13. Severe Weather: Thunderstorms, Tornadoes, and Windstorms

A. Hazard Profile

i. Hazard Description

Severe thunderstorms, tornadoes, and windstorms are what are known as severe weather, and these weather events can pose serious risks in New York City.

Severe Thunderstorms

Thunderstorms are caused by a combination of moisture, unstable air, and lift caused by cold or warm fronts moving into the area. Non-severe thunderstorms produce lightning, rain, small hail, and winds of less than 58 mph. According to the National Weather Service (NWS), the national average size of a thunderstorm is 15 miles in diameter and lasts an average of 30 minutes. Thunderstorms are normally localized events.

About 10% of thunderstorms are classified as severe. Severe thunderstorms consist of winds of 58 mph or higher, and/or large hail measuring at least 1 inch in diameter, and/or a tornado.

Hailstones are falling particles of ice. Hail develops as warm, moist air rises in the upper atmosphere and then cools. As the air cools below the freezing point, water vapor condenses into ice crystals. These ice crystals remain suspended by high-velocity updraft winds, grow larger, and eventually fall to the ground as hail, sometimes at speeds of 100 mph or greater. The size of hail is usually determined by the severity of the storm and for New York City typically ranges from 0.20 inches to 2.0 inches in diameter.

The NWS issues a Severe Thunderstorm Watch when severe thunderstorms are possible over a large area, in some cases several states. A Severe Thunderstorm Warning is issued when a severe thunderstorm is occurring or expected to occur within a matter of minutes.

Thunderstorms and hail can pose serious threats to human life and property in New York City. Severe storms can leave broken tree limbs, downed power lines, and other debris, which may lead to power outages, transportation disruptions, and damage to buildings and vehicles.

Tornadoes

Thunderstorms can also create a favorable environment for tornadoes, which are violent rotating columns of air with winds of up to 200 miles per hour or greater (vice winds up to 300 miles per hour). These short-lived storms generally appear as funnel-shaped clouds, gray to black in color, extending toward the ground from the base of a thundercloud. Tornadoes actually begin as transparent—and it is at this time that they are especially dangerous because they cannot easily be seen; as they pick up debris and dust, they acquire their grayish coloration. Most tornadoes move southwest to northeast at an average forward speed of 30 mph, but tornadoes can move in any direction and may vary from stationary to 70 mph. Tornadoes are most frequent east of the Rocky Mountains during spring and summer between 3 PM and 9 PM. They may also accompany hurricanes (see section 6. Coastal Storms).

Tornadoes are the most violent of all atmospheric phenomena and, over a small area, the most destructive—they can uproot trees and buildings and turn harmless objects into deadly missiles in a matter of seconds. Their damage paths can exceed one mile in width and 50 miles in length. Each year there are an average of 1,200 tornadoes nationwide, causing 60 to 65 fatalities and 1,500 injuries.

Windstorms

High-winds events are often associated with other storms, such as hurricanes or nor'easters (see 6. Coastal Storms), but may occur independently. High winds can cause downed trees and power lines, flying debris, and building collapses—all of which may lead to power outages, transportation disruptions, damage to buildings and vehicles, and personal injury and death. Flying debris is the primary cause of damage during a windstorm. While a building may remain generally structurally sound, broken glass from windows can cause injuries inside and outside the building and extensive damage to building contents.

ii. Severity

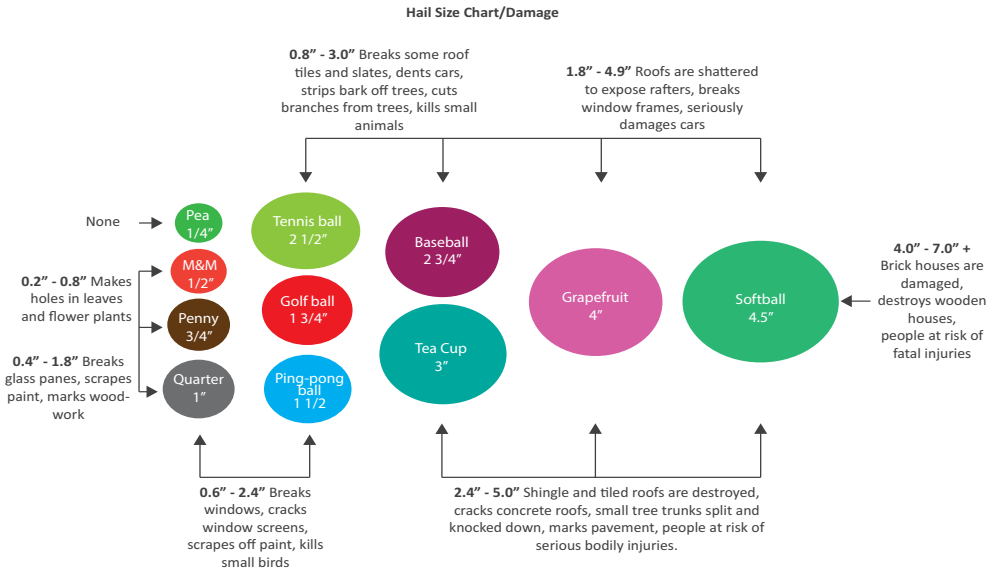
Severe Thunderstorms

A thunderstorm is considered severe if it produces wind gusts of at least 58 mph and/or large hail of at least 1 inch in diameter. Severe thunderstorms can also produce tornadoes. Generally the size of hailstones is correlated with the severity of the thunderstorm. As shown below in Figure 3.13.94, hailstones vary widely in scale.

Tornadoes

The Fujita Scale (F-Scale) used to be the standard measurement for rating the strength of a tornado. The NWS has used this scale and an analysis of damage after a tornado to infer wind speeds. On February 1, 2007, the

Figure 3.13.94: Hail Size and Related Damages (Source: Burt, 2007)



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

Table 3.13.66: Comparison of Fujita (F-Scale) and Enhanced Fujita (EF-Scale) Scales

F - Scale	3 -sec. gust speed (mph)	EF - Scale	3 -sec. gust speed (mph)	TYPICAL DAMAGE
F0	45 -78	EF0	65-85	Light damage. Some damage to chimneys. Branches broken off trees. Shallow-rooted trees pushed over, signboards damaged.
F1	79-117	EF1	86-109	Moderate damage. Peels surface off roofs. Mobile homes pushed off foundations or overturned. Moving autos blown off roads.
F2	118-161	EF2	110-137	Considerable damage. Roofs torn off frame houses. Mobile homes demolished. Boxcars overturned. Large trees snapped or uprooted. Light-object missiles generated. Cars lifted off ground.
F3	162-209	EF3	138-167	Severe damage. Roofs and some walls from off well-constructed houses. Trains overturned. Most trees in forest uprooted. Heavy cars lifted off the ground and thrown.
F4	210-261	EF4	168-199	Devastating damage. Well-constructed houses leveled. Structures with weak foundations blown away some distance. Cars thrown and large missiles generated.
F5	262-317	EF5	200-234	Incredible damage. Strong frame houses leveled off foundations and swept away. Automobile-sized missiles fly through the air in excess of 100 meters (109 yards). Trees debarked. Incredible phenomena will occur.

NWS transitioned from the F-Scale to the Enhanced Fujita Scale (EF-Scale). The EF-Scale is now the standard used to determine the strength of a tornado. References to the old F-scale are needed for historical purposes (see Historic Occurrences). The EF-scale is more complex and enables surveyors to assess tornado severity with greater precision. Table 3.13.66: Comparison of Fujita (F-Scale) and Enhanced Fujita (EF-Scale) Scales compares the F-Scale and EF-Scale and shows damages associated with these ratings.

Windstorms

The Beaufort Wind Scale, shown below, aids in the estimation of wind speed and corresponding typical effects (see Table 3.13.67).

Table 3.13.67: Beaufort Wind Scale (NOAA, 2013)

Force	Wind Speed (mph)	Name	Damage
0	Less than 1	Calm	Calm, smoke rises vertically
1	1 – 4	Light Air	Smoke drift indicates wind direction, still wind vanes
2	5 - 7	Light Breeze	Wind felt on face, leaves rustle, vanes begin to move
3	8 - 12	Gentle Breeze	Leaves and small twigs constantly moving, light flags extended
4	13 - 18	Moderate Breeze	Dust, leaves, and loose paper lifted, small tree branches move
5	20 - 24	Fresh Breeze	Small trees in leaf begin to sway
6	25–31	Strong breeze	Large branches in motion; whistling in telephone wires; umbrellas used with difficulty
7	32–38	Near gale	Whole trees in motion; resistance felt while walking against the wind
8	39–46	Gale	Twigs break off trees; wind impedes walking
9	47–54	Strong gale	Slight structural damage to chimneys and slate roofs
10	55–63	Storm	Seldom felt inland; trees uprooted; considerable structural damage
11	64–72	Violent storm	Very rarely experienced; widespread structural damage; roofing peels off buildings; windows broken; mobile homes overturned
12	73+	Hurricane	Widespread structural damage; roofs torn off homes; weak buildings and mobile homes destroyed; large trees uprooted

iii. Probability

Severe weather occurs often in New York City. Based on the frequency of past events, severe weather is highly probable for the future.

Severe Thunderstorms

While non-severe thunderstorms occur on 25 to 30 days annually across New York City, severe thunderstorms occur much less frequently, but at least a few times each year. Based on the annual frequency of past severe thunderstorms in New York City, the probability of at least one of the criteria for severe storms being met (usually winds) is high and happens multiple times on a local scale each year, whereas the recurrence interval for tornadoes and large hail is much lower.

From 1974 to 2013, there have been 49 major occurrences of severe thunderstorms and hail, and eight of these storms have been citywide events (impacting more than one borough). Although hail doesn't always occur during thunderstorms, all eight of the citywide events produced hailstones, which ranged from 0.75 inches to 1.75 inches in diameter. From 1974 to 2013, there were 40 occurrences of hail (equal or greater than 3/4 inch) in New York City.

Tornadoes

Although not as common as severe thunderstorms, tornadoes are still probable for the future. Over the past 40 years, 12 tornadoes have hit New York City, 11 of which were scaled F0 or F1. In the past six years, tornado activity has increased in New York City. There have been five tornadoes since 2007; in comparison to seven tornadoes over a 33 year period (1974 was the first occurrence of a tornado in NYC).

Windstorms

From 1974 to 2013, there have been 31 documented windstorms with gusts above 40 mph in New York City. During this same period, there have been 14 major windstorms with wind gusts ranging from 50 to 90 mph. Based on the historic occurrences, New York City experiences a high-wind event at least once a year.

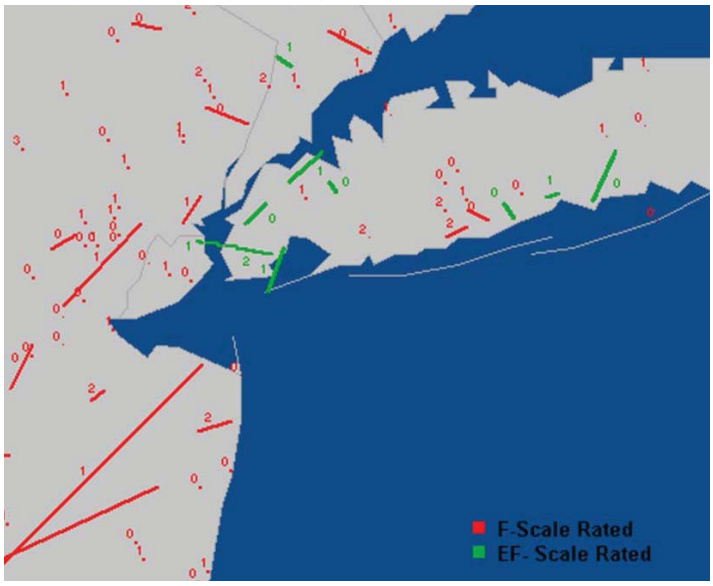
iv. Location

Based on historic events, severe weather has an equal probability of occurrence city-wide.

Thunderstorms and Hail

Although thunderstorms occur throughout New York City, they don't necessarily affect all five boroughs at the same time or with the same severity. Some thunderstorms are extremely localized events.

Figure 3.13.95: Tri-State Tornado Climatology, 1950 to 2012 (Source: NOAA 2013)



Tornadoes

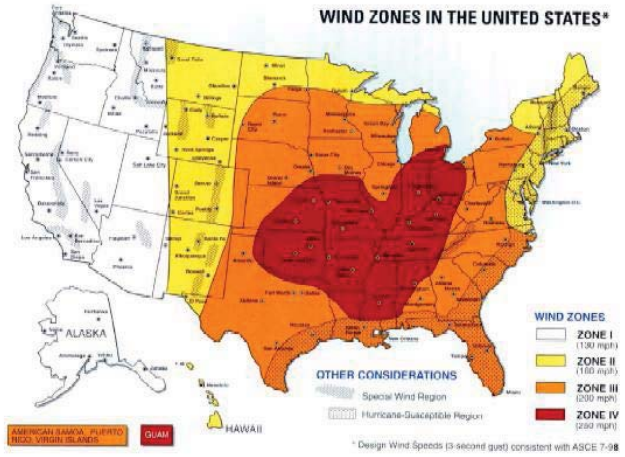
A common misconception is that tornadoes do not occur in dense urban areas such as New York City. Since 1950, at least one tornado has occurred in 4 of the 5 boroughs (none in Manhattan). Figure 3.13.95 shows the locations of previous tornadoes in the New York City area. Scientists say that although tornadoes are rare, they are possible in any part of the city.

Windstorms

New York City is located in an area that is susceptible to windstorms. Accordingly, 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 (see Figure 3.13.96). These wind zones portray the frequency and strength of extreme windstorms and help determine wind provisions for safe installation of manufactured homes. Figure 3.13.97 shows that New York City is located in Zone II, which means that the city is susceptible to 90-mph and 110-mph winds. Both figures also show that New York City is located in a hurricane susceptible region.

Figure 3.13.96: Wind Zones in the United States (Source: FEMA, 2013)



v. Historic Occurrences

Table 3.13.68, below, describes selected severe thunderstorms, tornadoes, and high-wind events from 1974 to 2013. Due to the high frequency of severe thunderstorms, the table only features major severe thunderstorms. Of these severe weather events, there have been two presidential disaster declarations.

Figure 3.13.97: Wind Zones in New York State (Source: FEMA, 2008)

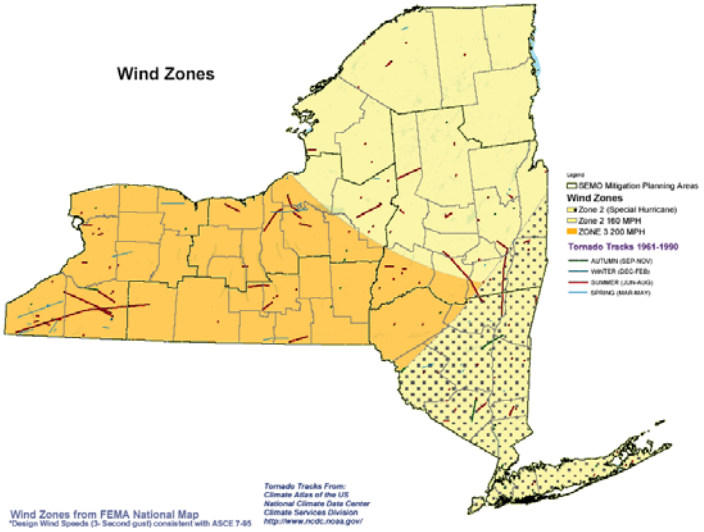


Table 3.13.68: Selected Severe Weather Events 1974 to 2013

Date	Event	Location(s)	Description
September 2, 1974	Tornado	Bronx	• F1 tornado • No injuries or fatalities
October 5, 1985	Tornado	Queens	• F1 tornado • Runs for 2 miles; width of 50 yards • No fatalities; 6 injuries
August 10, 1990	Tornado	Staten Island	• F0 tornado • Runs for 2 miles; width of 17 yards • No fatalities; 3 injuries
March 2, 1994	Windstorm	Citywide	• High winds of 61 mph
October 28, 1995	Tornado	Staten Island	• F1 tornado • No fatalities or injuries • Estimated damage $500,000
February 25, 1996	Windstorm	Citywide	• Intensity unknown • 1 fatality in Brooklyn due to a fallen tree • 1 reported injury
March 19, 1996	Windstorm	Citywide	• High winds of 79 mph • No fatalities or injuries
October 19, 1996	Windstorm	Citywide	• High winds of 92 mph • Fallen trees cause 3 fatalities; no additional injuries • Downed power lines and trees close Bayonne Bridge • Roof reported to be ripped off a Bronx building
March 6, 1997	Windstorm	Citywide	• Winds of more than 60 mph • Knocks down trees and power lines on houses and streets • 75-foot maple tree falls on school bus carrying 10 children • Two injuries caused by flying debris
November 2, 1997	Windstorm	Citywide	• Reported wind gusts of 40 to 46 mph • 1 fatality; 1 injury
November 4, 1997	Thunderstorms and hail	Bronx	• 1-inch hailstones from a line of scattered thunder-storms • Gusty winds and heavy rain
November 27, 1997	Windstorm	Manhattan	• Winds average 25 to 35 mph; gusts around 50 mph • Winds cause loss of control of parade balloon, which strikes a light pole, causing it to fall and inure 4 specta-tors
February 4, 1998	Windstorm	Manhattan	• Winds of 57 mph • No fatalities; 1 injury reported
June 30, 1998	Tornado/hail	Bronx/Queens	• 0.75-inch hail and damaging winds from a wave of severe storms in the Bronx • High winds in Queens down trees that strike and injure three girls • F1 tornado in Long Island

Date	Event	Location(s)	Description
September 7, 1998	Severe thunderstorms/hail	Citywide	• Intense line of severe thunderstorms • Wind gusts of 60 to 80 mph • Downed trees and power lines • Hailstones of 1.50 inches • On Staten Island high winds down trees, causing a building to collapse • Tree falls on three people in the Bronx, resulting in 1 fatality and two injuries • Two injuries in Brooklyn—one caused by downed tree and one by hailstones
March 18, 1999	Windstorm	Manhattan	• Winds of 40 to 47 mph • 15-foot metal rod tumbles 22 stories from top of 1 Times Square, injuring 3 women
May 18, 2000	Severe thunderstorms/hail	Bronx/Queens/ Brooklyn	• Line of severe thunderstorms produce damaging wind gusts • Large hailstones (0.75 to 1.0 inch) • Heavy rain and lighting • Downed trees in the Bronx • Large awning blown off building in Brooklyn • 1-inch hailstones in Woodside, Queens
December 12, 2000	Windstorm	Citywide	• Winds of 64 mph • Nor'easter • 1 fatality; 6 injuries
May 29, 2001	Severe thunderstorms/hail	Brooklyn/ Queens	• Scattered severe thunderstorms with high winds • People in 19 houses in Queens report downed trees and power lines • 0.75-inch hailstones reported in Brooklyn
August 2, 2002	Severe thunderstorms/hail	Manhattan/ Staten Island/ Bronx	• 0.75-inch hailstones in Staten Island • Man struck and killed by lightening in Manhattan • Thunderstorms in Bronx • High winds down power lines near Fordham University
September 11, 2002	Windstorm	Citywide	• Strongest winds measure 66 mph in Queens • Winds last at least 6 hours • 1 fatality; 4 injuries • Widespread power outages • Construction debris causes injuries
September 19, 2003	Windstorm	Bronx	• Winds of up to 46 mph • Hurricane Isabel • No fatalities; 1 injury • Downed trees and power lines
October 15, 2003	Windstorm	Queens	• Winds of 45 mph • No fatalities or injuries reported • Downed trees and power lines reported • Property damage estimated at a least $100,000
October 27, 2003	Tornado	Staten Island	• F0 tornado • No fatalities or injuries

Date	Event	Location(s)	Description
November 13, 2003	Windstorm	Citywide	• Winds of 64 mph • 1 fatality; no injuries reported
August 11, 2004	Severe thunder-storms/hail	Bronx	• Severe thunderstorms produce flash flooding • Wind damage and 1-inch hailstones
December 1, 2004	Windstorm	Brooklyn	• Winds of 70 mph • No fatalities or injuries reported
December 23, 2004	Windstorm	Queens	• Winds of 47 mph • 1 fatality caused by tree crushing traveling car; no injuries
March 8, 2005	Windstorm	Queens	• Winds of 58 mph • No fatalities or injuries reported
April 2, 2005	Windstorm	Queens	• Winds of 58 mph • No fatalities or injuries reported
October 16, 2005	Windstorm	Citywide	• Winds of 36 mph • No fatalities or injuries reported • Trees downed • Windows in a high-rise office building in Manhattan blow out • $17,000 in property damage
October 25, 2005	Windstorm	Citywide	• Winds of 48 mph • No fatalities or injuries reported • Downed trees reported • Property damage of $35,000 reported
November 24, 2005	Windstorm	Citywide	• Winds of 40 mph • Parade balloon strikes a lamppost causing a 30-pound light to fall into the crowd • Two injuries reported • No damage costs reported
January 15, 2006	Windstorm	Queens	• High winds of 63 mph • No fatalities; 1 injury reported
January 18, 2006	Windstorm	Bronx, Man-hattan, Staten Island, Queens	• Winds of 68 mph • No fatalities or injuries reported
February 17, 2006	Windstorm	Brooklyn, Queens, Staten Island	• Winds of 61 mph • No fatalities or injuries reported
October 20, 2006	Windstorm	Staten Island	• Winds of 58 mph • No fatalities or injuries reported
January 20, 2007	Windstorm	Citywide	• Winds of 47 mph • Flying construction debris results in 1 injury

Date	Event	Location(s)	Description
August 8, 2007	Tornado	Brooklyn	• EF2 tornado • Discontinuous path • 16 homes have moderate to severe roof damage • Tornado tears roof off a car dealership • Downed trees reported • Event accompanied by severe flooding • Federally declared disaster (DR-1724) with more than $5.1 million given in Individual and Household Program (IHP) funding from the Federal Emergency Management Agency (FEMA) • More than 3,700 residents file claims at Disaster Assistance Service Centers
March 8, 2008	Windstorm	Manhattan/ Bronx/Brooklyn	• Damaging winds cross over Lower Hudson Valley and New York City • Scaffold collapses in Manhattan • Downed power lines in the Bronx • Downed tree in Brooklyn
June 10, 2008	Windstorm	Citywide	• Wind gusts of 80 mph • Causes widespread downed trees
June 22, 2008	Severe thunderstorms/hail	Bronx	• Severe thunderstorms cross over Lower Hudson Valley • 0.75-inch hailstones reported along Pelham Parkway • Flash flooding
August 11, 2008	Severe thunderstorms/hail	Citywide	• 1.75-inch hailstones in the Bronx accumulate up to one inch • Hailstones damage cars, flower and vegetable gardens • Downed tree limb on Cross Island Parkway in Queens
August 15, 2008	Windstorm	Bronx	• Wind gusts of 70 mph
February 12, 2009	Windstorm	Citywide	• Wind gusts of 50 to 60 mph • One fatality in Staten Island • One injury caused by a fallen tree in Brooklyn
July 29,2009	Severe thunderstorms/hail	Citywide	• 0.75-inch hailstones in Staten Island • 70-mph wind gusts in Queens • Flash flooding forces some road closures in the Bronx
August 18, 2009	Severe thunderstorms/hail	Citywide	• 0.75-inch hailstones in Bronx • 80-mph wind gusts in Manhattan/Bronx • OEM reports a few hundred trees down in Central Park • Downed trees hit cars in Manhattan • Fewer than 100 trees down in Queens, but some fallen trees damage cars

Date	Event	Location(s)	Description
June 24, 2010	Severe thunderstorms/hail	Citywide	• 1.75-inch hailstones fall on Throgs Neck Bridge • One car damaged in Queens • Downed trees, utility poles, street lamps, and one chimney collapse in northeastern Queens • Wind gusts of 54 mph at La Guardia Airport • Downed trees in Bronx
July 25, 2010	Tornado	Bronx	• EF1 tornado touches down in the Bronx • Large tree damages car • Seven injuries • $150,000 in damage
September 16, 2010	2 Tornadoes	Brooklyn/ Queens	• EF0 tornado in Park Slope, Brooklyn, and EF1 tornado in Flushing, Queens • Park Slope tornado causes significant tree damage and estimated $8.5 million in damage • Queens tornado causes one fatality; severe damage to residential buildings; estimated $17.2 million in damage • Federally declared disaster (DR-1943) with $17.9 million total for Public Assistance (PA): $11.4 million for emergency work and $6.5 million for permanent work
October 1, 2010	Windstorm	Brooklyn/ Queens	• 60-mph wind gusts
August 1, 2011	Severe thunderstorms/hail	Queens	• Severe thunderstorms produce lime-size hailstones in Glen Oaks • 2.75-inch hailstones reported in Bayside, causing damage to cars
August 28, 2011	Tornado	Queens	• Hurricane Irene produces two confirmed tornadoes: one EFO in Cunningham Park and one on Long Island
July 26, 2012	Severe weather	Citywide	• Warm front triggers multiple severe thunderstorms • One fatality: lighting strikes the steeple of a Brooklyn church that collapses, striking and killing a pedestrian
August 15, 2012	Severe weather	Citywide	• Multiple rounds of severe thunderstorms • Downed trees in Brooklyn damage cars • 1-inch hailstones in Queens • Downed power lines and power outages in Queens
September 8, 2012	Tornado	Brooklyn/ Queens	• EFO tornado in Queens and EF1 tornado in Brooklyn • Tornado in Queens causes estimated damages of $20,000 • Tornado in Brooklyn causes structural damage to several homes and estimated damages of $250,000

B. Vulnerability Assessment

i. Social Environment

The City closely monitors severe weather, but thunderstorms, tornados, and windstorms can occur with little or no warning, increasing risk to the population by compromising public safety. People who are caught outdoors during severe weather are vulnerable to injury and death. Hailstones, which can fall at speeds faster than 100 mph, can strike and injure people.

Data on death and injuries from severe weather confirm the risks of these events. In New York City from 1996 to 2012, nine confirmed deaths and 69 injuries have occurred during the 263 severe weather events and lightning strikes. During a thunderstorm in August 2004, two individuals were killed after stepping out of their car into a flooded intersection electrified by a downed power line in New York City.

Large, older trees can fall on people and property, causing injury or death. At least 11 people have been killed by downed trees in New York City during a severe weather event:

- February 25, 1996 – 1 fatality during high-wind event
- October 19, 1996 – 3 fatalities during high-wind event
- March 6, 1997 – 4 fatalities during high-wind event
- September 7, 1998 – 1 fatality during severe thunderstorm/hail event
- December 23, 2004 – 1 fatality during high-wind event
- September 16, 2010 – 1 fatality during tornado

ii. Built Environment

Hail can cause severe damage to buildings, cars, and trains. According to the NWS, hail causes more than $1 billion in crop and property damage nationally each year. In addition, NWS also estimates that lightning costs more than $1 billion in insured losses each year.

High winds pose a serious threat to buildings and infrastructure. Due to New York City's dense urban environment, flying debris can severely damage structures. Areas with tall buildings—such as Midtown Manhattan, the Financial District, and Downtown Brooklyn—are at a greater risk because of increased wind pressures at greater heights. While these structures can withstand strong winds, glass windows pose a potentially fatal threat if broken.

Construction sites are also especially vulnerable to high winds. Tools and construction materials, cranes, scaffolding, and other building appurtenances may loosen in high winds.

Structural vulnerability to wind is related to the building's construction type and age. Wood structures and manufactured homes are more susceptible to wind damage, while steel and concrete buildings are more resistant to it. Less than 0.1% of the city's buildings are manufactured housing, and 54% are wooden structures. Ninety-three percent of Staten Island's structures are made of wood, increasing that borough's vulnerability to windstorms and tornadoes.

The 2008 New York City Construction Code addresses high winds in a dense, high-rise environment. The Construction Code establishes wind-exposure categories to set design requirements for new buildings. These requirements account for location, surroundings, and occupancy to ensure buildings can withstand extreme winds. For example, buildings along the coastline are subject to higher wind loads, as are buildings that are more than 300 feet tall.

It is not possible to estimate potential losses to specific structures from severe weather. However, historically tornadoes have caused up to $7.2 million in IHP funding from FEMA. (For more information on the structural vulnerability of the city's built environment, see New York City's Hazard Environment.)

iii. Natural Environment

Severe weather can negatively affect the natural environment. For example, severe thunderstorms, tornadoes, and windstorms can destroy historic trees and damage the aesthetic value of parks and open space. The secondary impacts from severe weather on the natural environment include lightning-induced fires and hazardous material leaks and spills.

iv. Future Environment

Predicting the impact of severe weather 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 could create an environment favorable for severe thunderstorms. However, these same conditions have been shown to reduce the wind shear necessary for tornadoes to get a full lift. At this point it is unclear how the long-term effects of climate change will impact the strength and occurrence of tornadoes.

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