a large earthquake occur. Unreinforced masonry (brick) buildings are most at risk because masonry is unable to absorb tensile forces during an earthquake. Instead of bending or flexing, walls, facades, and interior structures break or crumble. During a strong earthquake, the structural support system of an unreinforced masonry building has an increased risk of collapse. The typical modes of failure are:

- Failure of the roof-to-wall connection with a resulting collapse.
- Out-of-plane (when forces are exerted perpendicular to the surface) failure of unreinforced masonry walls.
- In-plane failure of unreinforced masonry walls, when cracks develop in the plane of the wall.[51]

Because wood is a lighter and more flexible building material, wood-frame buildings respond better to earthquakes. In NYC's fire districts, buildings constructed with wood frames are required to have a masonry veneer (or larger distances between buildings). Most one- to two-family houses in NYC are wood-frame construction. For these homes, an earthquake could damage the masonry facade, but the structure could still stand. However, for three- to four-story buildings with load-bearing masonry, the building's stability could be compromised during an earthquake.

[51] FEMA, *Unreinforced Masonry Buildings and Earthquakes: Developing Successful Risk Reduction Programs*, FEMA P-774, October 2009.

Even if an earthquake caused little damage aboveground, damage to a building's foundation could render it uninhabitable or unusable. A large portion of NYC's waterfront originated as wetland or wasteland that was filled in, reclaimed, and built up over time. Historically, this land was typically created by using fill with poor structural properties. Recently, more controlled fill and construction procedures were applied.

Infrastructure

If an earthquake occurs in NYC, there is a risk that its impact will compromise infrastructure such as bridges, tunnels, utility systems, dams, and highways. As part of other capital improvements being made here, some of NYC's existing bridges have been partially retrofitted to improve their seismic performance.

However, the seismic vulnerability of NYC's complex network of interlinked infrastructure remains poorly understood and exists as an area of high concern, even as parts of the infrastructure undergo change, upgrade, and renewal. Some of NYC's critical infrastructure systems are vulnerable because they have aged and have maintenance problems.

During an earthquake event, soil liquefaction could result in large-scale ground failure that damages pavements and building foundations and massively disrupts underground utilities. Areas with artificial fill are vulnerable to liquefaction and include JFK Airport, the World's Fair site in Flushing, Queens, and Chinatown in Manhattan. A seismic event could cause structures built atop liquefied soils to sink and settle. Damage to underground infrastructure usually occurs wherever pipes and other utility transmission lines are unable to withstand soil movements. Damage to these critical links could trigger secondary impacts that pose even greater risk to the public — water contamination, fires, and sudden, powerful explosions.

NATURAL ENVIRONMENT

Earthquakes can damage the natural environment, destroying trees and disrupting the landscape.

Competition for space can push development on formerly marginal lands. With increased urbanization, an earthquake (combined with effects of extreme weather) would also affect the more densely populated areas. What would once be a small, localized event would now become a catastrophic event.

With the increased occurrence of flash floods, hurricanes, extreme rainfalls, an earthquake could be combined with these climate-induced hazards which could increase the risk exponentially.

FUTURE ENVIRONMENT

As NYC's substantial stock of seismically vulnerable (pre-seismic code) buildings is gradually replaced with new structures conforming to more robust seismic building code specifications, the percentage of vulnerable buildings will gradually decline. However, this would take a very long time. The dollar value of NYC's vulnerability would be expected to decline as well; however, if the value and volume of NYC's built assets increase over time, the economic risk from seismic exposure could still increase.

Aging components of NYC's infrastructure could amplify the structural impacts of earthquakes in the future. Investments, such as improving the seismic performance of existing bridges, should reduce the risks from future earthquakes.

UNLIKE OTHER NATURAL HAZARDS, EARTHQUAKES OCCUR WITHOUT WARNING, PUTTING THE POPULATION AT IMMEDIATE RISK.

HOW TO MANAGE THE RISK?

Even though earthquakes hit without warning and cannot be prevented, many strategies can be used to reduce the risks associated with them. Risk-mitigation strategies continue to grow more successful as seismologists, geologists, engineers, architects, emergency responders, and other experts innovate new public safety initiatives in their respective fields.

The primary strategies involve more robust seismic building code requirements, enhanced seismic design requirements, increased effort to inspect and maintain critical infrastructure, and retrofitting of buildings.

SEISMIC BUILDING CODE PROVISIONS

The first seismic provisions in NYC's Building Code were signed into law in 1995 and took effect in February 1996.[52]

DOB further addressed NYC's structural vulnerability to earthquakes in 2008 and subsequently in 2014 and 2022, when it adopted the International Code Council's (ICC) family of codes as the basis of the NYC Construction Codes. It is important to note that while the NYC Construction Codes adopted the ICC codes, they also amended some portions to be more stringent than the ICC.

The 2008, 2014, and 2022 Codes aim to make buildings stronger, more flexible, and more ductile — able to absorb energy without breaking in a brittle manner. The Codes have sections on soil types and building foundations. Seismic detailing is required to enable a building's joints, structural connections, and piping to hold up during an earthquake. Currently, the Building Code is being updated.

Code Enforcement

To make sure that buildings are built to code, new construction and major renovations cannot begin until DOB has reviewed plans and issued work permits. Most of the details required by earthquake design are subject to special inspections performed by qualified private engineers who are responsible for reporting findings to DOB.

Engineering Strategies for Retrofit of Existing Buildings

To enhance seismic safety, retrofitting strategies for existing buildings include:

TABLE: RETROFITTING STRATEGIES TO ENHANCE SEISMIC SAFETY

TITLE	DESCRIPTION
Structural Connections	Strengthens connections between building elements, such as walls and foundations, and adds steel frames to unreinforced masonry to resist seismic forces.
Flexibility and Mass Reduction	Increases structural flexibility and reduces mass to lessen impacts from seismic activity.
Foundation Strengthening	Enhances stability by improving foundations situated in poor soil conditions.
Commonsense Solutions	Implements simple measures like anchoring furniture and water tanks in taller buildings to prevent injuries and maintain essential services during earthquakes.

[52] NYC Department of Buildings, "NYC Codes," City of New York.

Routine Maintenance

Routine maintenance on all buildings in NYC is essential to minimize the risks associated with earthquakes. This includes keeping roofs secure and in good condition, securing cornices and aluminum panels, repointing mortar regularly (especially on parapets and chimneys), and fixing all cracks.

Infrastructure Protection

Earthquakes can cause major damage to infrastructure that was not originally designed to withstand earthquake impacts — older bridges, tunnels, sewers, water supply systems, and wastewater treatment plants. NYC is acting to mandate that new infrastructure be designed to meet more robust seismic loading requirements, and that older infrastructure be retrofitted to meet those standards. Federal, state, and local government agencies all play roles in setting standards for and overseeing the implementation of seismic safety improvements for infrastructure.

Protecting Bridges

In New York, bridge owners hired seismologists to assess the risk of this hazard here. The Federal Highway Administration administers seismic retrofits of bridges through local authorities, under a 1991 inspection and rehabilitation program mandated by Congress. In 1998, the DOT developed seismic criteria guidelines, which it updates as new science and solutions emerge.[53]

NYC began seismic retrofitting of critical and essential bridges in 1998. Transportation agencies serving the NYC area either have retrofitted or are in the process of retrofitting the bridges that they manage.

DOT, which owns and maintains 799 bridges, is in the process of implementing seismic retrofits of all its critical, essential, and other bridges.[54]

PROTECTING OTHER INFRASTRUCTURE

The NYC Department of Environmental Protection (DEP) is currently conducting several projects to enhance seismic protection of the wastewater treatment system. DEP is retrofitting wastewater treatment facilities and methane gas storage systems to withstand earthquakes, because most were designed and built prior to implementation of the current, more stringent seismic standards. To reduce the risks associated with seismic activity to NYC's sewer system, DEP is inspecting and repairing structural deficiencies in some of the major sewers.

Research

Collaboration among seismologists, geologists, engineers, architects, politicians, and emergency managers is required to manage earthquake risks. Further research into the potential impacts of earthquakes on NYC will expand knowledge about this hazard and promote greater public awareness. This research may include earthquake impact modeling of NYC's unique built environment to estimate potential physical and economic losses, incorporating NYC's large stock of older buildings, soil conditions, and unique geological characteristics.

In 2023, USGS released a new version of the National Seismic Hazard Model of seismic hazard forecasts for the United States from induced and natural earthquakes.[55]

The State University of New York at Buffalo (UB) has recently advanced their research on the vulnerabilities of unreinforced masonry buildings. In 2023, further shake-table tests were conducted at the Structural Engineering and Earthquake Simulation Laboratory at UB as part of a National Institute of Standards and Technology-funded project aimed at improving the seismic performance and resilience of these structures. The tests focused on evaluating and refining retrofit methodologies that are not only reliable and cost-effective, but also address the urgent national need for safer unreinforced masonry buildings (URM) that often house critical infrastructure.

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[53] Federal Highway Administration, *Seismic Retrofitting Manual for Highway Structures: Part 1 — Bridges* (Publication No. FHWA-HRT-06-032), Turner-Fairbank Highway Research Center, U.S. Department of Transportation, January 2006. [54] NYC Department of Transportation, *2020 NYC DOT Bridges and Tunnels Annual Condition Report*, City of New York. [55] U.S. Geological Survey, "Short-Term Induced Seismicity Models," U.S. Geological Survey, October 24, 2019.

SHAKE-TABLE TEST AT UB
SOURCE: SUNY UB

Research (continued)

This latest research also supports the rationalization of building code provisions and the development of advanced tools for designing retrofit solutions, enhancing the seismic resilience of aging building stock in downtown areas — including those in high seismic risk zones across the U.S. The project represents the largest study of its type in the nation, utilizing a single-story double-wythe URM test structure equipped with 160 sensors and cameras to rigorously validate current retrofit practices.[56]

PREPAREDNESS

Many New Yorkers are unaware that their community is at risk of danger from earthquakes. Because earthquakes occur unexpectedly, New Yorkers will not have advanced warning that one will strike, so promoting awareness and preparedness among local communities is essential.

Ready New York

NYCEM's Ready New York campaign encourages New Yorkers to be prepared for all types of emergencies, to develop a personal disaster plan, and to stay informed about the entire range of hazards that may affect the city. The "Preparing for Emergencies in NYC Guide" explains what to do when an earthquake strikes and the steps to take immediately after.

Strengthening Communities

NYCEM's Strengthening Communities program offers grants to community networks to build their emergency preparedness plan and support local community resources. The training program focuses on five key areas to build an emergency plan specific to each community.

1. Creating a needs assessment.
2. Designing community maps of the area where services are provided.
3. Building a resource directory.
4. Preparing a communication strategy.
5. Creating donations and volunteer management plans.

NYCEM staff provide training, coaching sessions, and tools that guide participating networks through the program.

Great ShakeOut

NYCEM, along with FEMA and the Northeast States Emergency Consortium, promote the "Great ShakeOut," — an international initiative that encourages participants to engage in earthquake safety drills — held annually on International ShakeOut Day. By promoting the event on social media, and involving all staff members, NYCEM aims to elevate awareness and readiness within the community.

[56] State University of New York at Buffalo. "Investigation of the Resilience of a Rehabilitated Unreinforced Masonry Building with Shake Table Tests." Department of Civil, Structural and Environmental Engineering - University at Buffalo, March 28, 2023.

05

EXTREME HEAT

LEARN ABOUT EXTREME HEAT

What is the Hazard?
What is the Risk?
How to Manage the Risk?

On average, more deaths occur related to heat — annually in NYC and the United States — than as the result of any other extreme weather event. NYC is particularly susceptible to this hazard due to its dense urban environment. Prolonged periods of increased temperatures and humidity create a dangerous situation for individuals at greater risk for heat-related illness and strain utilities and infrastructure. Projections associated with climate change show that average temperatures will rise, and heat waves will become more frequent, intense, and prolonged.[57]

[57] New York City Department of Health and Mental Hygiene, "Climate and Health," City of New York.

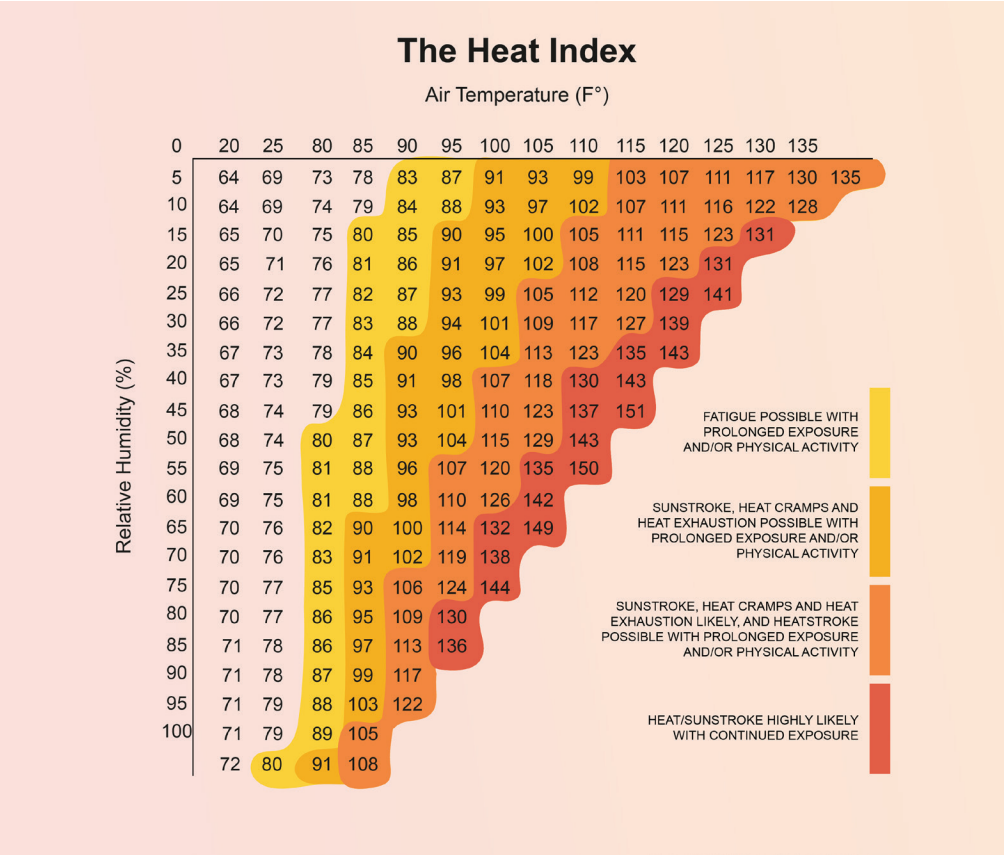
WHAT IS THE HAZARD?

During the summer, NYC usually experiences one or more periods of extreme heat. Heat is not only uncomfortable, but it can also be dangerous — causing dehydration, heat exhaustion, heat stroke, the worsening of several chronic and mental health conditions, and in severe cases, death.[58] Periods of extreme heat can also lead to pressure on the power grid, causing outages that can create cascading impacts throughout NYC.

Hazards from extreme heat are made worse when accompanied by high levels of humidity — the amount of moisture in the air. As the temperature climbs, the air can hold more moisture. High humidity hinders a person's body from cooling down naturally, leading people to perceive that the temperature feels hotter. The combination of temperature and humidity — what the temperature "feels like" — is known as the heat index.

SEVERITY

The NWS uses a heat index chart to determine the effects particular combinations of temperature and humidity will have on the general population.



Note that the heat index values used in this chart are calculated in the shade and are not adjusted for different levels of sun exposure. Thus, when people are exposed to direct sunshine, they can feel much hotter than the temperature indicated on this chart.

During hot weather, the stress a person experiences from the heat depends upon the temperature, location, and air movement as well as their level of physical activity, individual age and health status, and exposure to sunlight and radiant heat from nearby surfaces.

If indoors, where people spend the majority of their time, the presence or absence of air-conditioning is a critical factor in how much heat someone experiences.

PROBABILITY

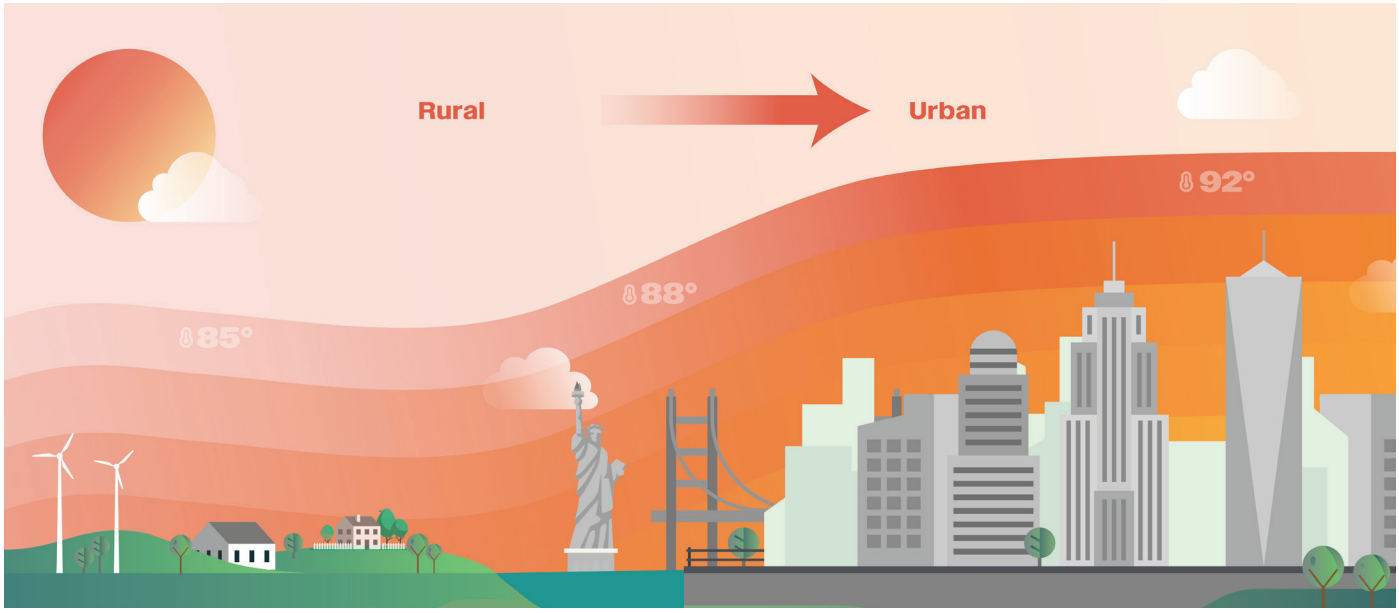
Based on the NPCC baseline (1981–2020), New York City currently experiences an average of 17 days per year with temperatures at or above 90°F and about two heat waves annually, each lasting around four days. Extreme heat events are already a concern, with projections building on this baseline indicating a rise in frequency and intensity. These trends underscore the existing risk of heat-related hazards, emphasizing the importance of monitoring and preparedness efforts to address current vulnerabilities.

[58] NYC Department of Health and Mental Hygiene, "Extreme Heat and Your Health," City of New York.

LOCATION

The built environment of NYC results in the phenomenon known as the "urban heat island effect." Heat islands develop in urban areas where formerly vegetated, permeable surfaces are now paved with asphalt or covered by buildings and other structures that absorb and retain heat. This condition impedes the overnight cooling process, keeping nighttime air temperatures significantly higher than temperatures in surrounding rural areas. Waste heat that emanates from air conditioners, vehicles, and other types of equipment also contribute to the urban heat island effect.[59]

THE URBAN HEAT ISLAND EFFECT



HISTORIC OCCURRENCES

TABLE: HISTORIC NYC HEAT WAVES

DATE	DESCRIPTION
July 27, 2006	Lasting eight days, this prolonged heatwave brought daily highs from the upper 90s to around 100°F, with 42 deaths attributed to the heat.
July 20, 2011	Lasted for five days with daytime temperatures rang-ing from 95° to 105°F and nighttime lows in the 70s and 80s, peaking at 115° F on July 22. Resulted in 20 deaths due to excessive heat in Southeast NY.
August 13, 2016	Excessive heat warning issued on August 13, 2016, with temperatures forecasted to reach up to 110°F. The heat warning lasted through the weekend, with heat index values peaking at 105° to 110°F.
July 19, 2019	Temperatures broke 100°F and nearly 50,000 NYC residents lost power, as Con Edison cut service to protect equipment from high heat and electrical demand.

[59] Environmental Protection Agency, "Reduce Urban Heat Island Effect," Environmental Protection Agency.

WHAT IS THE RISK?

More heat-related deaths occur in NYC and the United States annually, on average, than casualties resulting from any other type of extreme weather event.[60]

Periods of extreme heat put pressure on NYC's infrastructure. Heat waves cause people to increase their usage of air-conditioning, which can strain the power grid and trigger power outages. Power outages, in turn, can lead to adverse health impacts. Additionally, transportation infrastructure is vulnerable in terms of buckling and melting of road surfaces and warping of train rails and wheels.

SOCIAL ENVIRONMENT

One of the main impacts of heat is to human health. If a person has prolonged exposure to very high temperatures, they can experience serious health problems, including dehydration, heat exhaustion, heat stroke, and in severe cases, death. Symptoms of heat exhaustion include confusion, dizziness, fatigue, nausea, headaches, and muscle cramps. Without proper treatment, heat exhaustion may progress to heat stroke.

Heat stroke, the most serious of heat-related illnesses, occurs when the body is no longer able to maintain a core body temperature in the normal range. Common symptoms include hot, dry skin; seizures; disorientation; and loss of consciousness. Heat stroke can cause complications in the central nervous system and permanent damage to the brain and other vital organs. In many cases, heat stroke can result in death.

Prolonged periods of heat can also exacerbate certain chronic conditions, including renal, cardiovascular, and respiratory illnesses, which sometimes also results in death.[61] These deaths, also known as "excess deaths" or "heat-exacerbated deaths" are much greater in number than heat stroke deaths.

Each summer, an estimated 352 New Yorkers die prematurely because of extreme heat. This includes an average of 345 heat-exacerbated mortalities and 7 heat stroke deaths. About 115 of these heat-exacerbated deaths are attributed to extreme heat days, and the rest are attributable to hot, but not extreme, days, which have been increasing in number more quickly than extreme heat days.

The average number of these hot but non-extreme heat days increased from 52 in the years 1971–1975 to 74 days in the years 2016–2020, whereas the number of extreme heat days only increased from four in the years 1971–1975 to 11 in the years 2016–2020.[62]

In addition, there are about 600 emergency department visits and hospital admissions for direct heat-related illness and increases in visits for kidney conditions, heart and respiratory conditions, and mental health conditions, among others.[63]

In NYC, most heat-related deaths and illnesses could be prevented by using home air-conditioning. Approximately 80 percent of heat stroke deaths among New Yorkers are due to prolonged heat exposure at home. Heat-exacerbated deaths are also more likely to occur at home during extreme heat.[64] The high expense of purchasing and running a home air conditioner is an economic barrier that places many lower-income New Yorkers at risk. According to a random, digit-dial telephone survey conducted from September 22 to October 1, 2015, 13 percent of NYC adults aged 18 and older did not possess an air conditioner (AC), and another 15 percent used an AC infrequently or never. This is a concern because without air-conditioning, indoor temperatures can be significantly hotter than outdoors during and shortly after periods of extreme heat.[65]

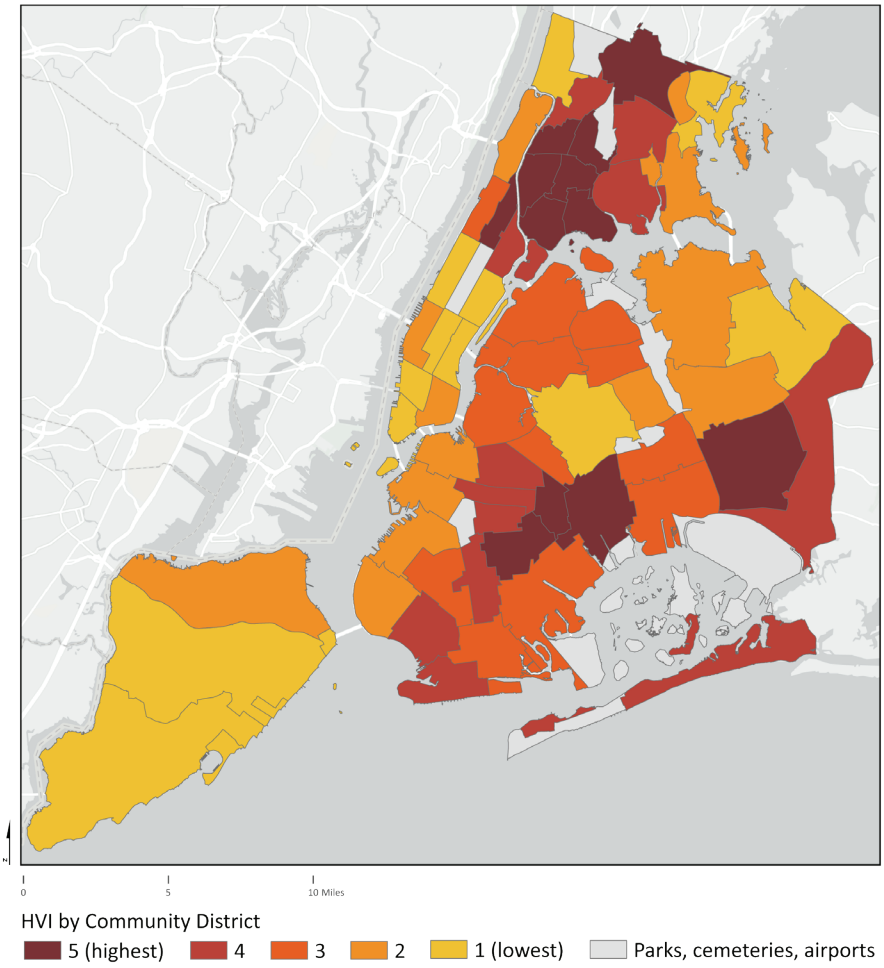
Vulnerable Neighborhood Communities

The neighborhood where a person lives may also be a factor in residents' risk for heat-related illness or death during hot weather. People living in certain areas and communities in NYC may be at higher risk than others during periods of extreme heat.

[60] National Weather Service, Office of Climate, Water, and Weather Statistics, "Natural Hazard Statistics: Weather Fatalities 2017," National Oceanic and Atmospheric Administration. [61] S. Lin, et al., "Extreme High Temperatures and Hospital Admissions for Respiratory and Cardiovascular Diseases," *Epidemiology* 20 (2009): 738–746. [62] Environment & Health Data Portal, "2023 NYC Heat-Related Mortality Report," City of New York. [63] Barbara A. Fletcher, Shao Lin, Edward F. Fitzgerald, and Syni-An Hwang, "Association of Summer Temperatures with Hospital Admissions for Renal diseases in New York State: A Case-Crossover Study," *American Journal of Epidemiology* 175, no. 9 (May 2012): 907–16. [64] Jaime Madrigano, Kazuhiko Ito, Sarah Johnson, Patrick L. Kinney, and Thomas Matte, "A Case-Only Study of Vulnerability to Heat Wave-Related Mortality in New York City (2000–2011)," *Environmental Health Perspectives* 123, no. 7 (March 2015): 672–78. [65] Jaime Madrigano, Kathryn Lane, Nada Petrovic, Munerah Ahmed, Michelin Blum, and Thomas Matte, "Awareness, Risk Perception, and Protective Behaviors for Extreme Heat and Climate Change in New York City," *International Journal of Environmental Research and Public Health* 15, no. 7 (July 2018): 1433.

The Heat Vulnerability Index (HVI) is based on an analysis of heat-related mortality in NYC and provides a measure of how at risk a neighborhood is during extreme heat events compared to other neighborhoods.

MAP: THE HEAT VULNERABILITY INDEX



The communities with highest vulnerability to death or illness during periods of extreme heat have the following characteristics: higher surface temperatures, less green space, lower median income, lower access to home air-conditioning, and non-Hispanic Black populations.[66] This is a result of historical disinvestment and systemic racism.[67]

The HVI enables NYC to prioritize resources to communities identified as having a high risk to the adverse health impacts of extreme heat. Actions taken by NYC include the following: programming to promote social cohesion, outreach efforts to educate residents about heat risks, coating roofs with white and installing green roofs (roofs with vegetation planted on them) where feasible, and planting street trees. These actions are part of a comprehensive initiative to keep NYC communities safe in extreme heat.

However, it is important to note that residents are still at risk for heat illness and death even if they reside in neighborhoods with low HVI scores. While some neighborhoods are more vulnerable to heat than others, there are vulnerable populations and individuals in every single neighborhood in NYC.[68]

BUILT ENVIRONMENT

Architecture and infrastructure can each contribute to NYC's extreme heat risk. Extreme heat can also negatively impact buildings, including the power grid and critical infrastructure.

Architecture

People who live and work in NYC can be placed at higher risk of heat-related illness if their building's architecture traps heat and limits ventilation, or if the cooling systems do not work or are absent entirely.

A building's construction materials can affect its internal temperature, potentially increasing the heat for workers or residents. Factors that can affect a building's internal temperature include the amount of air that escapes through gaps or cracks in the walls; the amount of insulation in the walls and roofs; the type and size of windows; and the materials with which a building is constructed, as well as the direction the building faces and, for apartments, the floor on which it is located.

[66] Jaime Madrigano, et al., "A Case-Only Study of Vulnerability to Heat Wave-Related Mortality in New York City (2000–2011)," 672–78.
[67] Bailey, Zinzi D, Nancy Krieger, Madina Agénor, Jasmine Graves, Natalia Linos, and Mary T Bassett. 2017. "Structural Racism and Health Inequities in the USA: Evidence and Interventions." *The Lancet* 389 (10077): 1453–63.
[68] Tiantian Li, Radley M. Horton, and Patrick Kinney, "Projections of Seasonal Patterns in Temperature-Related Deaths for Manhattan," *Nature Climate Change* 3 (2013): 717–21.

Other Infrastructure

Extreme heat poses a risk to the extensive network of ground transportation infrastructure serving NYC. High temperatures can cause damage such as cracking pavement on roads and bridges, buckling railroad tracks, and sagging wires. These effects can lead to service disruptions, hazardous travel conditions, and costly repairs. The impact of heat on infrastructure, while not often singled out in cost estimates, can be considerable. For example, heat-related costs to railways have been noted to be substantial, potentially increasing in the future.[69]

Public concern regarding service disruptions from heat is reflected in opinion surveys, indicating an increasing perception of climate change as significant threats. These disruptions, combined with the increasing awareness of climate issues, underscore the need for continued attention to the resilience of infrastructure against extreme heat.[70]

NATURAL ENVIRONMENT

It is difficult to determine whether extreme temperatures alone present any direct risk to the natural environment in NYC, since heat waves are naturally occurring weather events. Human activities and NYC's dense built environment exacerbate the amount of heat here, but do not directly cause the problem.

Secondary hazards associated with extreme heat are poor air quality and drought, which put NYC's natural environment at risk. Periods of hot weather trigger increases in energy use, which in turn contribute to higher emissions of pollutants and greenhouse gases. Long-term temperature changes from an increasingly warmer climate may cause shifts in habitat and cause some local species to go extinct if they are not adapted to withstand long stretches of extreme heat or cold.

FUTURE ENVIRONMENT

By the 2050s, days at or above 90°F could increase from 17 to 69, with up to 108 days by the 2080s. Heat waves, currently two per year, may rise to nine annually, with durations extending to 10 days. Days below freezing are expected to drop from 70 to as few as 9 by the 2050s and potentially 3 by the 2080s.

TABLE: PROJECTIONS OF EXTREME HEAT[71]

	BASELINE	10TH PERCENTILE			25TH PERCENTILE			75TH PERCENTILE			90TH PERCENTILE		
	1981-2020	2030s	2050s	2080s	2030s	2050s	2080s	2030s	2050s	2080s	2030s	2050s	2080s
Days ≥ 90°F	17	27	32	46	27	38	46	46	62	85	54	69	108
Days ≥ 95°F	4	8	10	17	8	14	17	17	32	54	27	35	73
Days ≥ 32°F	70	34	17	3	39	31	9	52	48	39	58	52	48
# of Heat Waves (days)	2	3	4	6	3	5	6	6	8	9	7	9	10
Avg. Length of Heat Waves (days)	4	5	5	5	5	5	5	5	6	8	6	6	10

[69] Rae Zimmerman, "Heat Measures for Climate and Infrastructure Services," *Urban Climate* 34 (December 2020): 100658. [70] Kathryn Lane, Katherine Wheeler, Kizzy Charles-Guzman, Munerah Ahmed, Michelin Blum, Katherine Gregory, Nathan Graber, et al., "Extreme Heat Awareness and Protective Behaviors in New York City," *Journal of Urban Health* 91, no. 3 (June 2014): 403–14. [71] Braneon, C., Ortiz, L., Bader, D., et al. "NYC Climate Risk Information 2023: Observations and Projections," NYAS, Under Review.

HOW TO MANAGE THE RISK?

Extreme heat events, which are projected to increase in frequency and severity in NYC over the next few decades, can have significant consequences for at-risk populations and infrastructure. More comprehensive risk management strategies may be required to address these changing conditions.

Some of the most important near-term strategies include informing at-risk populations about health risks, keeping internal building temperatures cool, and mitigating the urban heat island effect through more trees, vegetation, and reflective surfaces.

POLICY AND REGULATION

Financial Assistance

Cooling assistance through the Home Energy Assistance Program (HEAP) is available for NYC residents. Administered by the New York State Office of Temporary and Disability Assistance and NYC Department of Social Services, eligible individuals can receive financial aid to buy and install air conditioners if they meet income requirements and have a heat-exacerbated medical condition.

PlaNYC

PlaNYC targets extreme heat through a series of measures aimed to enhance citywide resilience by 2030. This includes setting mandatory cooling requirements for all new constructions by 2025 and reforming HEAP to support both equipment and energy costs for low-income New Yorkers' cooling needs. The plan also advocates for expanding the urban tree canopy to 30 percent and mandates the installation of 1 million square feet of cool roofs annually.

PlaNYC 2023 introduces several measures aimed at safeguarding New Yorkers from the impacts of climate change:

- Establish a maximum summer indoor temperature policy by 2030 to protect residents from extreme heat.
- Implement mandatory cooling systems in all new constructions by 2025, requiring updates to local laws and building codes.
- Modify HEAP to include funding for both the equipment and the energy costs of cooling.

Local Law 148 of 2023

Enacted to reinforce PlaNYC's goals, Local Law 148 mandates the protection, maintenance, and expansion of the urban forest canopy. The law sets a strategic objective to increase the forest canopy coverage to 30 percent of the City's land area, leveraging green infrastructure to mitigate the impacts of extreme heat. During heat waves, NYC and its partners take the following actions to keep vulnerable populations and the general public safe:

Resiliency Hubs

As part of PlaNYC 2023, 10 hubs will be established by 2030, providing cooling, medical refrigeration, and emergency support in areas prone to extreme heat and other natural hazards.

Local Law 97 of 2019

Part of the Climate Mobilization Act, this law sets ambitious carbon emissions caps for buildings over 25,000 square feet, affecting around 50,000 properties. It introduces phased carbon caps starting in 2024, with increasing stringency through 2049, culminating in zero emissions requirements by 2050. The law specifies emissions limits for 60 different property types to accommodate variations in energy usage.[72]

Climate Resiliency Design Guidelines (CRDG)

These guidelines are in pilot phase across 23 City agencies, incorporating heat mitigation measures such as heat exposure assessments based on the Heat Vulnerability Index (HVI).

Local Laws 92 and 94 for Sustainable Roofing

Enacted in 2019, these laws mandate the installation of sustainable roofing systems on all new buildings and major renovations where the entire roof is replaced. The laws require either green or solar roofs, or the use of highly reflective materials when other options are not feasible, aligning with NYC's objective of achieving carbon neutrality by 2050.[73]

[72] NYC Department of Buildings, "Local Law 97," City of New York. [73] NYC Department of Buildings, "Local Law 92 of 2019 and Local Law 94 of 2019: Green and Solar Roof Requirements for New Buildings and Complete Roof Replacements," City of New York, October 2019.

OUTREACH

Before a heat wave strikes, the public — especially at-risk populations — must understand the dangers of prolonged exposure to extreme heat, the types of people that are most at risk and why, and the practical measures people can take to protect themselves, their families, and their neighbors.

The City has implemented several initiatives to mitigate the risks to residents, especially vulnerable populations, before heat waves occur. These initiatives are aimed at promoting resiliency to current extreme conditions and adapting to future increases in temperature:

Prevention

Under the Cool Neighborhoods NYC initiative by the Mayor's Office of Climate and Environmental Justice, Department of Health and Mental Hygiene (DOHMH) collaborates with various partners to enhance heat resilience. This includes the "Be A Buddy" program, a community-led initiative aimed at boosting social cohesion and resilience against extreme heat and other severe weather events.

Outreach

The City engages in outreach to inform and prepare the public and key partners, including health care providers, community, faith groups, and service agencies, on mitigating risks from extreme heat. Methods include press releases, social media, in-person training, and workshops, as well as direct electronic communications. During heat emergencies, there is a concerted effort to encourage partners and the public to check on those at increased risk for heat-related illnesses.

Publications

The Ready New York website features a "Beat the Heat" page by NYCEM, providing safety tips online and in print. DOHMH also distributes information on heat-related health impacts and prevention to the public and health care providers.

Advisories and Alerts

NYCEM monitors and activates the City's Heat Emergency Plan in collaboration with NWS and DOHMH, issuing advisories through Notify NYC and specialized alerts to health care providers and organizations serving vulnerable populations.

Cooling Centers

Over 500 air-conditioned public spaces, including 16 pet-friendly locations, are made available to reduce heat-related illness risks.

Homeless Populations

Enhanced outreach efforts include round-the-clock engagement and emergency interventions during extreme heat.

Support during Outages

Utility companies maintain communication with customers reliant on life-support equipment, especially during power outages.

INFRASTRUCTURE

NYC pursues a wide range of short- and long-term strategies to manage risks associated with heat-related hazards to infrastructure. Some long-term initiatives have the critical short-term benefit of reducing demand on the power grid and the associated risk of power outages.

Energy Systems

NYC's primary utility providers, Con Edison and PSEG, are strengthening their power sources and energy infrastructure by making utility systems more flexible and by diversifying energy sources to minimize impacts of extreme weather events. Utilities also employ "demand-side" strategies to manage load on the system and continue operations during extreme heat events.

Utilities employ "supply-side" strategies to reduce strain on the system and continue operations during extreme heat events:

- **System Reinforcements**: Utilities enhance infrastructure resilience by increasing power supply feeders, upgrading cables, enhancing transformer capacity, constructing new substations, and redistributing loads.
- **Improving System Reliability**: This includes routine inspections, maintenance, component repairs, circuit redesigns, demand rebalancing, and advanced monitoring through automated switches and mobile scanning.
- **Operational Readiness**: Preparatory measures for summer include engineering studies, voltage reduction, employing an Incident Command Structure on peak heat days, specialized response teams, staff training, and ensuring generator capacity.
- **Backup Generators**: Positioning backup generators in areas vulnerable to high demand ensures continuous power supply.

Transportation Systems

Transportation systems can be protected from hazards associated with periods of extreme heat with measures such as the following:

- **Rail Systems**: The MTA has invested in protective measures against heat-related damage including new redundancy measures and structural improvements to trains, railroad tracks, and buses.[74]
- **Roads and Bridges**: The DOT is exploring the use of permeable pavements for roads and bridges, which not only manage heavy precipitation and snowmelt but also reduce surface temperature and damage during heat wavesves.[75]

Protecting Buildings

Several long-term strategies in NYC aim to increase the energy efficiency of buildings and to lower indoor air temperatures — steps that help to reduce energy consumption over the long term. Using these strategies with NYC's built environment can reduce the risk of power outages and reduce reliance on other short-term strategies, such as utility demand-response programs.

NYC CoolRoofs

A partnership between the NYC Department of Small Business Services (SBS), its Workforce1 Industrial & Transportation Career Center, Mayor's Office of Climate and Environmental Justice (MOCEJ), and the HOPE Program, promotes and facilitates the cooling of NYC's rooftops by installing a reflective coating to dark roofs .[76]

NATURE-BASED STRATEGIES

NYC strategically utilizes its natural environment to mitigate the effects of extreme heat across its neighborhoods. By expanding green infrastructure, such as the planting of trees and vegetation, and focusing on the most vulnerable neighborhoods, the City effectively reduces the urban heat island effect and mitigates from the effect of extreme heat.

Urban Heat Island Effect Mitigation

- NYC's natural vegetation reduces the urban heat island effect, where areas with more trees and vegetation are cooler than those with impervious surfaces like asphalt.
- Strategic planting of trees and vegetation in open spaces and along streets significantly lowers local air temperatures, contrasting with heat-trapping built surfaces.

Cool Neighborhoods NYC Initiative

- Launched in 2017, the City released its first heat resiliency plan, Cool Neighborhoods NYC, which is a set of strategies and programs to mitigate the effects of rising temperatures due to climate change.
- Represents the highest tree planting total in six fiscal years, reflecting canopy targets from PlaNYC.

Focus on Heat Vulnerable Neighborhoods

- In 2023, over 5,700 new trees were planted in neighborhoods identified as heat vulnerable, including parts of the Bronx, Brooklyn, Manhattan, and Queens.
- Since 2017, 15,677 trees have been planted in the most vulnerable neighborhoods, with plans for an additional 9,700 trees through spring 2024.
- Mitigation efforts are supported by $136 million to ensure tree planting in every viable location in the most affected areas by 2026.

GREEN INFRASTRUCTURE SOLUTIONS
SOURCE: NYC MAYOR'S OFFICE

[74] Metropolitan Transit Authority, *MTA Climate Adaptation Task Force Resiliency Report*, Metropolitan Transit Authority. [75] Environmental Protection Agency, "Soak Up the Rain: Permeable Pavement," Environmental Protection Agency. [76] NYC Mayor's Office of Climate & Environmental Justice, "NYC Cool Roofs," City of New York.

06

FLOODING

LEARN ABOUT FLOODING

What is the Hazard?
What is the Risk?
How to Manage the Risk?

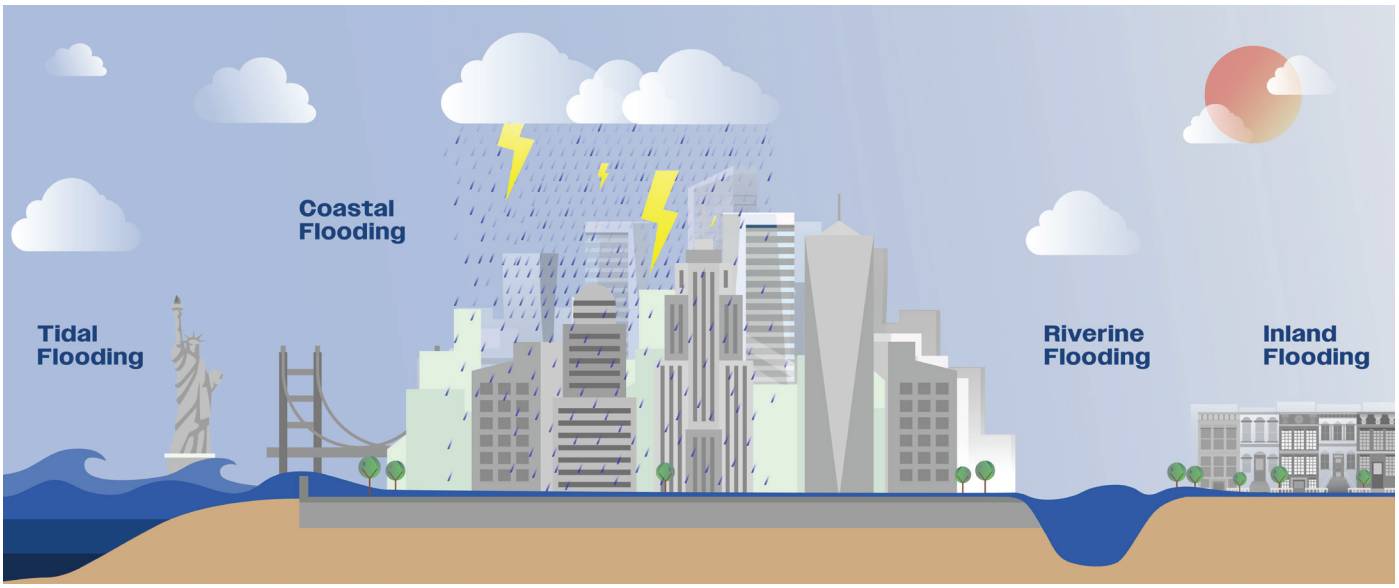
NYC has 520 miles of shoreline, with its large natural harbor, rivers, ocean, inlets, canals, and bays, which support its economic, social, and environmental context. Today, many New Yorkers and businesses inhabit low-lying coastal areas, former wetlands and watercourses, and interior floodplains. The natural landscape in the city has been historically transformed in such a way that impedes natural floodplain functions, thus causing vulnerability to a variety of types of flooding ranging from severe flash flooding to urban and nuisance flooding. Climate change has exacerbated — and will continue to exacerbate — flooding conditions in NYC.

WHAT IS THE HAZARD?

A flood is an overflow of water from oceans, rivers, or rainfall that submerges areas that are usually dry. Flooding is a natural phenomenon that happens due to a combination of weather events and hydrologic processes, but the hazards associated with flooding in NYC are often intensified by features of the diverse, densely packed city environment.

Flooding takes many forms — for example, heavy rainfall, storm surge, groundwater capacity exceedance, and the lack of capacity of drainage infrastructure to match flooding needs. Inland areas are also susceptible to flooding from extreme rainfall events.

TYPES OF NYC FLOODING



TYPES OF FLOODING

Coastal

Coastal flooding is primarily caused by the storm surge that generally accompanies a strong coastal storm, such as a tropical storm, hurricane, or nor'easter. The wind field and the coastal storm's low pressure cause water levels to rise and create a hazardous storm surge.

Storm surge can cause "stillwater" flooding — a rise in seawater levels without significant waves — and/or flooding accompanied by waves. In either case, coastal flooding can cause erosion, structural damage, and other hazardous conditions.

The elevation and slope of a shoreline influence how storm surge behaves. For example, low-lying areas on the coast are at greater risk of flooding. Additionally, NYC's geography magnifies the effect of storm surge, as well as the likelihood of coastal floods, when severe coastal storms funnel ocean water into New York Harbor.

A FLOODED NEIGHBORHOOD STREET
SOURCE: NYCEM

Tidal

Tidal flooding caused by normal variations in the lunar cycle and can occur even in the absence of a storm.

Seawater levels fluctuate daily due to the gravitational forces and orbital cycles of the moon, sun, and earth. Two high tides and two low tides occur daily. These daily high tides are at their highest twice a month during “spring tides,” when the earth, sun, and moon are aligned.

Tidal flooding currently affects some sections of NYC, including neighborhoods with low-lying shorelines.

As climate change causes sea levels to rise, low-lying neighborhoods will experience more frequent flooding, including those that do not currently experience tidal flooding regularly, which could significantly disrupt neighborhoods and gradually erode shorelines.

Inland

Inland floods can be caused by short-term, high-intensity, localized rainfall. Inland flooding can occur if excessive amounts of rain fall upon low-lying areas overwhelm and exceed the design capacity of the sewers or stormwater management infrastructure. Improper street grading and blocked sewer outfalls can also contribute to inland flooding.

While the intensity and landfall of coastal flooding can typically be forecast with better accuracy, inland flooding can occur with far less warning and can be highly localized, with some areas receiving higher rainfall amounts than others. The impacts of inland flooding can worsen when flash floods are preceded by days of steady, moderate rain.

NYC’s sewers are typically designed to manage a storm based on a five-year return period (e.g., 1.75 inches per hour for a one-hour storm; 20 percent chance of occurrence in any given year). Certain older areas of the city are designed for a three-year storm event. The intensity and duration of a storm with a five-year return period is likely to increase due to climate change, further stressing the existing sewage infrastructure.

Riverine

Riverine flooding occurs when the volume of fresh water flowing through a river or stream exceeds the holding capacity and water overruns the rivers or stream’s banks. The existence of dams or other impoundments can exacerbate the problem.

When large rivers flood, it is usually due to prolonged rainfall from a large-scale weather system over a significant area. During these types of weather events, rainfall can flood smaller basins that drain into major rivers, contributing to riverine flooding.

Narrow rivers and streams are more susceptible to flooding if a local weather system pours rain intensely over a smaller, more concentrated area.

Groundwater

Groundwater flooding in NYC occurs when heavy rains lead to soil over-saturation, allowing water to seep through vulnerabilities such as cracks in foundations or leaking drains. This flooding is especially problematic due to NYC's extensive underground infrastructure, which can be severely impacted by rising groundwater levels. While comprehensive assessments of this hazard are not yet complete, preliminary studies are in progress.

The risks associated with groundwater flooding may increase with sea-level rise, potentially causing more frequent and severe events. This would not only stress the existing drainage systems but also exacerbate issues like sewer overflows.[77]

While this profile mentions groundwater flooding to acknowledge its importance, it will not delve deeper into this hazard. Ongoing monitoring and emerging research will inform future updates to our understanding of this type of flooding.

PREPERATION OF A TIGER DAM
SOURCE: NYC WATER

[77] Bernice Rosenzweig, Franco A. Montalto, Philip Orton, Joel Kaatz, Nicole Maher, Jerry Kleyman, Ziyu Chen, et al. 2024. “NPCC4: Climate Change and New York City's Flood Risk”. Annals of the New York Academy of Sciences. Wiley. doi:10.1111/nyas.15175

SEVERITY

Flood severity depends on the type of flood, its cause, its duration, and other existing conditions, such as the capacity of sewers and other pathways that allow water to exit. The National Weather Service (NWS) categorizes the severity of flooding as minor, moderate, and major.

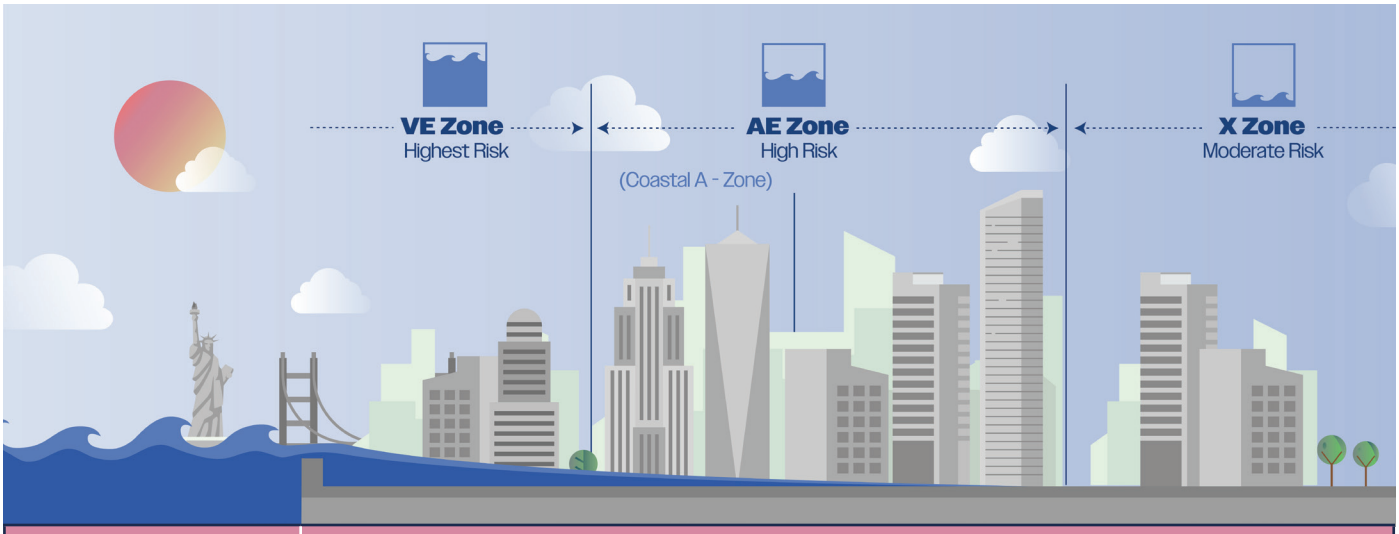
TABLE: NATIONAL WEATHER SERVICE FLOOD CATEGORIES

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.

PROBABILITY

Flood probability projections in NYC are based upon the frequency of past flood events of different intensities and the intervals of time between them. Flood probability classifications range from low probability, high impact (e.g., Hurricane Sandy) to high probability, low impact (e.g., more frequent, smaller events).

FEMA FLOOD ZONE CATEGORIES



FLOOD ZONE CATEGORY	DESCRIPTION
VE*	• Coastal areas subject to inundation by a 1 percent annual change flood. • Additional hazards associated with storm-induced waves more than 3 feet high. • *E indicates that base flood elevation is determined on the FIRMs.
Coastal A	• A sub-area of A/AE flood zone that has additional hazards associated with storm-induced waves that are between 1.5 to 3 feet high.
AE*	• Areas subject to inundation by a 1 percent annual change flood. • *E indicates that base flood elevation is determined on the FIRMs.
X	• Areas of moderate flood hazard subject to inundation by a 0.2 percent annual change flood, also called the “500-year flood zone.”

Coastal Flooding

The probability of coastal and riverine flood hazards in NYC is determined by several factors, including severe weather events, such as hurricanes, and regular high tide.

In 1983, NYC created its first Flood Insurance Rate Maps (FIRMs) when it joined the National Flood Insurance Program (NFIP). These initial FIRMs, digitized in 2007, maintained their original modeling and risk assessments.

The flood zones shown on the FIRMs are geographic areas classified according to levels of flood risk, with each zone representing a different severity and/or type of flooding, with a focus on denoting the highest-risk areas that are subject to 1 percent and 0.2 percent annual chances of flooding.

The 1 percent annual chance floodplain, commonly called the "100-year floodplain," indicates an area that has a 1 percent-or-greater chance of experiencing coastal or riverine flooding in any given year. Floodplain management standards apply to land located within the 100-year floodplain. Owners of property located within the 100-year floodplain are mandated to purchase flood insurance if they have a federally backed mortgage or previously received federal disaster assistance.

To determine areas that have a mandatory requirement for flood insurance, NYC references the FEMA Risk Rating 2.0, which better reflects the risk of flood damage to an individual structure and reduces the costs of flood insurance for lower-risk homes. While the FIRMs previously determined these flood insurance rates, under the implementation of FEMA's Risk Rating 2.0, they are now used solely to establish high-risk flood areas across the city. The FIRMs graphically represent the federal government's official assessment of flood risk in specific parts of NYC.

Tidal Flooding

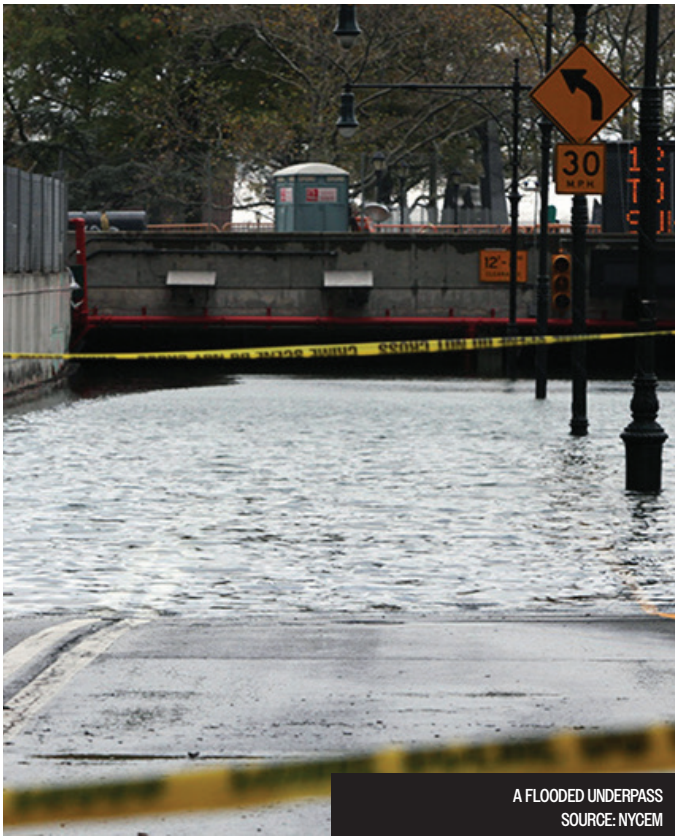
The probability that specific parts of NYC will experience tidal flooding depends on the area's proximity to a tidal area and on the lunar cycle. NYC's coastal neighborhoods, particularly those at lower elevations, regularly face flooding during high tides. Many of these areas are already experiencing regular tidal flooding today. In addition to being a nuisance today, tidal flooding poses escalating risks for the future. What may currently be considered minor inconveniences could evolve into significant life safety risks, impacting infrastructure, property, and human wellbeing. These risks necessitate proactive measures to mitigate the increasing hazards associated with tidal flooding.

Inland Flooding

Unlike coastal and tidal floods, inland floods can occur with much less or no warning. The probability of inland flooding is hard to predict because the heavy rainfall from storms and other weather events that cause inland flooding is often localized and can occur at any time of the year.

Inland flood risk in NYC is exacerbated by the degree of impervious ground coverage, local topography, and sewer capacity in the area. These factors, along with the volume of rainfall, can complicate predictions about the timing and location of inland floods, even with accurate storm or rain forecasts.

Climate trends project that NYC will experience even heavier rainfall in the future. If this occurs, the sewer system is likely to become overburdened more regularly and outfalls — drainage infrastructure for stormwater runoff and CSOs — are likely to be inundated more frequently. In combination with sea-level rise, which is expected to increase as high as 30 inches in NYC by the 2050s, this will further exacerbate inland flooding.[78]



A FLOODED UNDERPASS
SOURCE: NYCEM

[78] Vivien Gornitz, Michael Oppenheimer, Robert Kopp, Philip Orton, Maya Buchanan, Ning Lin, Radley Horton, et al., "New York City Panel on Climate Change 2019 Report, Chapter 3: Sea Level Rise," Annals of the New York Academy of Sciences 1439 (2019): 71–94.

LOCATION

New York's unique topography and variations in its built environment greatly affects the degree to which different parts of the city experience flooding.

Coastal Flooding

Coastal flooding can occur anywhere along NYC's 520-mile shoreline, but the severity of the hazard varies widely across NYC. The extent of coastal flooding beyond the shoreline and the elevation of the 1 percent annual chance flood event is not uniform across all neighborhoods.

The shoreline's elevation and slope influence how a storm surge behaves and how sea-level rise will affect an area. NYC's shoreline conditions are diverse, ranging from soft marshy or sandy areas of coastline to waterfront that is reinforced with hard rock and/or concrete.

NYC's proximity to the open ocean and its long shoreline exposes it to risks from damaging wave action. Low-lying areas, whether on the coast or inland, are at greater risk of, and are particularly vulnerable to, flooding. The geography of the New York Bight — the right angle formed by Long Island and New Jersey — increases the effect of storm surge by funneling the water into New York Harbor, as described in more detail in the Coastal Storms Hazard Profile.

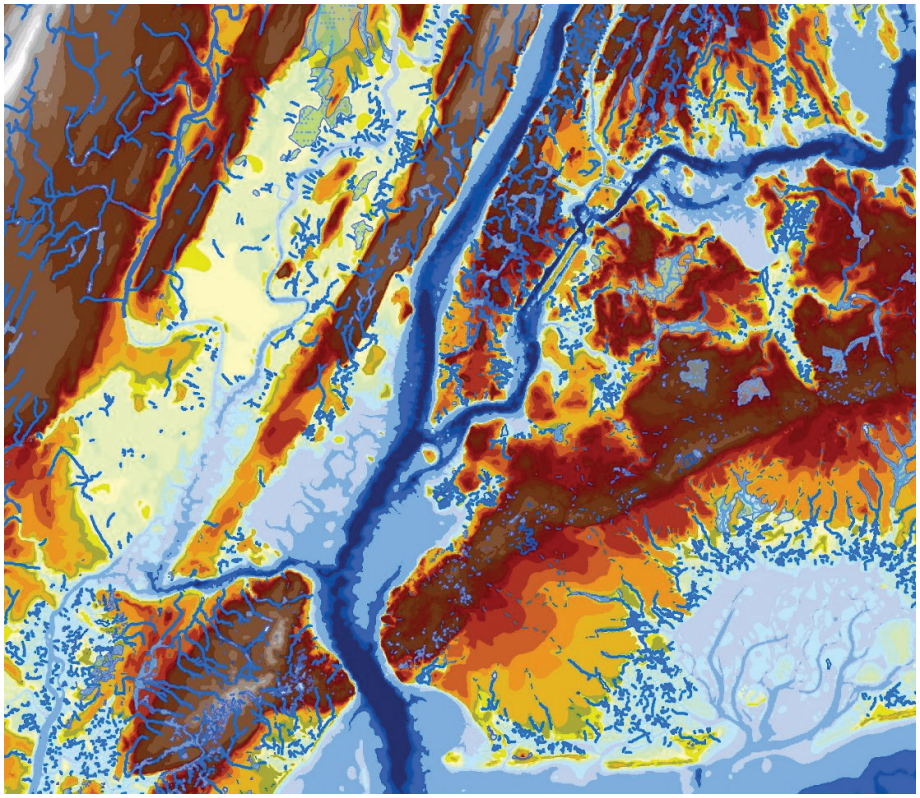
BLUE BELT, STATEN ISLAND
SOURCE: NYC MAYOR'S OFFICE

Riverine Flooding

Riverine flooding affects only a very small portion of flood-prone areas in NYC. Staten Island and the Bronx are the boroughs most vulnerable to riverine flooding due to the watershed characteristics in those boroughs. The Bronx and Hutchinson Rivers can create floods in the Bronx. On Staten Island, flooding can come from streams and river networks along the south shore and mid-island.

The NYC Streams, Rivers, and Waterways map shows the bodies of water in the NYC area in 1609, along with elevation. It is hypothesized that Rockaway Peninsula did not exist 400 years ago, leaving Jamaica Bay open to the ocean and without today's islands.

NYC STREAMS, RIVERS, AND WATERWAYS



SOURCE: ERIC SANDERSON / WILDLIFE CONSERVATION SOCIETY

Tidal Flooding

Some low-lying neighborhoods throughout NYC are currently vulnerable to flooding from lunar or seasonal high tides. As sea levels rise over time, the vulnerability of these low-lying neighborhoods will gradually increase due to more frequent flooding from daily and monthly high tides.

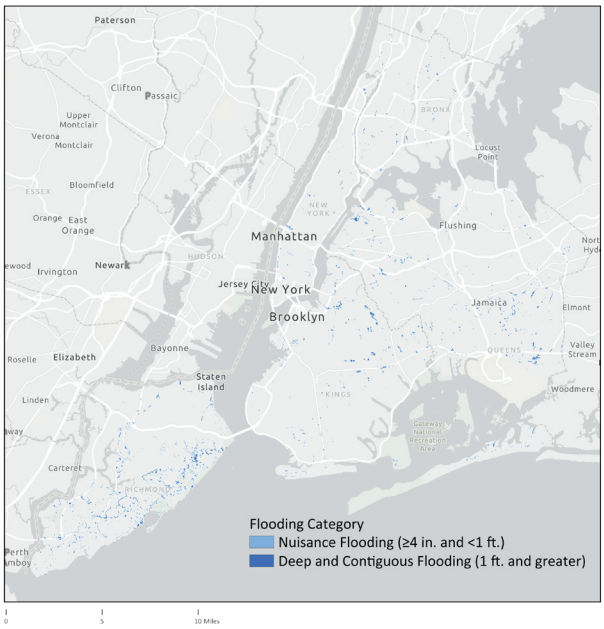
The risk of regular tidal flooding is most pronounced in the lowest-lying areas in NYC — such as in the Broad Channel and Hamilton Beach neighborhoods in and around Jamaica Bay in southeastern Queens, on portions of the bay side of Rockaway Peninsula, and in low-lying sections of Staten Island.

Inland Flooding

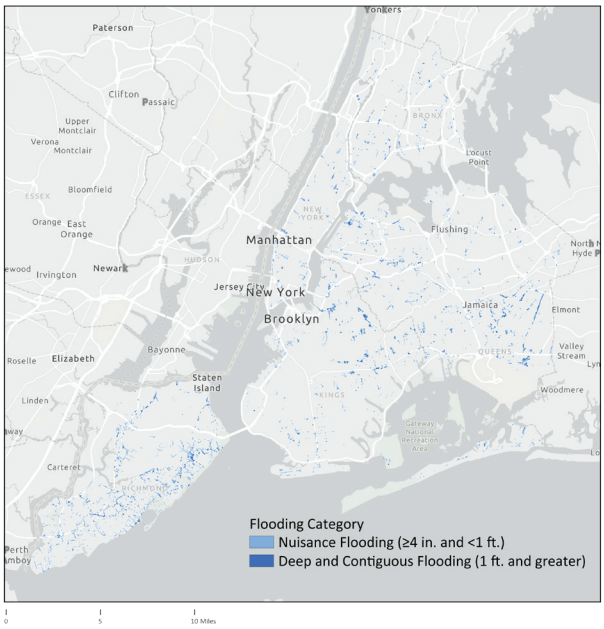
NYC areas that are prone to inland flooding are often low-lying, with an abundance of impervious surface cover, and typically have poor drainage, further exacerbating flood risks. Inland flooding occurs not only when the amount of rainfall received and the total volume of the water exceeds the capacity of the sewer system, but also during prolonged rain events, rapid snowmelt, or failures of dams and levees.

The NYC Stormwater Flood Maps, produced by the NYC's Mayor's Office of Climate and Environmental Justice (MOCEJ) and Department of Environmental Protection (DEP), illustrate the relative risk of flooding in public areas specifically due to stormwater runoff from rainfall. It includes three scenarios, mapping moderate stormwater flooding under current sea-level-rise conditions as well as moderate and extreme stormwater flooding scenarios under sea-level-rise projections for 2050 and 2080. Incorporating sea-level rise allows the City not only to better understand the magnitude of the risk in the coming decades, but also to evaluate the impact of sea-level rise on the performance of the existing drainage system.

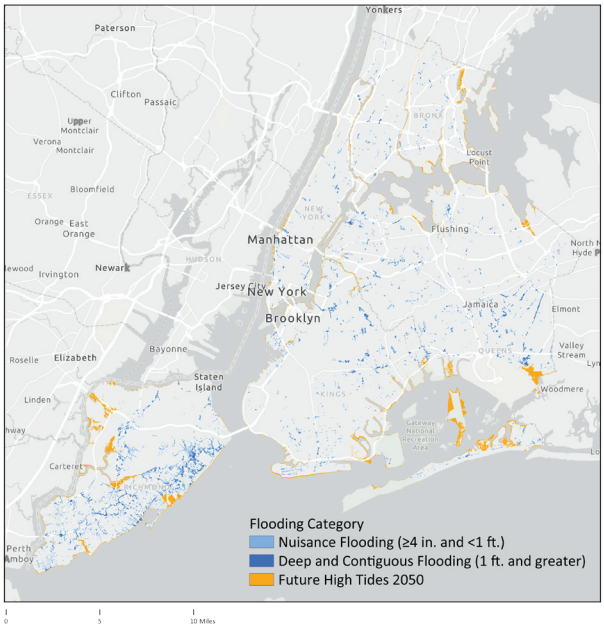
LIMITED FLOOD (1.77 IN/HR) WITH CURRENT SEA LEVELS



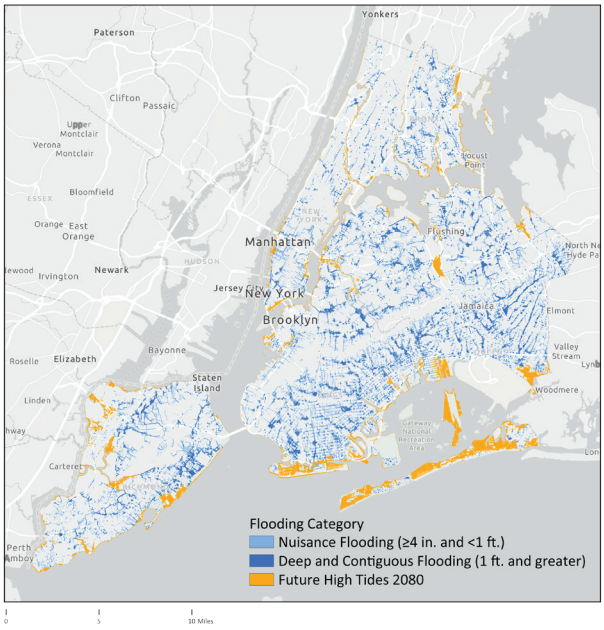
MODERATE FLOOD (2.13 IN/HR) WITH CURRENT SEA LEVELS



MODERATE FLOOD (2.13 IN/HR) WITH 2050 SEA LEVEL RISE



EXTREME FLOOD (3.66 IN/HR) WITH 2080 SEA LEVEL RISE



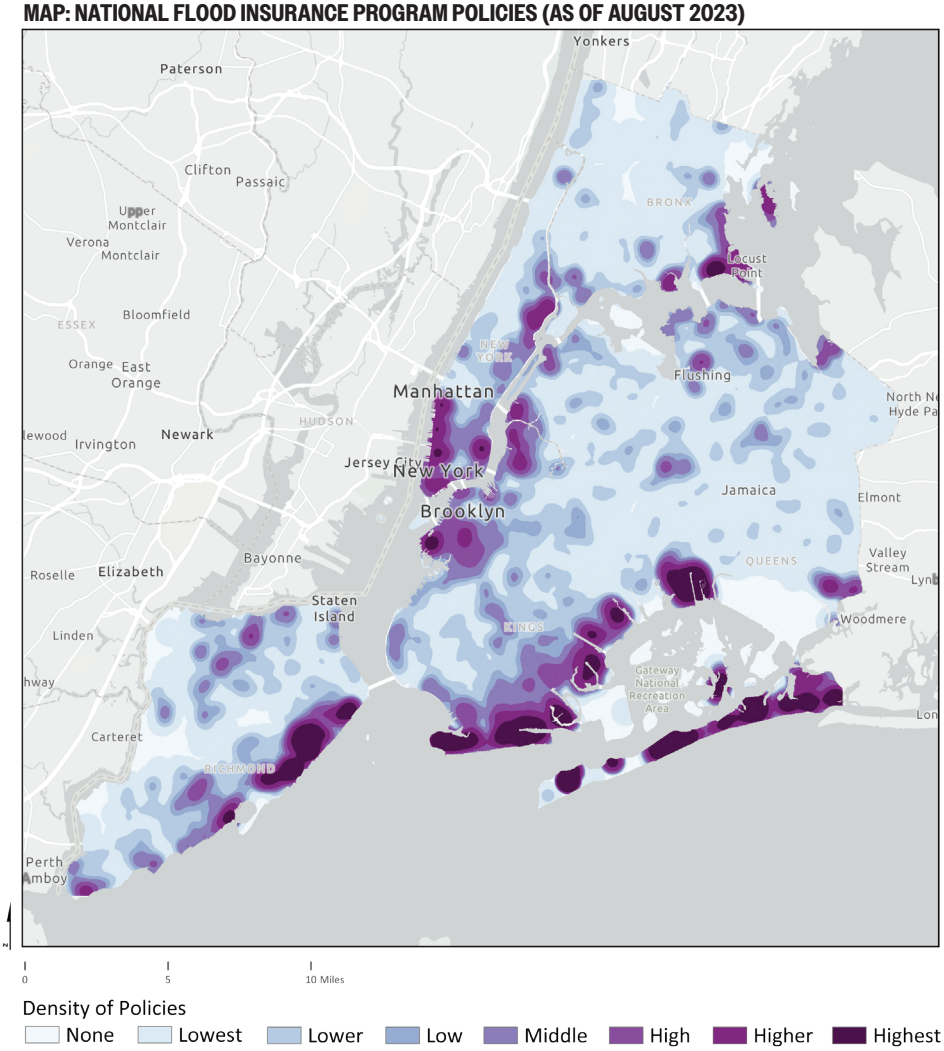
National Flood Insurance Program Analysis

FEMA administers the NFIP and sets insurance premiums. Flood insurance purchase requirements and minimum building standards are based on FEMA's FIRMs. Property owners are required to carry flood insurance if they have a federally backed mortgage on structures located within the 100-year floodplain designated on FIRMs.

FEMA collects a vast quantity of information on insured structures in NYC through the NFIP, including the number and location of flood insurance policies; claim payment amounts; and the number of claims per insured structure, including Repetitive Loss and Severe Repetitive Loss structures. These terms are defined as follows:

- **Repetitive Loss structures:** Structures for which a policyholder receives two or more claim payments of $1,000 or more after flood events within a 10-year period.
- **Severe Repetitive Loss structures:** Any insured structure that has incurred flood damage for which:
  - at least two separate claim payments have been made under a Standard Flood Insurance Policy, with the cumulative amount of such payments exceeding the fair market value of the insured buildings on the day before each loss; or
  - at least four or more claim payments over $5,000, and with the cumulative amount of claim payments exceeding $20,000.

MAP: NATIONAL FLOOD INSURANCE PROGRAM POLICIES (AS OF AUGUST 2023)



RAIN GARDENS DURING HEAVY RAIN
SOURCE: NYC WATER

[79] National Weather Service, "Night of July 8: Tropical Storm Elsa," National Oceanic and Atmospheric Administration.

HISTORIC OCCURRENCES

TABLE: HISTORICAL NYC FLOODING DISASTERS

NAME	DATE	DESCRIPTION
Tropical Storm Elsa	July 1, 2021	Impacted NYC and the Tri-state area with significant flooding, testing the City's in-frastructure as it struggled to manage the heavy rainfall and its effects.
Tropical Storm Henri	August 21, 2021	Intense rainfall in NYC, resulting in signif-icant subway flooding and infrastructure challenges. The storm produced two rounds of flash flooding spanning two days.
Post-Tropical Cyclone (PTC) Ida	September 1, 2021	The remnants of Hurricane Ida brought devastating rains to the Northeast, inun-dating NYC's subways, washing away ve-hicles, and halting flights. The cata-strophic flooding resulted in at least 44 deaths across four states, including 13 in NYC.
Severe Storm and Flooding	September 29, 2023	Occurred during a rising full moon high tide, enhancing the risk of compound flooding and sewer overflows in New York Harbor and Jamaica Bay. Heavy rain af-fected Manhattan, the Bronx, Brooklyn, and Queens, with rainfall rates of one to three inches per hour. JFK Airport record-ed eight inches, the highest for any Sep-tember day since 1960.[79]

WHAT IS THE RISK?

Vulnerability to flooding across NYC varies significantly, with different neighborhoods facing distinct levels of risk. In general terms, risk refers to the potential for loss or damage when a hazard interacts with the vulnerability of a system. In the context of flooding, this risk is primarily determined by several key factors: the type of flood, the population density of the area, the nature of properties and infrastructure most exposed to flooding, the degree of exposure to floods, and the resiliency of the built environment to withstand flood damage. These variables collectively define how susceptible a particular area is to the impacts of flooding.

SOCIAL ENVIRONMENT

Less than 5 percent of New Yorkers, or approximately 440,000 people, live within the 100-year floodplain and are at greater risk of coastal flooding hazards.

In addition to their proximity to the coastline, other factors can be used to determine residents' vulnerability to flood risk. Socioeconomic and demographic characteristics are important factors in determining vulnerability. 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 NYC, vulnerable populations include, but are not limited to, children, seniors, low-income residents, the "linguistically isolated" (those who speak English less than "very well"), people with disabilities and other access and functional needs or other preexisting health conditions, and in-patient populations at hospitals and other health care facilities.

Seniors

New Yorkers 65 years or older are approximately 15 percent of the NYC's total population and are among the most vulnerable during a flood-related disaster. They are more likely to have health conditions and disabilities that require regular access to health services and medication. During major flooding events, these services are often disrupted or severely restricted.

Low-Income

Communities with low-income are disproportionately affected by almost all disasters, including floods, with far fewer resources available to recover. These impacts are particularly acute in waterfront industrial areas and environmental justice areas, where high proportions of low-income communities are often located. A flood can damage and/or destroy homes, businesses, and inventory. Floods can also damage critical infrastructure and disrupt vital services.

Housing Stability and Mobility

Housing stability means secure access to a safe, healthy home and neighborhood tailored to residents' needs. While housing programs traditionally focus on stabilizing neighborhoods through economic and living condition improvements, certain areas, like the Rockaways and Hollis, face unique challenges. These communities are increasingly vulnerable to chronic high tide flooding and other impacts of climate change, which threatens uninterrupted access to decent, safe housing. NYC's built-out infrastructure complicates efforts to manage these risks effectively. It is crucial to pursue various climate adaptation strategies simultaneously. As sea levels rise, some locations will become unsuitable for residential use, necessitating new housing developments both outside of the flood zones and within coastal areas to accommodate long-term needs. This approach supports both immediate stability and future mobility, ensuring that all New Yorkers have access to safe and resilient housing.

BUILT ENVIRONMENT

Considerations of geography, land use, and the density of built assets that are exposed to flood risk are all factors that are used to assess a particular property's vulnerability. This section examines risks posed to NYC's buildings as well as its critical assets and infrastructure systems.

Risk to Buildings

NYC's diverse land use and building stock pose varied risks across its neighborhoods. Dense residential and commercial zones along the Hudson and East Rivers, industrial areas by Long Island Sound and New York Harbor, and oceanfront residential neighborhoods each face unique challenges.

Flood risk differs based on building height, type, materials, and age. Generally, low-rise buildings are more vulnerable to flood damage due to their construction with lighter, wood-stud frames and ground-floor primary uses. In contrast, mid-rise and high-rise buildings, often built with more robust materials like steel, masonry, or concrete, are less prone to structural damage.

Newer buildings, adhering to strict building and zoning regulations since 1983, face less flood damage. Currently, around 61,700 buildings, housing significant numbers of low- and moderate-income residents, are in the 100-year floodplain. These include multifamily buildings built before 1983 floodplain standards, covering crucial community functions and housing over 440,000 residents.

Critical Assets

Flooding poses a serious threat to critical infrastructure, with systems like transportation, energy, telecommunications, and wastewater at risk. Many critical assets lie in flood-prone areas highlighting the need for resilient infrastructure planning.

Wastewater Systems

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

The majority of NYC's wastewater treatment infrastructure is at risk of being damaged in severe storms or floods, which could lead to increased combined sewer overflows and contamination of the waterways. Floodwaters from a surge can cause significant damage both to wastewater management facilities and to the critical equipment they house. The corrosive impact of seawater on these facilities' electrical systems has the potential to disrupt the power supply and potentially cause an overflow of either partially treated or untreated sewage into waterways.

Transportation Systems

To facilitate their operations, many parts of NYC's transportation system, such as ferry terminals, are located on or near the waterfront. Some transportation assets are built in low-lying areas or even below sea level. Some rail and vehicular tunnels and many subway stations — which make up a significant portion of the NYC's transportation network — are located underground.

NYC's vast network of impervious streets is also vulnerable to flooding from heavy precipitation, storm surge, or, as in the case of the Hamilton Beach and Broad Channel neighborhoods in Queens, high tides. Approximately 72

percent of NYC's 305 square miles of land area consists of impervious surfaces.

Energy Infrastructure

Much of NYC's underground electric and steam distribution systems and generating facilities are located near the coast, placing them at risk from storm surge and floodwaters. Projections of sea-level rise indicate that in the coming decades there will be a growing number of electrical infrastructure facilities at risk.

For NYC's natural gas system, storm surge poses the biggest risk to the distribution infrastructure. Although flooding itself will not necessarily stop the flow of gas, service can be compromised if water enters the pipes. Low-pressure distribution systems are particularly vulnerable. Furthermore, flooding could disrupt critical communications infrastructure used for the gas distribution system, reducing the utility's ability to manage the system infrastructure remotely and to maintain situational awareness of how the system is faring during the emergency.

NYC's electricity and steam power generation are largely dependent on natural gas and liquid fuel. All power plants in NYC are dual-fuel capable, primarily running on natural gas, but using fuel oil as a backup. Any disruption to the gas transmission infrastructure or to the fuel supply chains can disrupt power and steam production. Given the location of key fuel terminals, pipelines, and refineries — and the importance of waterfront access to move fuels into NYC — the biggest risk to the liquid fuel supply is storm surge.

Telecommunication Infrastructure

NYC's telecommunication services — telephone, wireless, internet, and cable — are vulnerable to flooding, particularly from storm surge. Telecommunications facilities are generally situated farther from the floodplain than other types of infrastructure, yet almost 13 percent of critical telecommunication facilities lie in the 100-year floodplain. Vulnerability to the telecommunications infrastructure is projected to increase with climate change. With up to two and a half feet of sea-level rise expected by the 2050s, the risk to critical central offices, which provide connectivity across major telecom services — including the two largest central offices serving southern Manhattan — is likely to increase.

NATURAL ENVIRONMENT

NYC's open space and 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 most vulnerable assets to flooding hazards.

All types of flooding present significant risk to the City's park systems. Coastal flooding can submerge wetlands for prolonged periods of time and cause barrier islands to narrow or split. Wave action and storm surge can flood inland vegetation with saltwater, erode the shoreline edge, and damage non-salt tolerant trees and shrubs that act as a buffer for inland parks and neighborhoods and serve as habitat for a variety of species. Balanced, biodiverse ecosystems are a vital element of NYC's resilience.

NYC parklands also contain recreational amenities and landscaped areas including but not limited to ball fields, recreation centers, pools, plazas, amphitheaters, and bicycle and pedestrian paths. Coastal flooding and wave action have the potential to damage or destroy these constructed features, as well as recreational park amenities and landscaped areas. Inland parks, open space, recreational features, and natural areas are also at risk from heavy rainfall. Intense rain events, which produce several inches of rain within a short time period, can severely damage planted park areas that lack adequate drainage, often resulting in loss of vegetation or loss of porous soils that help slow the release of water and impact on adjacent areas.

FUTURE ENVIRONMENT

Future projections by the NPCC series indicate increased frequency and height of 1 percent annual chance floods in NYC. The NPCC2 report initiated these projections, while NPCC3 expanded the analysis to include effects of sea-level rise on monthly tidal flooding and introduced broader scenarios like Antarctic Rapid Ice Melt. It also provided updated citywide maps showing potential sea-level rise and flooding patterns. NPCC4 focuses on enhancing the understanding of compounded risks from storm and tidal surges and stormwater flooding.

Precipitation

Days with over 1 inch of rain are projected to increase slightly from 14 to 17 by the 2080s. Days with over 2 inches may rise from 3 to 6. Extreme events with over 4 inches, currently rare at 0.2 days per year, could increase to 0.7 days by the 2080s, reflecting a trend toward more intense precipitation.

TABLE: PROJECTIONS OF PRECIPITATION

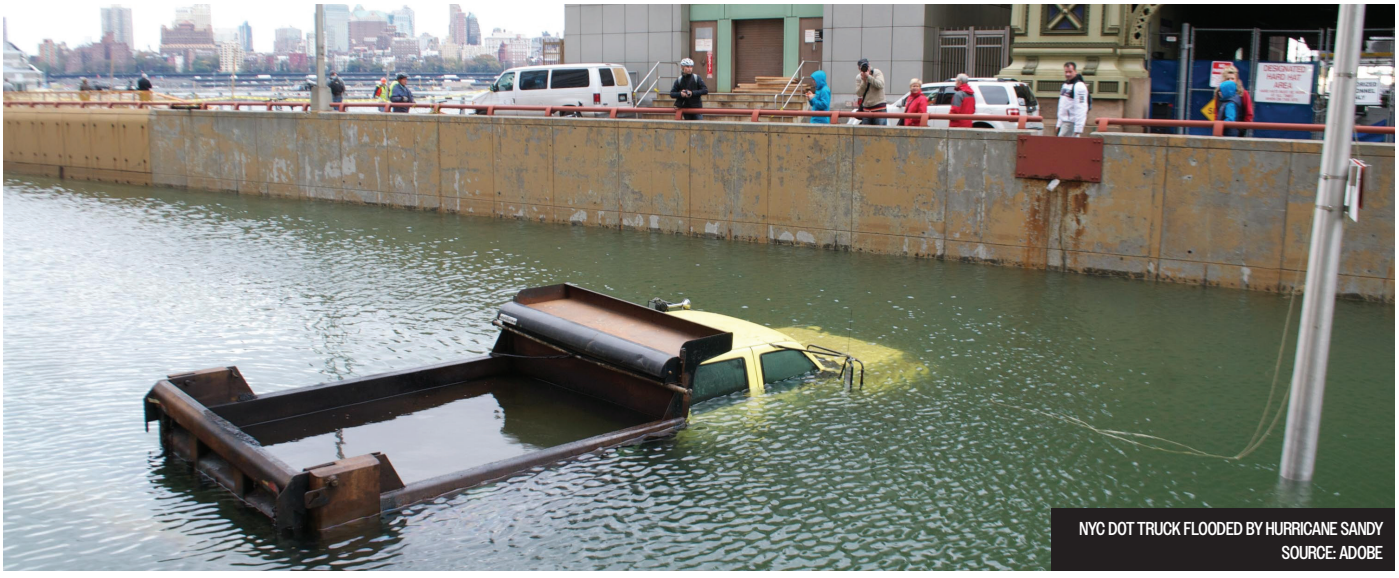
	BASELINE	10TH PERCENTILE			25TH PERCENTILE			75TH PERCENTILE			90TH PERCENTILE		
	1981-2020	2030s	2050s	2080s	2030s	2050s	2080s	2030s	2050s	2080s	2030s	2050s	2080s
Days over 1" precipitation	14	14	14	14	14	15	15	16	17	17	17	17	18
Days over 2" precipitation	3	3	3	4	3	4	4	4	5	6	5	5	6
Days over 4" precipitation	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.6	0.4	0.4	0.7

Sea-Level Rise

Projections based on a 1995–2014 baseline show sea levels rising 12 to 23 inches by the 2050s and up to 45 inches by the 2080s. By 2100, levels could reach 65 inches, with potential increases as high as 177 inches by 2150. These projections highlight the importance of planning for a range of future scenarios.

TABLE: PROJECTIONS OF SEA LEVEL RISE

	2030s	2050s	2080s	2100	2150
10TH PERCENTILE	6 in.	12 in.	21 in.	25 in.	38 in.
25TH PERCENTILE	7 in.	14 in.	25 in.	30 in.	47 in.
75TH PERCENTILE	11 in.	19 in.	39 in.	50 in.	89 in.
90TH PERCENTILE	13 in.	23 in.	45 in.	65 in.	177 in.

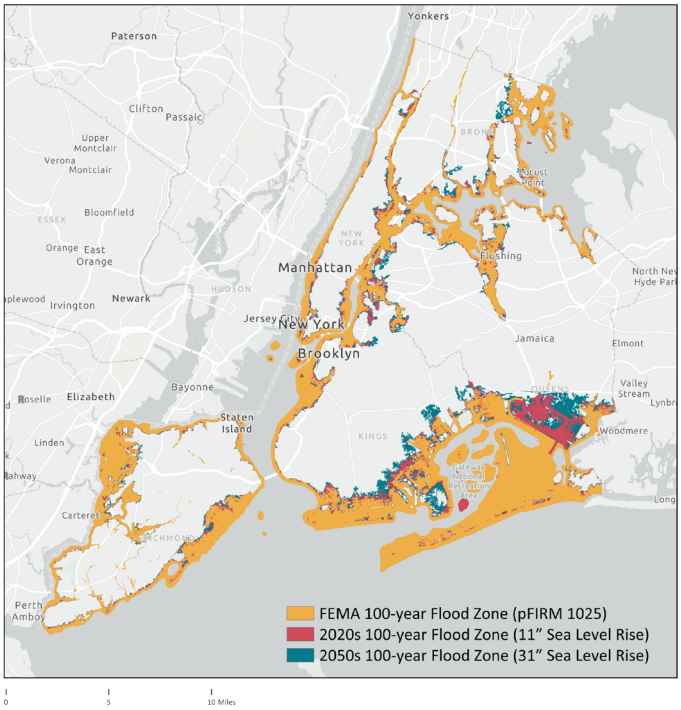


NYC DOT TRUCK FLOODED BY HURRICANE SANDY
SOURCE: ADOBE

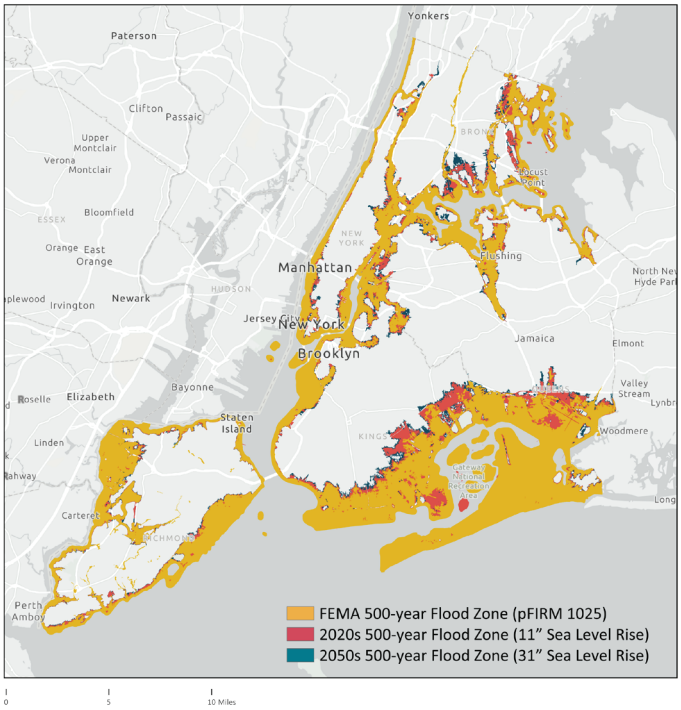
Future Flood Maps

NYC, in partnership with NPCC, has created a series of forward-looking flood maps to anticipate future coastal flood hazards arising from climate change. These include a map depicting the 100-year floodplain for the 2020s, combining FEMA's Preliminary Work Map data with an 11-inch sea-level-rise projection by the NPCC, and a map for the 500-year floodplain for the 2050s, factoring in a predicted 31-inch rise in sea levels. These maps are essential for providing a detailed picture of potential future coastal flood hazards, helping in the assessment and management of flood risks. They are particularly important for understanding the likelihood of flooding in various areas, with zones considered high risk having a 1 percent or higher annual chance of flooding.

100-YEAR FLOOD ZONE WITH PROJECTED SEA LEVEL RISE



500-YEAR FLOOD ZONE WITH PROJECTED SEA LEVEL RISE



HOW TO MANAGE THE RISK?

An integrated approach to managing flood risk begins with the recognition that flooding is a natural process that cannot altogether be prevented.

Taken together, these strategies — regulatory controls, land-use management policies, surface and subsurface measures, protections for buildings and infrastructure, and environmental restoration — add up to a broad but deliberate, multidimensional approach to promoting flood risk resiliency in NYC.

POLICY AND REGULATION

ManagingManaging flood risk is a collaborative effort involving government agencies at the federal, state, and local levels. The federal government sets the basic guidelines and building standards for flood management. However, at the state and local levels, particularly in NYC, these standards are often further developed and enhanced. NYC is known for implementing more stringent measures than the federal minimums, adapting and refining these guidelines to better suit the NYC's specific needs and conditions. This approach ensures a higher level of safety and resilience for the city against the threats of flooding.

The National Flood Insurance Program (NFIP)

FEMA's NFIP offers flood insurance for property owners, renters, and businesses in participating NYC communities. To participate and maintain eligibility for the NFIP, the City is required to adopt building codes that meet or exceed FEMA standards for floodplain management. All owners of property within the 100-year floodplain who hold federally backed mortgages must purchase flood insurance. It is worth noting that this insurance is also available to properties located outside the 100-year floodplain, extending coverage options to a broader range of property owners.

Parametric Insurance Pilot Study

Parametric insurance is coverage for weather-related events like storms, floods, or earthquakes. Instead of paying based on damages, it pays out based on the size and location of the event, as measured by official government sources. The City has advised on a pioneering parametric flood recovery assistance program, the Flood Recovery Fund, which is backed by major firms including Swiss Re Corporate Solutions, reinsurance broker Guy Carpenter, and data technology firm ICEYE. This fund is part of a broader city effort to enhance the financial resilience of low- and moderate-income households exposed to flood risk.

Insurance Research and Consumer Education

For insurance to play the appropriate role in providing financial protection to individuals and businesses from climate risks, policyholders must be aware of the flooding risks they face and know exactly what coverage their insurance policies include and exclude.

To enhance New Yorkers' understanding of their flood risk, the Center for NYC Neighborhoods, MOCEJ, and the Governor's Office of Storm Recovery jointly initiated FloodHelpNY. This consumer education program and its accompanying website offer vital information to raise awareness about flood risks, flood insurance requirements, and flood-resiliency measures.

In addition to outreach, the City is actively conducting research on flood insurance in the city. In 2017, the MOCEJ commissioned research organization RAND to study one- to four-family, owner-occupied primary residences within the 2015 PFIRM 100-year floodplain. The study, The Cost and Affordability of Flood Insurance in NYC, found that flood insurance is difficult to afford for many households, especially low-income households. The average premium paid for flood insurance by those with coverage as of June 2016 was approximately $1,880 (including fees) for owner-occupied one- to four-family properties in the high-risk zones of the 2007 FIRM and around $530 outside these zones.

Additionally, as part of the City's efforts to increase flood insurance enrollment and communication on flood risk awareness, MOCEJ is implementing innovative strategies to expand resident knowledge of flood hazards and to foster financial resilience against flood events. This approach aligns with FEMA Headquarters' efforts from 2020 to 2022, where several campaigns under NFIP were conducted to promote flood insurance, increase its accessibility, and mitigate flood risks.

Development Trends and Strategies

The following present changes in development that have occurred in flood-prone areas that decrease the community's vulnerability.

City of Yes

The "City of Yes for Housing Opportunity," aims to make 500,000 new homes available to New Yorkers over the next decade.

The plan includes several key measures:

- Eliminating mandates that require parking spaces to be constructed with new homes, which has previously made some housing construction impossible for developers.
- Creating additional affordable and supportive homes.
- Enabling the conversion of empty offices into homes, a move bolstered by the emptying of Manhattan offices during the pandemic.
- Allowing the construction of two- to four-stories of apartments above laundromats, shops, and other businesses along certain commercial strips.
- Making it easier for owners of one- and two-family homes to turn basements, attics, garages, or backyard cottages into Accessory Dwelling Units (ADUs).
- Making it easier for institutions with large, underused lots, such as churches and schools, to build housing.

HEAVY RAINFALL IN QUEENS, 2023
SOURCE: NYC WATER

Climate Resiliency Design Guidelines (CRDG)

NYC Local Law 41 of 2021 mandates a five-year pilot program that started in 2021. This program aims to ensure that new City infrastructure and public facilities are prepared for the worsening impacts of climate change, including intense rainfall, coastal storm surge, chronic high tide flooding, and extreme heat.

Under this program, 23 City capital agencies will begin designing and constructing dozens of new projects using the standards in the CRDG. The pilot program is expected to save taxpayers money in future repair and recovery costs, as for every dollar invested in resiliency, six dollars are saved. Making investments in preparedness now will pay dividends in the future.

The Construction Code

In 2022, the NYC Building Code (NYCBC) updated Appendix G, which contains flood requirements that have critical implications for building projects. The 2022 edition of NYCBC introduced several enhanced provisions, including mandatory annual inspections, full-scale triennial deployments of dry floodproofing systems, enforcement of restrictive declarations in residential buildings to prohibit future changes in the use of wet floodproofed enclosures, and requirements for an alternate means of emergency egress for dry floodproofed buildings.[80]

NYC Local Law 48 of 2015

NYC Local Law 48 of 2015 (Law No. 2015/048) mandated that catch basins — storm drains or sewer grates that collect storm water — be cleaned and maintained annually instead of the previously mandated three-year cycle. If a nonfunctioning catch basin is found, it must be fixed within nine days..

NYC Local Law 172 of 2018

NYC Local Law 172 of 2018 (Law No. 2018/172) requires the City to produce maps showing areas of the city most vulnerable to increased flooding due to the anticipated effects of climate change and to publish a long-term plan to prevent or mitigate such increased flooding.

NYC Stormwater Resiliency Plan

The Mayor's Office of Climate and Environmental Justice, per NYC Local Law 172 of 2018, and in collaboration with City agencies, developed the Stormwater Resiliency Plan (2021). The Stormwater Resiliency Plan outlines the City's approach to managing the risk of extreme rain events. The plan commits to four goals that optimize emergency response to extreme rainfall events and ensure that future City investments manage this climate risk.

Rainfall Ready NYC Action Plan

Following the aftermath of PTC Ida, the City developed the Rainfall Ready NYC Action Plan, which outlines the shared responsibilities and actions New Yorkers and City government can take to plan for, prepare against, and recover from intense storms.

Land Use Management and Zoning Law

Municipal governments shape the way land is used through zoning, a policy tool that determines the permitted size and use of buildings, where buildings are located, and the density of neighborhoods.

In NYC, DCP administers zoning law and DOB enforces it. DCP has used zoning as a way to manage flood risk at different scales, ranging from site-specific to neighborhood wide.

Special Coastal Risk Districts

In 2017, DCP established Special Coastal Risk Districts in Broad Channel and Hamilton Beach in Queens, and in Oakwood Beach, Graham Beach, and Ocean Breeze on the East Shore of Staten Island, following extensive engagement with these communities. Since 2017, Special Coastal Risk Districts have also been established in Gerritsen Beach, Brooklyn, and in Edgemere, Queens.

The special districts place limits on the density and uses allowed within these areas to limit future growth where flood risks are exceptional in their magnitude and frequency and cannot be managed through infrastructure investment. The special district in Staten Island was designated a buyout area by New York State. For this reason, new development in this area now requires approval from the City Planning Commission.

Housing Mobility and Land Acquisition

Through NYC's new PlaNYC: Getting Sustainability Done Action Plan, the City is now seeking to establish a voluntary housing mobility program to mitigate flooding risks. The City seeks to engage with interested residents and acquire difficult-to-protect flood-vulnerable properties that can support flood control, natural areas, or parklands. The program will be entirely voluntary for residents in select areas of the city with the highest coastal and stormwater flood risk and where other options to reduce flood vulnerabilities are limited.

Parks Flood-Resiliency Manual

NYC Parks created Design and Planning for Flood Resiliency: Guidelines for NYC Parks, a manual that guides development and renovation of resilient coastal waterfront city parks.

[80] NYC Department of Environmental Protection, "Stormwater Management," City of New York.

DEP's Coastal Resiliency Bureau

The creation of the Coastal Resiliency Bureau at the NYC DEP marks a significant stride in the City's ongoing efforts to combat and adapt to the challenges posed by climate change. This bureau is specifically tasked with developing and implementing strategies to protect the NYC's extensive coastline from the increasing risks of sea-level rise, storm surges, and coastal flooding.[81]

Managing Surface and Groundwater

The impacts of flooding can be reduced by cleaning and maintaining drainage infrastructure, building out the sewer infrastructure, managing surface water runoff, employing green infrastructure, and providing floodwater storage. Scientific research on groundwater flooding is in an early stage, and the City is exploring ways to bolster the understanding and data about the impacts of groundwater flooding.

Design and Construction of Stormwater Management Systems

DEP is responsible for designing and developing the drainage plan for the city. DEP also governs and oversees the construction of private sewers and drains to ensure compliance and that drainage capabilities are adequate. DEP is pioneering sustainable stormwater management strategies, including bluebelts and green infrastructure.

Sewers, Drainage, and Green Infrastructure

NYC is improving stormwater management by investing in sewer and drainage infrastructure to expand its capacity — adding high-level storm sewers, improving pumping stations, installing backflow valves, and increasing the effectiveness of catch basin and storm drain maintenance.

NYC's pumping stations convey millions of gallons of sewage from homes, businesses, hospitals, and numerous o or back up into basements. Projects are currently underway to protect pumping stations and make them more resilient to service interruptions caused by flooding.

Preserving and/or Restoring Natural Drainage Corridors

Natural drainage corridors — including streams, ponds, wetland areas, parks, and open spaces — help convey, store, and filter stormwater. Sometimes referred to as "bluebelts," these corridors are ecologically rich and cost-effective drainage systems that naturally handle the precipitation runoff from streets and sidewalks by preserving natural drainage corridors.

Cloudburst Program

A "cloudburst," as seen during PTC Ida, is a sudden, heavy downpour that occurs in a short amount of time and may lead to flooding, property damage, disruptions to critical infrastructure, and pollution of NYC's waterways.[82] Cloudburst management implements a combination of methods that absorb, store, and transfer stormwater to reduce flooding. Using gray infrastructure (e.g., drainage pipes and underground storage tanks) and green infrastructure (e.g., rain gardens and porous pavement), cloudburst management can minimize damage by reducing the strain on the municipal sewer system. DEP and NYCHA are designing cloudburst pilot projects to protect residents from these types of intense rainfall events at South Jamaica Houses in Queens and Clinton Houses in Manhattan.

Green Infrastructure

Green infrastructure allows water to infiltrate the ground more easily, reducing the volume of stormwater runoff that would otherwise have drained into the sewer system. Reducing the volume of water entering the sewer system can help to reduce sewer overflow and, in some instances, minimize flooding, particularly if the green infrastructure is sized to manage more than a water quality storm event.

A NYC STREET SEVERELY FLOODED
SOURCE: NYC MAYOR'S OFFICE

[81] NYC Department of Environmental Protection, "Climate Resiliency," City of New York.
[82] City of New York, PlaNYC: Getting Sustainability Done, City of New York, April 2023.

Water Conservation and Reuse

Water conservation and reuse primarily conserve potable water, but also offer the benefit of re-ducing the burden on the sewer system and wastewater facilities. DEP currently promotes water conservation and reuse through the “Wait . . .” program, which notifies participants when to use less water during a heavy rainstorm to protect sewer and drainage infrastructure. DEP also funds water conservation and reuse as part of the Water Demand Management Program, which includes municipal partnerships and a Water Conservation and Reuse Grant Pilot Program for private prop-erties.

Protecting Buildings

Many strategies are used in NYC to make buildings more flood resilient.

TABLE: FLOODING RESILIENCY ACTIONS

TITLE	DESCRIPTION
Dry Floodproofing	Utilizes watertight construction methods like temporary shields, barriers, or permanent floodwalls to keep water out.
Wet Floodproofing	Involves using flood-resistant materials in building construction to allow water to enter and exit without causing significant structural damage.
Building Elevation	Involves raising the structure so that the lowest floor is at or above the Design Flood Elevation (DFE), which is the height of a 1 percent annual chance flood plus a safety margin.
Equipment Elevation	Elevates critical mechanical and utility equipment above the DFE by placing it on higher floors, raised platforms, or suspending it from overhead structures to prevent flood damage. High-rise buildings may modify elevator systems to stop them from descending into floodwaters.
Backwater Valves	Installs a valve with a "flapper" mechanism to a building’s plumbing system. This valve closes to prevent sewer backflow during overflow, protecting against sewage entry. It reopens to allow normal wastewater flow once the overflow subsides.

Note that the building use, size, typology, and age, as well as the cost of different options, should be considered when selecting the appropriate protection measure or retrofit.

NYC DEP ON A FLOODED STREET
SOURCE: NYCEM

FLOOD DAMAGED GOODS OUTSIDE A HOME
SOURCE: NYC MAYOR'S OFFICE

Ida Mitigation Assessment Team (MAT) – Building Science Disaster Support Program

Following PTC Ida, FEMA deployed a MAT to investigate the performance of buildings and infrastructure impacted by the storm. The MAT's evaluations led to the development of several crucial recommendations aimed at enhancing building resilience against flooding.

TABLE: BUILDING RESILIENCE MEASURES

TITLE	DESCRIPTION
Water Sensors	Involves installing water sensors in basements or on first floors to alert residents of incoming water. Advanced systems may integrate these sensors with sump pumps to actively manage water intrusion.
Flooding Emergency Plans for Apartment Buildings	Encourages building owners to develop comprehensive emergency plans that include signing up for localized alerts like NotifyNYC, establishing clear communication strategies during floods, and facilitating safe evacuation for lower-floor residents.
Home Improvements	Advises homeowners to consult with licensed professionals to raise entry points and modify basement windows and doors to prevent water ingress and ensure safe escape routes during flooding. Improvements may include raising doors and windows and installing "blow-out" panels to prevent doors from jamming during floods.

These focused strategies derived from the MAT findings aim to significantly mitigate the risk and impact of future flooding events in vulnerable neighborhoods.

Protecting Infrastructure

Protecting critical infrastructure against the risk of floods includes protecting infrastructure assets such as subway entrances and tunnels, electricity and steam generation facilities, gas and steam distribution systems, water supply systems, wastewater treatment plants, health care facilities, and other facilities housing vulnerable populations.

Strategies to protect infrastructure from damaging floods vary widely depending on the type of infrastructure and can range from floodproofing or elevating individual facilities and equipment to implementing larger operational or design changes.

Coastal Resilience Projects

Prior to Hurricane Sandy, NYC implemented structural solutions to protect flood-prone properties. Post-Sandy, these initiatives have expanded to include integrated flood protection systems, increased coastal edge elevation, and protection of infrastructure and critical services.

Hard Structures

TABLE: FLOODING PREVENTION MEASURES

TITLE	DESCRIPTION
Bulkheads or Seawalls	Bulkheads are made from stone, concrete, or steel and stabilize shorelines and manage everyday tidal activities but are not primarily designed for storm surge flooding. Seawalls are engineered to protect against storm surges and vary based on local wave energy and soil conditions.
Levees	Also known as dikes, these are earthen embankments built at the shoreline to protect land from flooding, commonly used along riverbanks throughout the country.
Floodwalls	Permanent or deployable vertical structures anchored in the ground either at the shoreline or upland to prevent flooding from rivers or storm surges.
In-Water Surge Barriers	Typically used in combination with larger flood protection systems such as levees, floodwalls, and pumps, providing a high level of protection from storm surges.

Nature-Based Strategies

Some of the potential tradeoffs of hard-based shoreline structures include lack of access to waterfront recreational areas, loss of wildlife habitat, and a higher risk of coastal erosion. Nature-based systems can be integrated into coastal defense strategies alongside the hard-structure approach.

Some natural protective features, such as wetlands, dunes, and vegetation, naturally absorb energy from storm surge and waves, providing varying degrees of protection for structures located behind them. The following are examples of some natural and nature-based strategies.

Tottenville is an innovative coastal infrastructure project designed to reduce or reverse erosion and damage from storm waves, improve the ecosystem health of Raritan Bay, and encourage stewardship of nearshore waters. The NYS Office of Resilient Homes and Communities and City agencies are planning a breakwater project in Tottenville on the South Shore of Staten Island.

Wetlands

Wetlands, which use plants and soils to retain and filter water, are important wildlife habitats in NYC. Large wetlands use friction to help slow the rate of storm surge, and in some cases reduce flood heights. The degree to which wetlands offer an opportunity to reduce flood risk depends upon the storm's speed and intensity and the size of the wetland. Flooding can even enhance the natural health and functionality of wetlands.

Beaches, Beach Nourishment, and Dunes

Beaches, beach nourishment, and dunes are three natural and nature-based protective features that function as sandy buffers, helping to protect shorelines from the destructive impact of strong waves and flooding. These natural features are sometimes reinforced with vegetation, geotextile cores, or an engineered core made up of stone or steel.

07

HIGH WINDS

LEARN ABOUT HIGH WINDS

What is the Hazard?
What is the Risk?
How to Manage the Risk?

High-wind events are a common occurrence in NYC. A variety of windstorm types can occur with little warning, damaging property and infrastructure, disrupting transportation, downing trees and power lines, and causing serious personal injuries.

NYC's dense high-rise environment, high number of older buildings, and many open construction sites heighten its vulnerability to dangerous winds.

WHAT IS THE HAZARD?

Most New Yorkers recognize that they must battle high winds from time to time, but not all high-wind events are caused by the same type of weather systems.

Hazardous high-wind events can occur from tight pressure gradients, strong frontal systems, nor'easters, hurricanes, and severe thunderstorms, which may produce straight-line winds or tornadoes.[83] High-wind events may or may not be accompanied by precipitation and can vary in geographic extent, intensity, and duration.

For example, events can range from short bursts of high-speed winds, such as with a severe thunderstorm, to longer periods of sustained winds from events such as a hurricane. Severe thunderstorms typically have less than an hour of warning lead time, but nor'easters, tropical cyclones, and other types of high-wind events usually have several hours to a few days of warning lead time.

TABLE: CHARACTERISTICS OF HIGH-WIND EVENTS

HIGH-WIND EVENTS	CHARACTERISTICS
Straight-line Winds	• Most common with storms • Typically blow in one direction, but can vary during the course of the event • Speeds exceeding 50-60 miles per hour (mph) • Associated with intense low atmospheric pressure • Duration of up to one day
Thunderstorms	• Storms capable of producing high wind speeds, heavy rain, and hailstones • Storms sometimes accompanied by tornadoes
Tornadoes	• Associated with a severe thunderstorm • Violently rotating column of air • Wind speeds range from 65 to 300 mph
Microbursts / Macrobursts	• Associated with a thunderstorm • Powerful downdraft that can cause severe, localized damage
Hurricanes	• Highest intensity of a tropical cyclone weather system • Counterclockwise rotation around a center of low pressure • Maintains strength over water • Associated with bands of strong thunderstorms and possibly tornadoes • Well-defined low-pressure center ("eye") • Sustained winds of 74 mph or greater
Nor'easters	• Counterclockwise rotation around a center of low pressure • Forms and maintains strength over either land or water • Often associated with wintry precipitation (snow, sleet, freezing rain)

[83] NOAA National Severe Storms Laboratory, "Research at NSSL: Damaging Winds," National Oceanic and Atmospheric Administration.

SEVERITY

Depending on the type of high-wind event affecting NYC, NOAA uses two different scales to describe the event. The Enhanced Fujita Scale is used to classify the severity of tornadoes, and the Beaufort Wind Scale is used to classify the intensity of wind speed. Each associates higher numbers on the scale with higher levels of property damage. The size of hailstones and wind gust speeds can also be used to measure the severity of thunderstorms.

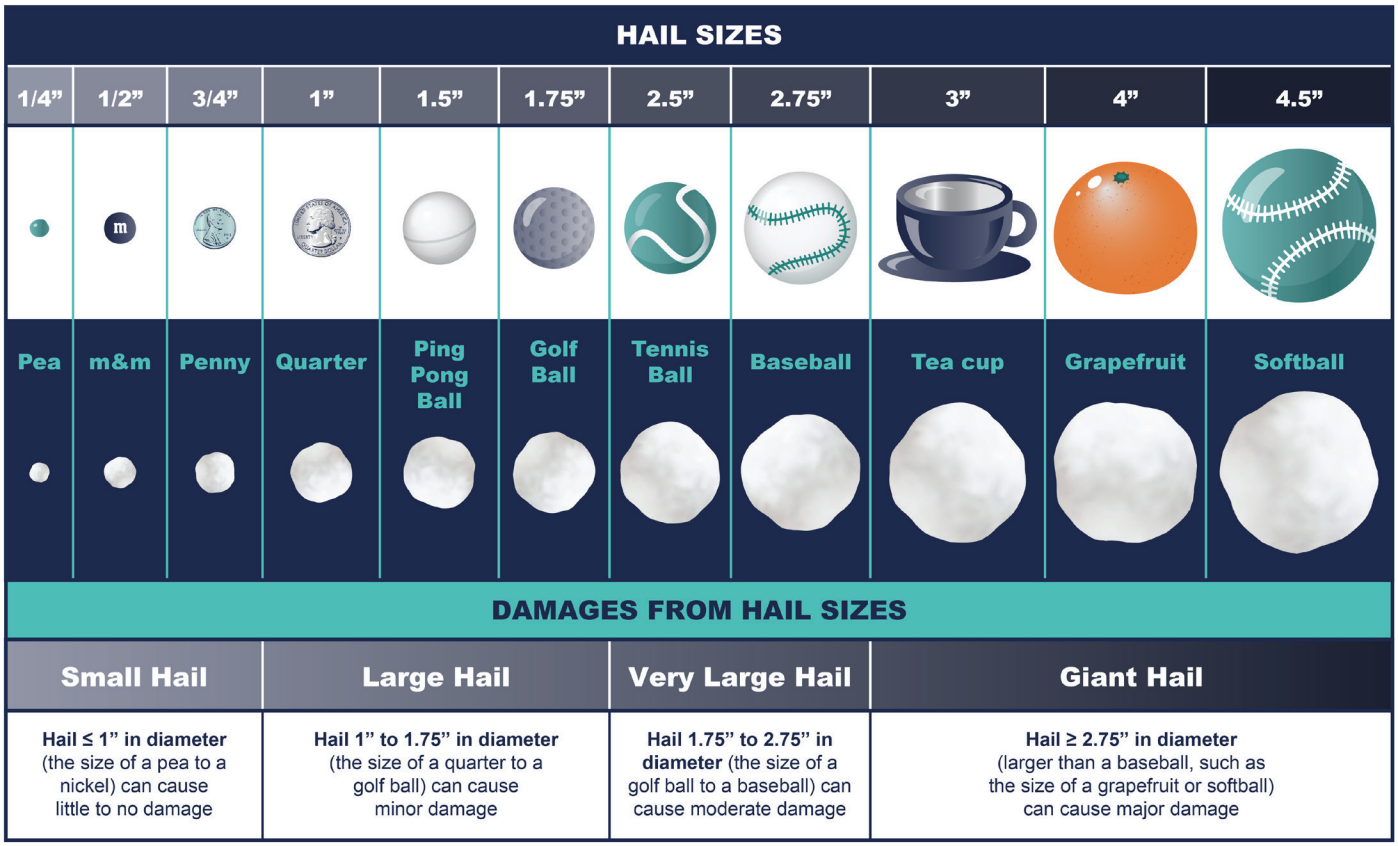
Severe Thunderstorms

A severe thunderstorm produces wind gusts of 58 mph or more and/or hailstones of one inch or more in diameter. Hailstone size varies widely, and the size correlates with the severity of the thunderstorm.

Hail Size and Related Damages

HAIL SIZE AND RELATED DAMAGES

Source: Burt, *Extreme Weather*, 2007 [84]



Tornadoes

Severe thunderstorms can also produce tornadoes. The NWS uses the Enhanced Fujita Scale (EF-Scale) as its standard measurement.

TABLE: ENHANCED FUJITA SCALE

Source: National Oceanic and Atmospheric Administration (NOAA)

EF RATING	3 SECOND GUST (MPH)
0	65-85
1	86-110
2	111-135
3	136-165
4	166-200
5	Over 200

[84] Christopher C. Burt, Extreme Weather: A Guide and Record Book Climate Change Edition (New York: W.W. Norton & Company Inc., 2007).

Windstorms

The Beaufort Wind Scale is used to associate observations made during wind events with different levels of wind force and speed.[85]

BEAUFORT WIND SCALE Source: windy.app

#	WIND TYPE	WIND SPEED	WAVE HEIGHT	LAND CONDITIONS
00	Calm	0 m/s	0 m	Calm. Smoke rises vertically.
01	Light air	0-2 m/s	0 m	Wind motion visible in smoke.
02	Light breeze	2-3 m/s	1 m	Wind felt on exposed skin. Leaves rustle.
03	Gentle breeze	3-5 m/s	1 m	Leaves and smaller twigs in constant motion.
04	Moderate breeze	5-8 m/s	1-2 m	Dust and loose paper is raised. Small branches move.
05	Fresh breeze	8-11 m/s	2-3 m	Smaller trees sway.
06	Strong breeze	11-14 m/s	3-4 m	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult.
07	Near gale	14-17 m/s	4-5 m	Whole trees in motion. Some difficulty walking into the wind.
08	Gale, fresh gale	17-21 m/s	5-7 m	Twigs broken from trees. Cars veer on road.
09	Severe gale	21-24 m/s	7-10 m	Light structure damage.
10	Storm whole gale	24-28 m/s	9-12 m	Trees uprooted. Considerable structural damage.
11	Violent storm	28-33 m/s	12-16 m	Widespread structural damage.
12	Hurricane force	≥ 33 m/s	≥ 14 m	Considerable and widespread structural damage.

PROBABILITY

High winds and severe weather frequently affect NYC. Based on the frequency of these events in the past, the hazards associated with high winds are highly probable in the future.

Severe Thunderstorms

The probability of future severe storms and damaging winds in NYC is high and events at a local scale may happen multiple times each year. By comparison, the recurrence interval for tornadoes and large hail in NYC is much lower.

Tornadoes

Tornadoes in NYC are less common than severe thunderstorms, but they are still likely to occur in the future. Reports of tornadoes have increased in NYC over the years. Six tornadoes were reported between 2007 and 2024, compared with only seven reported in the previous 39 years.

Non-Thunderstorm High Wind Events

Non-thunderstorm, high-wind events happen very frequently in NYC, including tropical cyclones, nor'easters, atmospheric conditions forcing air from high- to low-pressure areas, and interactions between strong cold and warm frontal systems.

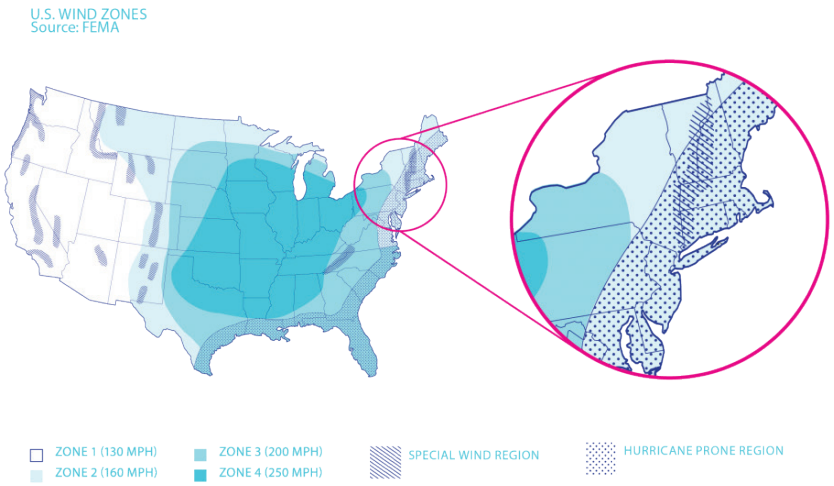
[85] National Weather Service, "Beaufort Wind Scale," National Oceanic and Atmospheric Administration.

LOCATION

NYC is in an area of the United States that FEMA classifies as susceptible to all types of high-wind events.

FEMA and the National Fire Protection Association's (NFPA) Model Manufactured Home Installation Standards categorize the United States into four wind zones: Zone I, Zone II, Zone III, and the highest wind zone, Zone IV. These wind zones portray the frequency and strength of extreme windstorms and are used to determine wind provisions for safe installation of manufactured homes.[86]

U.S. WIND ZONES Source: FEMA



NYC is in Zone II, which indicates that it is susceptible to winds in the 90–110 mph range. As noted in the magnified New England detail on the graphic, NYC is also considered to be in a hurricane-prone region.

HISTORIC OCCURRENCES

TABLE: HISTORIC NYC STORMS

NAME	DATE	DESCRIPTION
1950 Wind and Coastal Flooding Event	November 25, 1950	Experienced wind gusts near 100 mph, downing many large trees and causing power outages. Coastal flooding occurred in Lower Manhattan and on runways at LaGuardia Airport.
1987 Thunderstorm	May 29, 1987	A severe thunderstorm tipped over a commuter aircraft at Kennedy Airport due to a wind gust of 71 mph. Though the aircraft was damaged, all 24 onboard, including an infant, escaped unharmed.
2010 Nor'easter	March 13, 2010	A Nor'easter developed off the Delmarva Peninsula, producing prolonged heavy rainfall across southeast New York, with Central Park recording 3.84 inches and LaGuardia Airport 3.16 inches of rain. Five hundred and sixty trees were downed, power lines were affected, and coastal flooding closed portions of the Belt Parkway. Notable storm surges and coastal damage occurred, with multiple locations observing significant water rise above moderate flooding benchmarks.
Hurricane Sandy	October 29, 2012	The storm caused 14 ft. of storm surge with winds of 40 to 60 mph and gusts up to 90 mph.
Tropical Storm Isaias	August 3, 2020	Winds reached up to 28 mph, and over 29,000 tree emergencies were reported. The storm caused signif-icant power outages, affecting approximately 289,000 customers according to Con Edison.[87]

[86] FEMA, "Wind Zone Comparisons," in Protecting Manufactured Homes from Floods and Other Hazards: A Multi-Hazard Foundation and Installation Guide, FEMA, 2009. [87] Con Edison Media Relations, "Con Edison Off to a Fast Start on Post-Isaias Restoration," Con Edison, August 5, 2020.

WHAT IS THE RISK?

High-wind events can damage property and infrastructure, disrupt transportation, down trees and power lines, and cause serious personal injury. NYC's dense high-rise environment, high number of older buildings, and many open construction sites heighten its vulnerability to dangerous winds.

SOCIAL ENVIRONMENT

Monitoring and Risk: NYC monitors high-wind events which can occur unexpectedly, posing significant risks to public safety, especially for that outdoors like construction workers, outdoor workers, and people who are unsheltered.

Health and Safety: Risks include injuries or fatalities from hailstones traveling over 100 mph and falling trees or branches. Data from 1996 to 2022 indicates 47 deaths and 99 injuries from severe weather events and lightning strikes in NYC.

Vulnerable Populations: High winds can cause property damage and injuries, disproportionately affecting vulnerable and financially constrained populations who may struggle to recover.

Utilities: Downed trees from high winds can disrupt utilities, leading to power outages that affect residents who depend on life-sustaining equipment and medical institutions.

Travel: High winds disrupt essential city operations, impacting bridges, ferry services, flights, and overall city travel, essential for NYC's role as a global commerce and tourism hub.

BUILT ENVIRONMENT

Severe thunderstorms, characterized by high winds, pose a substantial risk to the built environment in NYC. Nationally, hail and lightning (associated occurrences to high-wind events) account for over $1 billion each in annual damages to crops, property, and insured losses. Since 2000, NYC has experienced three storm events involving tornadoes severe enough to prompt FEMA to provide Individual and Public Assistance grants.[88] Risk in NYC is exacerbated by the "urban canyon effect." This phenomenon can modify the speed and direction of winds in cities with high concentrations of tall buildings, and relatively narrow streets such as Midtown Manhattan, the Financial District, and downtown Brooklyn. Large buildings in these areas are not at risk because they are designed to withstand hurricanes. However, smaller buildings in these neighborhoods can be at greater risk of damage because they may not be specifically designed to accommodate the increased wind speeds and resulting higher wind loads.

TABLE: NOTEABLE STORMS THAT PROMPTED FEMA ASSISTANCE

DATE	SEVERE WEATHER HAZARDS	FEMA GRANT AWARDS
August 8, 2007	Severe thunderstorm, heavy rain, high winds, tornado	$7 million in Individual Assistance grants
October 29, 2012	Hurricane Sandy, coastal flooding, high winds	$773 million in Individual Assistance grants; $7.6 billion in Public Assistance grants
August 4, 2020	Tropical Storm Isaias, flash flooding, high winds	$4.4 million in Public Assistance across New York State
September 1, 2021	Post-Tropical Cyclone (PTC) Ida, flash flooding, high winds	$135 million in Individual Assistance grants; Public Assistance grants were also available, but the data is still being processed

[88] FEMA, "Declared Disasters," FEMA.

NATURAL ENVIRONMENT

High-wind events primarily pose significant challenges in NYC by causing substantial tree damage, which can have serious implications beyond aesthetic losses in parks and open spaces.

The potential hazards posed by fallen trees include obstructed roads, damaged property, damaged utility lines, and endangered lives. Additionally, thunderstorms bring secondary risks such as lightning-induced fires and the potential for hazardous material spills, particularly when heavy rains encounter improperly stored chemicals.

FUTURE ENVIRONMENT

Predicting the impact of high-wind events on the future environment is complex and varies by the type of weather event. Some of the impacts of climate change are warmer weather and moister air, which can create an environment favorable for severe thunderstorms, nor'easters, and tropical cyclones, but there may be unforeseen impacts that could limit the frequency of these events. At this point, it is unclear how the long-term effects of climate change will impact the strength and occurrence of high-wind events.

HIGH WINDS CAUSE TREE DAMAGE
SOURCE: NYC MAYOR'S OFFICE

HOW TO MANAGE THE RISK?

POLICY AND REGULATION

NYC's immense, dense building stock constitutes such a significant risk exposure that this section begins by focusing upon risk-mitigation actions to strengthen buildings.

NYC Construction Codes

Since 2008, the NYC Construction Codes have mandated that new buildings, including those undergoing major renovations, be designed to withstand high winds. The Building Code specifies wind-exposure categories based on location, surroundings, and building occupancy. Buildings along the coastline or taller than 300 feet face stricter wind load requirements. These standards are tailored to protect against hurricane-level winds typical in the eastern United States and address unique challenges posed by NYC'sdense, high-rise landscape.

New Buildings

New buildings are designed and constructed so that they can resist high-wind events — this includes the building structure and envelope.

[89] National Wind Institute, "Protection from Extreme Wind," Texas Tech University.

Structural engineers use highly refined methods to analyze how buildings and structures respond to wind loads. Most of the wind loads on high rises in NYC are evaluated using wind tunnel testing. Wind tunnel testing uses small-scale models of the built environment and simulates various levels of wind conditions. The structures are designed with highly sophisticated computer programs that not only provide for the building's resistance to wind, but also account for the comfort of occupants during high-wind events.

Retrofitting Existing Buildings

Older buildings can be retrofitted to withstand high-wind loads.[89] Recommended measures include:

- Strengthening the connections of a building's structural components by anchoring a wooden building to its foundations and by anchoring its roof frame to load-bearing walls.
- Replacing unreinforced brick masonry parapets with reinforced masonry parapets that are securely anchored to the rest of the building.
- Replacing roof coverings with larger pavers to meet code standards to reduce the risk of the pavers being blown off.
- Installing windows that are rated by the American Architectural Manufacturers Association (AAMA).
- Installing window shutters.
- Reinforcing and securing rooftop equipment, such as heating, ventilation, and air-conditioning units.

MAINTENANCE

Protecting existing building stock requires inspection, maintenance, and repair of structural weaknesses. For buildings whose construction predates the 1968 Building Code, maintenance is particularly important to lower the risk of damage from high winds. Retrofitting and design strategies can also be used to minimize damage caused by hailstones. Research on the following topics informs revisions to the NYC Construction Codes:

- How high winds impact different building types, partially completed buildings, and construction sites.
- The new standard referenced for wind in the 2022 NYC Building Code addresses roofing and wind resistance, specifically the section SBCCI SSTD 11.
- How a building's age, construction, materials, and height affect its vulnerability to structural damage from high winds.

The NYC Mayor's Office of Climate and Environmental Justice (MOCEJ), in consultation with DOB, was required by Local Law 81 of 2013 to complete a report to analyze the impact of high winds on certain at-risk buildings. The study, which was completed in 2021, served to confirm that the existing codes were sufficient.

TREE PRUNING

Pruning trees and implementing appropriate tree maintenance strategies can help reduce the risk from damaged trees. The NYC Parks oversees pruning of trees on public streets. Con Edison has a similar pruning program, which trims branches near power lines along rights-of-way. This initiative also removes damaged or unhealthy trees and vegetation to create safe, minimum cleared distances between power lines and the surrounding trees.

PREPAREDNESS

When dangerous weather conditions threaten the area, the City monitors and disseminates information it receives from NWS and other sources. The NWS Storm Prediction Center (SPC) issues a Severe Thunderstorm Watch whenever a large, multistate area is at risk, providing a few hours' notice in which people can take necessary precautions against wind and rain hazards. The NWS SPC issues a Severe Thunderstorm Warning either during the storm or very soon before it is expected to occur. The timing of this warning can range from a few minutes to an hour ahead of the danger. Some communication strategies include:

- **Emergency Alerts:** Notices are sent via Notify NYC, press releases, websites, and social media to inform about severe thunderstorms and high-wind events.
- **Community Outreach:** NYCEM collaborates with community partners and programs to enhance communication with vulnerable groups, activating the Advance Warning System during severe weather to reach organizations aiding individuals with disabilities. Additional partnerships, such as with the NYC Department of Social Services, extend outreach to unhoused populations.
- **Notify NYC:** As the City's official emergency information source, it delivers timely notifications in 14 languages to over 11 million subscribers, ensuring broad and inclusive reach.
- **Weather Advisory Notifications:** Targeted alerts to property owners, contractors, and developers about preventive actions for securing construction sites and other areas prone to wind-related hazards.

[89] National Wind Institute, "Protection from Extreme Wind," Texas Tech University.

Public Education

Public education efforts in NYC focus on equipping residents with the knowledge and strategies necessary to effectively prepare for and respond to high-wind events. These initiatives encompass a range of preventive actions and planning measures designed to enhance safety and minimize damage.

Preparation and Safety Tips

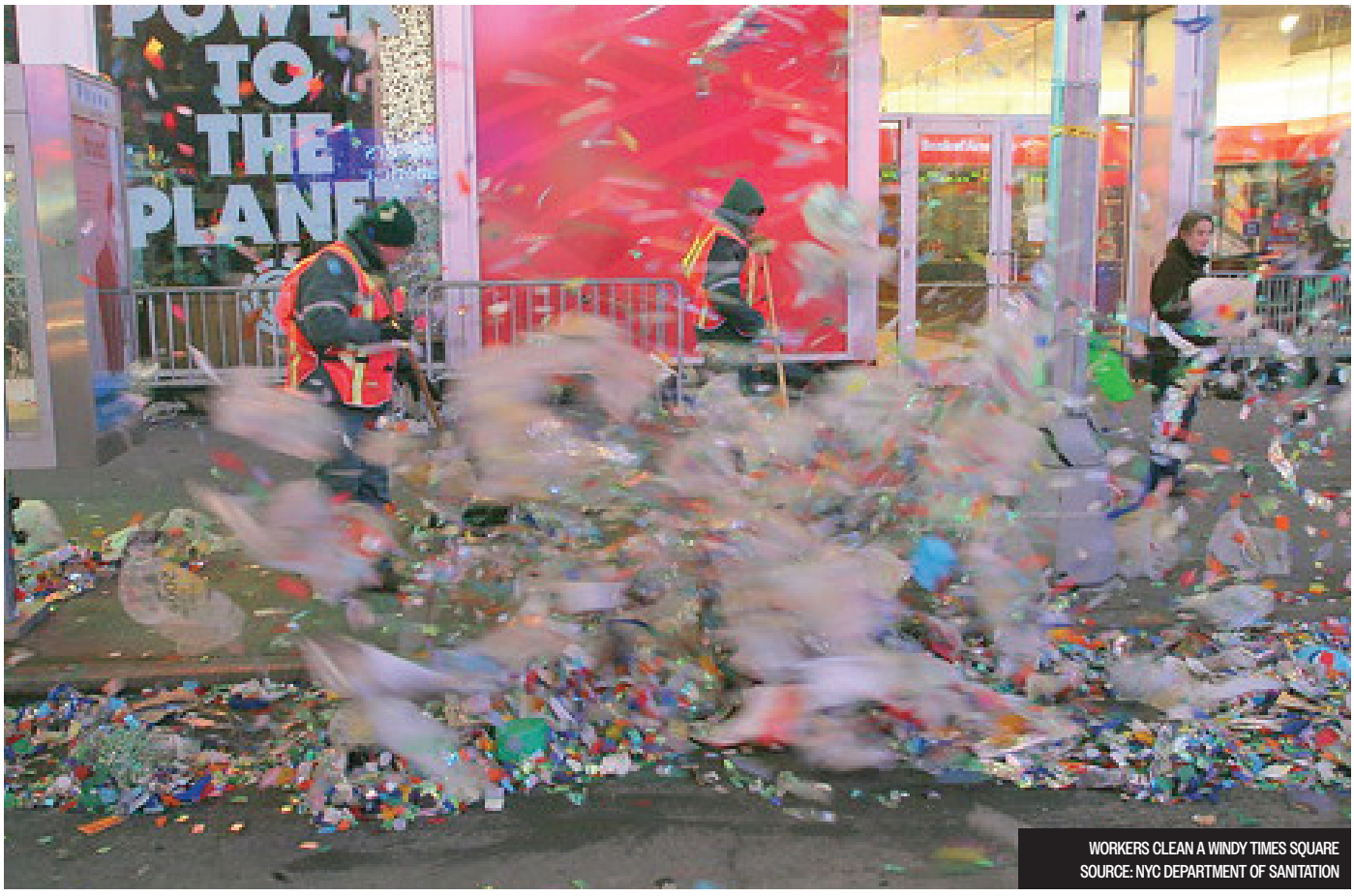
- Residents are advised to know safe locations within buildings to take cover during tornadoes or high-wind emergencies.
- Securing loose outdoor items such as furniture on porches and balconies is crucial to prevent them from becoming airborne hazards.
- Building owners and residents should develop and familiarize themselves with emergency action plans for responding to building-related incidents during severe weather.

Educational Resources and Support

NYCEM's Ready New York: Offers guidance on household preparations for severe weather, helping families stay safe during high-wind events.

NYCEM's Strengthening Communities Program: Provides grants to community networks to enhance local emergency preparedness and support community resources.

NYCEM's Reduce Your Risk Guide: Educates homeowners on reducing risks from tornadoes and severe winds, emphasizing routine maintenance, structural inspections, and necessary repairs to fortify buildings against damage.



WORKERS CLEAN A WINDY TIMES SQUARE
SOURCE: NYC DEPARTMENT OF SANITATION

08

POOR AIR QUALITY

LEARN ABOUT POOR AIR QUALITY

What is the Hazard?
What is the Risk?
How to Manage the Risk?

Poor Air Quality is defined as the presence of high levels of pollutants in the atmosphere that can endanger human health and the environment. Despite significant improvements since the 1970 Clean Air Act, NYC is one of many regions across the country that experience unhealthy pollutant levels, posing threats to both public health and delicate ecosystems. In light of ongoing environmental and climatic changes, and the rapid implementation of greenhouse gas (GHG) emissions reductions strategies, tracking air quality over time and the impact in NYC is crucial.

WHAT IS THE HAZARD?

Air Quality is the extent to which the air is pollution free. There are multiple pollutants that can contribute to air pollution, each one with distinct methods of measuring as well as federal standards. One way that air quality is represented by the Environmental Protection Agency (EPA) for ease of interpretation is by the Air Quality Index (AQI).[90] The AQI tells us how clean or polluted the air is, and what associated health effects might be of concern. The AQI runs from 0 to 500 — the higher the number, the greater the level of air pollution. An AQI of 101 or more is considered unhealthy for sensitive groups, and 201 or more is considered very unhealthy for anybody.

SEVERITY

Poor air quality can be caused by multiple factors. Vehicle exhaust, wood stove emissions, industrial emissions, wildfire smoke, windblown dust, and other sources can be harmful to health. All of these sources contribute to high levels of pollutants.[91] NYC's Department of Health and Mental Hygiene (DOHMH) has tracked two primary sources of poor air quality, and the level of risk each has on the health of residents: Particulate Matter and Ground-Level Ozone. Throughout the year, the city may experience poor air quality due to a high level of fine particles in the air. Exposure to PM2.5 can worsen serious health problems.

PROBABILITY

The EPA uses action days as a means of notifying the public about air quality issues, and these can be announced for a variety of issues ranging from PM2.5 to high pollen counts. Air quality action days, for people with weaker respiratory or cardiovascular systems, are announced when either ozone or PM2.5 levels are above 100, and for the general population when levels are above 150 (unhealthy).[92] The number of action days issued by the EPA for PM2.5 has decreased since at least 2001.

NYC has seen remarkable reduction in the amount of PM2.5 in the last 20 years due to local, state, and federal regulations on sulfur in heating oil, coal-fired powerplants, and fuel standards for motor vehicles. While there has been a reduction in PM2.5, the NYC's air can still be impacted for short periods of time.

Wildfires in California in 2021 and wildfires in Canada in 2023 caused NYC brief, but severe, drops in air quality. The impact that fires can have been very hard to forecast. It depends on the severity of the fires, large-scale wind patterns, atmospheric chemistry, and localized weather. The impact external factors play on short-term air quality in NYC and the challenges in forecasting — along with the prediction of increasing drought in wildfire-prone areas — make tracking wildfire smoke-related air quality events over time essential.

Source: National Oceanic and Atmospheric Administration (NOAA)

LOCATION

The New York City Community Air Survey, an extensive air quality monitoring program, lets us understand neighborhood-by-neighborhood differences in air quality and pinpoint neighborhoods with the worst air quality. Concentrations of NO2 (Nitrogen Dioxide), NO (Nitric Oxide), and PM2.5 are higher in industrial zones with more diesel truck traffic, neighborhoods with large numbers of restaurants, and areas of higher traffic and building density.

POOR AIR QUALITY IN NYC
SOURCE: MATTHEW KIMINSKI

[90] Environmental Protection Agency, "Air Data Basic Information," Environmental Protection Agency. [91] UW Emergency Management, "Outdoor Air Quality," University of Washington [92] Environment & Health Data Portal, "Air Quality Action Days," City of New York.

HISTORIC OCCURRENCES

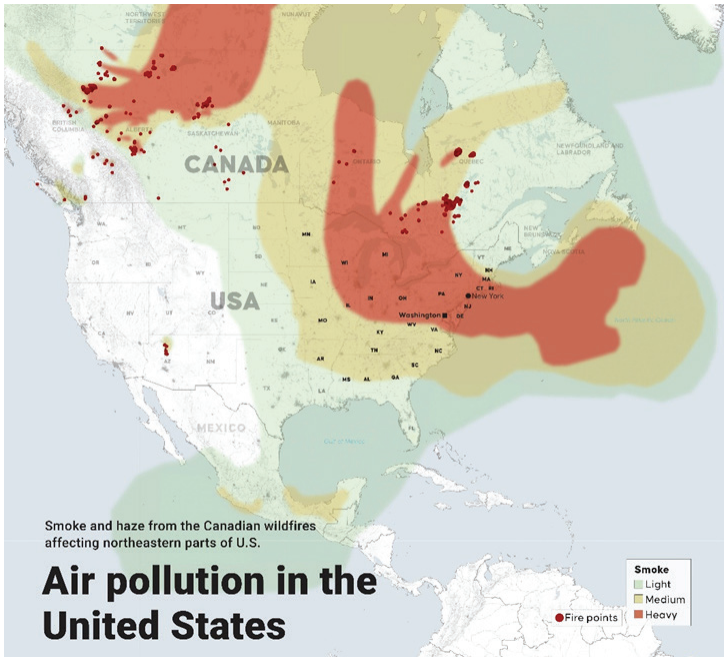
TABLE: HISTORIC NYC AIR IMPACT OCCURRENCES

NAME	DATE	DESCRIPTION
Coal Era Impact	Mid-1900s	Air quality in NYC was notably poor during this period due to the widespread use of coal, contributing to an increase in deaths from pulmonary emphysema and chronic bronchitis. This was exacerbated by prevalent smoking habits and emissions from power plants and automobiles.
Environmental Awareness and Legislation	1960s	The 1960s experienced disastrous air quality levels in NYC, leading to public health concerns and legislative actions, including the development and enactment of the Clean Air Act, aimed at significantly reducing air pollutants.
September 11 Impact	September 11, 2001	Following the September 11 attacks, NYC saw severely degraded air quality due to smoke and particulates from destruction and fires, significantly impacting the air environment.
Fireworks Impact	July 5, 2017, and 2021	Significant spikes in AQI readings exceeding 200 were recorded on July 5 of both 2017 and 2021, directly linked to extensive fireworks use during Independence Day celebrations.
2023 Canadian Wildfires	June 06, 2023	NYC faced significant air quality issues due to smoke from Canadian wildfires, resulting in poor air quality readings similar to those observed during the September 11 attacks.

Case Study: 2023 Canadian Wildfires

During the summer of 2023, smoke from wildfires in Canada drifted across the United States and drastically impacted the air quality of NYC.[93] Levels ranged between 100 and over 200 AQI in certain areas. At the time of the incident, there were reports of close to 400 active wildfires across Canada's West Coast[94] Toward the east, Alberta had the second-highest number of active fires with 126, Quebec with 126, and New England with 106. The map titled Air Pollution in the United States illustrates the smoke travel pattern experienced by NYC in the summer of 2023.[95]

Peak wildfire season in Canada is NYC's summer. Globally we are seeing longer and longer wildfire seasons — a result of rising temperatures and decreased precipitation. With climate change, wildfire frequencies are projected to continue rising, suggesting that NYC is likely to experience similar air quality events in greater numbers in future years.[96]



[93] NYC Emergency Management, "NYC Emergency Management and New York City Department of Health and Mental Hygiene Urge New Yorkers to Take Precautions and Prepare for Poor Air Quality," City of New York, July 17, 2023. [94] Emily Mae Czachor, "Canadian Wildfire Maps Show Where Fires Continue to Burn across Quebec, Ontario and Other Provinces," CBS News, July 19, 2023. [95] Emma Newburger, "Air Quality in NYC Could Gradually Improve Friday as U.S. Chips in to Fight Canada Wildfires," CNBC, June 9, 2023. [96] Grace Rauh, "New York City Must Prepare Against Future Air Quality Threats; Here's How," *Gotham Gazette*, June 15, 2023.

WHAT IS THE RISK?

AIR QUALITY DATA

Survey monitors check pollutants that cause health problems, such as fine particles, nitrogen oxides, sulfur dioxide, ozone, and elemental carbon (a marker for diesel exhaust particles).

Although NYC's air quality is improving, DOHMH's health impact estimates from 2015 to 2017 found that fine particle pollution alone each year caused:

- At least 2,000 deaths,
- About 1,400 hospital admissions for lung and heart conditions, and
- 3,750 emergency department admissions for asthma.[97]

These figures reflect the cumulative effects of everyday pollution rather than short-term air quality emergencies driven by events like wildfire smoke or high ozone days.

RAVENSWOOD GENERATING STATION, QUEENS
SOURCE: MATTHEW KIMINSKI

SOCIAL ENVIRONMENT

The risk of Poor Air Quality is particularly acute for those sensitive to pollutants, including individuals with cardiovascular or respiratory diseases, those experiencing poverty, those without access to healthcare, and those living in environments that do not allow for significant home improvements. Additionally, issues of poor housing quality and lack of maintenance can prevent residents from creating effective seals in their living spaces, necessary to retain clean air during prolonged periods of poor air quality.

BUILT ENVIRONMENT

Many residential properties lack air-conditioning systems with air filters, except sometimes in newer buildings. Many residents rely on window air-conditioning units during summer, which can introduce polluted air indoors.

Heat pumps are an energy-efficient alternative to furnaces and air conditioners for all climates. Like your refrigerator, heat pumps use electricity to transfer heat from a cool space to a warm space, making the cool space cooler and the warm space warmer. The adoption of heat pumps is increasing, offering a viable solution for maintaining indoor air quality without compromising temperature control.

NATURAL ENVIRONMENT

Poor air quality often coincides with heat waves, when stagnant air traps pollutants over urban areas. Ozone, a key component of smog, forms when emissions from cars, power plants, industrial boilers, and other sources react chemically under sunlight. Elevated temperatures can boost ozone levels, exacerbating respiratory issues for many people.[98]

FUTURE ENVIRONMENT

While NYC's air quality has seen improvements over the years, air pollution still contributes to 6 percent of annual deaths in the city, ranking it among the most critical environmental health issues. Enhancements in air quality could yield significant health benefits, comparable only to the impact of reduced smoking rates from recent City initiatives.

To mitigate the effects of air pollution, targeted actions are necessary to address key local sources like motor vehicle exhaust, building heating oil, and outdated technology in aging power plants. Under the City's sustainability plan, PlaNYC, various emission reduction initiatives have been implemented, with more planned for the future.[99] These measures promise multiple benefits, including reduced greenhouse gas emissions. However, achieving these goals requires both financial investments and behavioral changes among New Yorkers. It is crucial for residents to understand the health impacts of air pollution, the advantages of proactive measures, and the costs associated with inaction.

[97] Environment & Health Data Portal, "Asthma Emergency Departments Visits Due to Ozone," City of New York.
[98] Alejandra Borunda, "Extreme Heat Makes Air Quality Worse — That's Bad for Health," National Public Radio, September 6, 2023.
[99] NYC Mayor's Office of Climate & Environmental Justice, *PlaNYC: Getting Sustainability Done*, City of New York.

HOW TO MANAGE THE RISK?

REGULATIONS

The Clean Air Act

U.S. federal legislation addressing air pollution began with the Air Pollution Control Act of 1955 and evolved through several iterations: the Clean Air Act of 1963, the Air Quality Act of 1967, and significant amendments in 1970, 1977, and 1990. These laws have established a framework for studying air pollution, developing pollution control techniques, and enforcing emissions reductions.

Environmental Protection Agency (EPA)

The EPA was established in 1970, consolidating federal environmental responsibilities into a single agency. This move was in response to public concerns about urban air quality, litter in natural areas, and contaminated urban water supplies.

Local Law 97

Enacted in April 2019, as part of the NYC Green New Deal within the Climate Mobilization Act, Local Law 97 imposes stringent energy efficiency and greenhouse gas emissions limits on NYC buildings.

PREPAREDNESS

Best Practices for Preparedness for Unhealthy, Very Unhealthy, or Hazardous Air Quality:

- Be mindful of current and projected weather and air quality conditions and consider rescheduling outdoor activities or planning indoor alternatives if needed.
- Develop plans with family, friends, and coworkers to support individuals who are particularly vulnerable during poor air quality events, including arranging for necessary leave.
- Ensure your air conditioning and air filtration systems are maintained to keep indoor air clean. If unsure of maintenance procedures at work, submit a maintenance request.
- Collaborate with healthcare professionals, if you belong to a sensitive group, to devise a proactive plan for managing your health during poor air quality days.
- Avoid using bandannas or wet cloths as face coverings during air quality events; consult with a healthcare provider to determine whether wearing a specialized mask like an N95 or KN95 is advisable for your situation.

Monitor and Limit Exposure to Air Pollution:

- Regularly check air quality levels using reliable sources like AirNow.gov.
- Stay informed with forecasted air quality updates via the NYS DEC's website (dec.ny.gov), which also offers alert subscriptions via email, text, or app.
- Subscribe to Notify NYC for air quality alerts.
- Pay attention to air quality alerts broadcasted through radio and TV.
- Limit outdoor activities when air quality is poor, and be cautious of indoor air quality, particularly if there is indoor smoking.
- Schedule outdoor activities for times when air pollution levels are reported to be low.

For those with medical conditions exacerbated by poor air quality, ensure you have:

- Adequate supplies of food and water for several days.
- Access to necessary medications and detailed medical management plans.
- Availability of N95 or KN95 masks and air filters.
- Other essential supplies to minimize the need to go outside.

09

WINTER WEATHER

LEARN ABOUT WINTER WEATHER

What is the Hazard?
What is the Risk?
How to Manage the Risk?

The winter months in NYC subject residents to prolonged periods of extremely cold temperatures and various storms that sometimes deliver large amounts of snow, ice, sleet, freezing rain, and strong winds.

The number or absence of storms per season, the amount of snow from each storm, and prolonged periods of extreme cold can affect people, buildings, infrastructure, and the economy. Hazardous wintry conditions also induce dangers like traffic accidents, power outages, hypothermia, and frostbite.

In the future, climate change could cause winter weather to be warmer, the length of NYC's snow season to decrease, and snowfalls to become less frequent, leading to "snowless" winters. However, despite these overall climate trends, individual winter weather events in NYC will still have the potential in the future to deliver as much snow and snow cover as they do today.

WHAT IS THE HAZARD?

Extratropical cyclones, the most frequent type of storm in the Northeast, commonly cause rain, snow, and wind, creating severe winter storms that threaten NYC.

Temperature differences between the subtropics and the polar regions cause these frontal storm systems. The storm's surface wind strength is primarily determined by surface pressure gradients created between the storm's low pressure and the surrounding area of high pressure.

WINTER WEATHER TYPES

According to the National Climatic Data Center, NYC averages 24.4 inches of snowfall annually. Heavy snow, one of the primary winter hazards affecting NYC, is defined as either a six-inch-or-more accumulation of snowfall within 12 hours or fewer, or an eight-inch-or-more accumulation within a 24-hour period.

TABLE: WINTER WEATHER DEFINITIONS

Source: National Weather Service (NWS)

NAME	DESCRIPTION
Snow	Precipitation in the form of ice crystals that form directly from water vapor freezing in the air.
Sleet	Pellets of ice composed either of fully or partially frozen raindrops, or of refrozen, partially melted snowflakes.
Snow Showers	Snow falling at varying intensities for brief periods with accumulations of one inch or less.
Blizzard	Visibilities being reduced to less than 1/4 mile for three hours or more by a combination of sustained winds or frequent gusts greater than or equal to 35 mph accompanied by falling and/or blowing snow.
Snow Squalls	Intense, brief periods of moderate-to-heavy snowfall, accompanied by strong, gusty surface winds and possibly lightning, with a risk of significant snow accumulation.
Thundersnow	A snowstorm accompanied by thunder and lightning, that can occur over intense, low-pressure systems or other similar conditions of relatively strong instability and abundant moisture.
Ice Storms	Freezing rain producing ice accumulations of 1/2 inch or greater or causing significant disruptions to travel or utilities.
Bomb Cyclones	A low-pressure system that intensifies very rapidly with a fall in pressure of at least 24 millibars in 24 hours.

All types of wintry precipitation — snow, sleet, and freezing rain — contribute to hazardous travel conditions. However, freezing rain is considered among the most treacherous since it falls initially as rain but freezes on contact with a surface, forming a glaze of ice.

ICE STORMS

Ice storms present potentially greater hazards for infrastructure in NYC than heavy snowfall because ice storms develop quickly and have a greater chance of downing overhead power and telecommunications lines, leaving New Yorkers without power and communications. Even a trace of ice accumulation is a hazard, as it makes walking and driving extremely dangerous, makes roads impassable, and even affects commuter train rail beds and switches in the mass transit system.

Icing severity can be assessed in several ways. Two popular methods are through the NWS Winter Storm Severity Index (WSSI), and Sperry-Piltz Ice Accumulation Index (SPIA Index).

NWS Winter Storm Severity Index (WSSI): The NWS WSSI tool is designed to help maintain situational awareness and to help communicate a general level of potential societal impacts and their spatial distribution for winter weather. This tool uses both meteorological datasets (official NWS-gridded forecasts from the National Digital Forecast Database (NDFD)) and non-meteorological or static datasets (e.g., climatology, land use, urban areas) to forecast impacts for Snow Amount, Snow Load, Ice Accumulation, Blowing Snow, Ground Blizzard, Flash Freeze, and a Summary graphic, which is a composite of the maximum impact from any of the six components.

NWS WSSI Ice Accumulation: This indicates potential infrastructure impacts (e.g., roads/bridges) due to combined effects and severity of ice and wind. Designated urban areas are also weighted a little more than non-urban areas. NWS acknowledges contributions to the field of ice impact forecast graphics made by Sidney Sperry (Oklahoma Association of Electric Cooperatives) and Steven Piltz (NWS) in the development of the SPIA Index.

NWS WSSI Flash Freeze Index: Indicates the potential impacts of flash freezing (temperatures starting above freezing and quickly dropping below freezing) during or after precipitation events.

The WSSI provides a classification of individual winter weather hazard severity and overall expected winter weather severity using the following terminology: “Minor,” “Moderate,” “Major,” and “Extreme” as seen in the table below. The “Winter Weather Area” pertains to areas where winter weather conditions are expected but are not anticipated to impact daily life.

WINTER STORM SEVERITY INDEX (WSSI) Source: NOAA

	Winter Weather Area **Expect Winter Weather.** • Winter driving conditions. **Drive carefully.**
	Minor Impacts **Expect a few inconveniences to daily life.** • Winter driving conditions. **Use caution while driving.**
	Moderate Impacts **Expect disruptions to daily life.** • Hazardous driving conditions. **Use extra caution while driving.** • Closures and disruptions to infrastructure may occur.
	Major Impacts **Expect considerable disruptions to daily life.** • Dangerous or impossible driving conditions. **Avoid travel if possible.** • Widespread closures and disruptions to infrastructure may occur.
	Extreme Impacts **Expect substantial disruptions to daily life.** • Extremely dangerous or impossible driving conditions. **Travel is not advised.** • Extensive and widespread closures and disruptions to infrastructure may occur. • Life-saving actions may be needed.

THE SPERRY-PILTZ ICE ACCUMULATION INDEX Source: SPIA Index

ICE DAMAGE INDEX	DAMAGE AND IMPACT DESCRIPTIONS
0	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
1	Some isolated or localized utility interruptions are possible, typically lasting only a few hours. Roads and bridges may become slick and hazardous.
2	Scattered utility interruptions expected, typically lasting 12 to 24 hours. Roads and travel conditions may be extremely hazardous due to ice accumulation.
3	Numerous utility interruptions with some damage to main feeder lines and equipment expected. Tree limb damage is excessive. Outages lasting 1 – 5 days.
4	Prolonged & widespread utility interruptions with extensive damage to main distribution feeder lines & some high voltage transmission lines/structures. Outages lasting 5 – 10 days.
5	Catastrophic damage to entire exposed utility systems, including both distribution and transmission networks. Outages could last several weeks in some areas. Shelters needed.

EXTREME COLD

An extreme cold event typically involves an extended period with temperatures at or below 32°F. These extended periods of subfreezing temperatures commonly occur in NYC between December and March. Although wind gusts and frigid temperatures often accompany winter storms, extremely cold temperatures can occur in NYC independent of these other types of winter weather events. As the temperature drops and wind speed increases, heat drains from people's bodies more rapidly than normal, creating a "wind chill effect" that can make people feel even colder than the actual temperature.

When winter weather conditions warrant, NWS issues cold weather advisories or extreme cold watches and warnings for the NYC region.

NWS issues a cold weather advisory when temperature or wind chill values are expected to fall to between minus 5°F and minus 14°F. NWS issues an extreme cold warning when values are expected to fall to minus 15°F or below.

Wind Chill Chart

Temperature (F°)

Wind (mph)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times

30 Minutes

10 Minutes

5 Minutes

Where, T= Air temperature (°F) V= Wind Speed (mph)

Wind Chill (°F) = 35.74 + 0.6215T - 35.75(Vo.16) + 0.4275T(V0.16)

SEVERITY

Currently, The NWS uses the WSSI. The purpose of the WSSI is to provide NWS partners and the public with an indication of the level of winter precipitation (snow and ice) severity and its potential related societal impacts.

The WSSI uses meteorological (NWS forecast parameters — for example, snow accumulation, blowing snow, wind speed, and temperature) and non-meteorological data to model predicted severity of specific characteristics of winter weather.

Each of the components produce a 1 to 5 output scale value that equates to the potential severity based on the winter weather hazards.

The final WSSI value is the maximum value from all the sub-components. The five levels are given the following descriptors: Limited, Minor, Moderate, Major, and Extreme.

Non-forecast datasets include:

- Urban area designation
- Land-use designations
- National Oceanic and Atmospheric Administration (NOAA)/National Centers for Environmental Information (NCEI) gridded annual snowfall climatology

PROBABILITY

Winter storms are common in NYC. Historically, the NYC can expect to see significant snowfall of 16 inches or more about once every nine years. Instances of thundersnow, where thunder occurs during a snowstorm, are rare. The most recent thundersnow event was on March 7, 2018, and these are more likely during warmer months rather than the coldest winter months.

According to the New York City Panel on Climate Change (NPCC), days with temperatures below freezing have been decreasing. Observations from Central Park and LaGuardia stations show a decline of two to three freezing days per decade. Over the last 30 years, the average number of days below freezing has dropped to less than 70 annually, down from 87 days during the period from 1900 to 1929.

LOCATION

All areas of NYC are vulnerable to winter storms, but the amount of snow can vary significantly. For instance, during the winter storm on February 9, 2017, Staten Island received 8.5 inches of snow, while the Bronx saw 12.5 inches.

NYC generally experiences milder winter temperatures than other areas in the greater metropolitan area due to two factors: the urban heat island effect, which makes the city warmer, and its proximity to the ocean, which moderates temperatures. Coastal areas often have slightly warmer temperatures in winter than inland areas, but strong winds near the shore can lead to dangerous wind chill conditions that pose risks to residents.

HISTORIC OCCURRENCES

TABLE: HISTORIC NYC WINTER STORMS

NAME	DATE	DESCRIPTION
Blizzard of 1996	January 1, 1996	One of three winter snowstorms sufficiently damaging to warrant a presidential disaster declaration for NYC and the surrounding region.
Presidents' Day Snowstorm II	February 1, 2003	Another severe winter event earning a presidential disaster declaration due to its significant impact on New York City and nearby areas.
Blizzard of 2010	December 1, 2010	This blizzard was the third event in the last 25 years to receive a presidential disaster declaration for causing extensive damage due to heavy snowfall and harsh conditions.
Blizzard of 2016	January 1, 2016	Set a record for NYC's history with over 30 inches of snowfall, coinciding with the spring tide, which contributed to moderate storm surge and flooding in coastal areas.
Southeaster Storm Event of December 2022	December 1, 2022	A significant weather event occurred when a southeaster storm aligned with the King Tide, leading to exceptionally high tides and substantial storm surge and flooding, impacting both coastal and inland areas around Jamaica Bay during a sudden temperature drop.

WHAT IS THE RISK?

SOCIAL ENVIRONMENT

Health Risks

Extreme cold and strong winds increase the risk of hypothermia, frostbite, and exacerbate chronic conditions like respiratory and cardiovascular diseases in New Yorkers. Signs of hypothermia:

- **Frostbite:** Exposure to freezing temperatures can cause the skin and outer tissues to freeze, particularly affecting extremities and exposed skin, potentially leading to permanent damage or amputation.
- **Carbon Monoxide (CO) Poisoning:** Winter increases the risk of CO poisoning from improperly maintained or ventilated heating appliances and from running vehicles in enclosed spaces, which can be fatal.
- **Mental Health:** Cold exacerbates chronic impacts mental health, contributing to anxiety and depression during colder months.

BUILT ENVIRONMENT

Infrastructure

Winter storms significantly impact NYC's infrastructure, posing risks to residents, emergency responders, and all types of travelers. Snow-covered streets can lead to traffic accidents and hinder emergency services, while buried fire hydrants slow down fire deparment responses. Ice accumulation on roads, rail beds, and mass transit systems creates hazardous conditions, particularly on bridges and overpasses which freeze more quickly than other surfaces. Extreme cold can also damage transit railways.

Buildings

Winter weather affects NYC's buildings differently, depending on factors such as window type and size, air leakage, and insulation levels. Older buildings, built to less stringent codes, are more susceptible to drafts from leaks in walls, windows, and doors. Conversely, buildings constructed under recent codes and the NYC Energy Conservation Code are better protected against the cold.

NATURAL ENVIRONMENT

In NYC, when snow and ice melt, the water runs off into NYC's sewer system. This can be a problem if the amount of water from the melt combines with household and industrial waste to exceed what NYC's wastewater treatment plants can handle. NYC has a combined sewer system, meaning it uses the same pipes for rainwater runoff, sewage from homes, and wastewater from industry. Normally, all this wastewater is sent to a treatment plant. However, if there's too much runoff, the system cannot handle it all. This overflow can end up in nearby rivers and lakes, leading to temporary pollution of these waterways.[100]

FUTURE ENVIRONMENT

The NYC Panel on Climate Change's fourth assessment (NPCC4) predicts a decrease in freezing days from about 70 to 34–58 by the 2030s because of climate change. However, it is important to note that these predictions average over several years, some winters might still feel just as cold snowy as they do now, but be less frequent.

SLEDDING IN DUMBO DURING A 2017 SNOWSTORM
SOURCE: NYC MAYOR'S OFFICE

[100] Environmental Protection Agency, "Combined Sewer Overflows (CSOs)," Environmental Protection Agency, n.d.

HOW TO MANAGE THE RISK?

Snow Load Management

Since 1899, NYC's Building Code has mandated design standards for roof snow loads, updated in 2022 to reflect national standards. These regulations apply to new and significantly modified buildings, and DOB plans to adopt a code for existing buildings to streamline resiliency upgrades.

Building Inspections and Retrofits

Regular building inspections encourage necessary retrofits and maintenance to enhance resilience against extreme winter conditions, ensuring structures can withstand harsh weather.

Protecting Infrastructure and Equipment

Innovative Materials: Explore the use of alternative pavement materials that accelerate snow melting, which would improve access for emergency responders. It would also reduce reliance on traditional methods like salt spreading and snowplows, which damage streets and affect traffic safety.

Green Infrastructure: Strategies like bioswales and green roofs mitigate winter weather impacts by managing stormwater runoff and snowmelt, preventing overwhelming wastewater systems and subsequent pollution discharges.

Tree Pruning

Managed by NYC Parks' Forestry Division, the block pruning program involves trimming all street trees on a block every seven to eight years to prevent branch and power line damage from snow and ice accumulation. To maintain reliable service, Con Edison, manages a tree maintenance program that trims branches along the rights-of-way to ensure that trees do not encroach upon power lines during winter weather conditions.

Preparedness

NYC focuses on educating the public about preparing for and responding to winter weather through:

- Immediate communication initiatives:
  - Sending emergency alerts prior to severe weather, targeting vulnerable populations including those with disabilities and functional needs, non-English speakers, and people experiencing homelessness.
  - Notifying property owners, contractors, and developers about preventive actions to protect properties, such as clearing gutters and removing rooftop snow and ice.
  - Coordinating with agencies for consistent messaging about weather conditions, supported by press conferences during major storms.
  - Utilizing various media channels, including social media, press releases, notifications to elected officials, and emergency alert systems, for real-time updates.
- Long-term educational initiatives:
  - Educating the public on preparing for severe winter weather.
  - Assisting homeowners in maintaining buildings to reduce heat loss, prevent roof leaks, and avoid roof collapses.
  - Raising awareness about the lethal risks of carbon monoxide poisoning from gas appliances.

SUBWAY IN A 2017 SNOWSTORM
SOURCE: NYC MAYOR'S OFFICE

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