4.10 SEVERE WEATHER

SECTION 4.10 SEVERE WEATHER

4.10-1 HAZARD OVERVIEW

Severe weather events in New Jersey are common and can occur at any time. This profile includes information and analysis on high winds, tornadoes, thunderstorms, and hailstorms.

Hazard Definitions

High Winds

High winds, other than tornadoes, are experienced in all parts of the United States. In New Jersey, the northwest ridge tops experience the highest winds most often, followed by coastal locations (Robinson, 2013).

Winds are generated by differences in air pressures, caused by uneven heating of the earth's surface. Generally, they are considered horizontal in nature. Wind occurs at all scales, from local breezes lasting a few minutes to persistent global wind fields. Effects from high winds can include downed trees and power lines, and damages to roofs, windows, etc. (Ilicak, 2005).

Extreme windstorm events are associated with extra-tropical and tropical cyclones, severe thunderstorms, and accompanying mesoscale offspring such as tornadoes and downbursts. Winds may vary from zero at ground level to 200 miles per hour (mph) in the upper atmospheric jet stream at six to eight miles above the earth's surface (FEMA, 1997).

A type of windstorm that is occasionally experienced during rapidly moving thunderstorms is a derecho. A derecho is a long-lived windstorm that is associated with a rapidly moving squall line of thunderstorms. It produces straight-line winds gusts of at least 58 mph. To be considered a derecho, these conditions must continue along a path of at least 240 miles. Derechos are more common in the Great Lakes and Midwest regions of the United States, though, on occasion, can persist into the mid-Atlantic and northeast United States including New Jersey (ONJSC Rutgers University, 2013a).

Tornadoes

Tornadoes are violent storms and can cause fatalities and devastate neighborhoods in seconds. A tornado appears as a rotating, funnel-shaped column of air that extends from a thunderstorm to the ground with whirling winds that can reach over 200 mph. Damage paths can be greater than one mile in width and 50 miles in length. Tornadoes typically develop from either a severe thunderstorm or hurricane as cool air rapidly overrides a layer of warm air. Tornadoes move at speeds which appear stationary to speeds of 60 mph and can generate internal winds exceeding 300 mph (NWS, 2023). The lifespan of a tornado rarely is longer than 30 minutes (FEMA, 1997).

Tornadoes do occur in New Jersey, although generally they are relatively weak and short lived. Climatologically, past occurrences indicate that the State experiences about two tornadoes per year. Tornado season in New Jersey is generally March through October, though tornadoes can occur at any time of the year. Over 80% of all tornadoes strike between noon and midnight.

Thunderstorms

A thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS, 2009). A thunderstorm forms from a combination of moisture, rapidly rising warm air, and a force capable of lifting air such as a warm and cold front, a sea breeze, or a mountain. Although thunderstorms generally affect a small area when they occur, they have the potential to become dangerous due to their ability in generating tornadoes, hail, strong winds, flash flooding, and lightning. The NWS considers a thunderstorm severe only if it produces damaging wind gusts of 58 mph or higher or large hail one inch (quarter size) in diameter or larger or tornadoes (NWS, 2010). Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes. During the warm season, thunderstorms are responsible for most of the rainfall.

Hailstorms

Hail forms inside a thunderstorm where there are strong updrafts of warm air and downdrafts of cold water. If a water droplet is picked up by the updrafts, it can be carried well above the freezing level. Water droplets freeze when temperatures reach 32°F or colder. As the frozen droplet begins to fall, it may thaw as it moves into warmer air toward the bottom of the thunderstorm. However, the droplet may be picked up again by another updraft and carried back into the cold air and re-freeze. With each trip above and below the freezing level, the frozen droplet adds another layer of ice. The frozen droplet, with many layers of ice, falls to the ground as hail. Most hail is small and typically less than one inches in diameter (NWS 2010).

The size of hailstones is a direct function of the size and severity of the storm. The size varies and is related to the severity and size of the thunderstorm that produced it. The higher the temperatures at the earth's surface, the greater the strength of the updrafts, and the greater the amount of time the hailstones are suspended, giving them more time to increase in size. Damage to crops and vehicles are typically the most significant impacts of hailstorms.

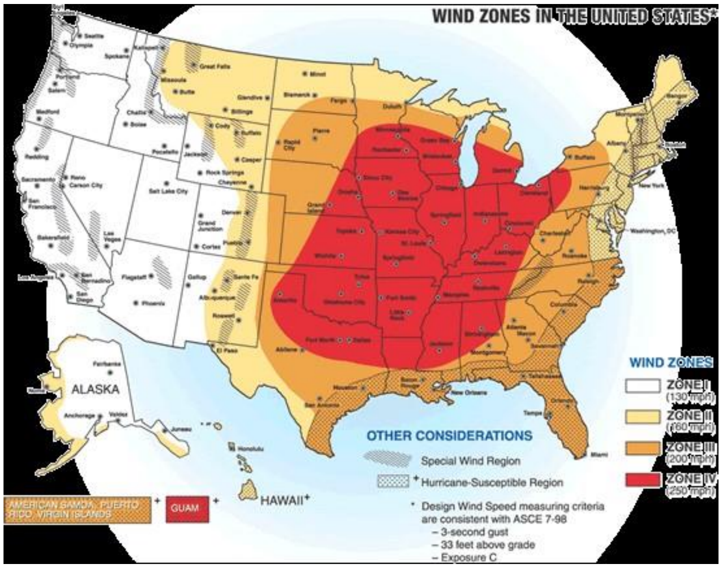
4.10-2 LOCATION, EXTENT, AND MAGNITUDE

Location

High Winds

Figure 4.10-1 indicates how the frequency and strength of windstorms impacts the United States and the general location of the most wind activity, based on 40 years of tornado data and 100 years of hurricane data analyzed by FEMA. The entire state of New Jersey is located within Wind Zone II, which may experience wind speeds from 131 mph up to 160 mph.

Figure 4.10-1 Wind Zones in the United States

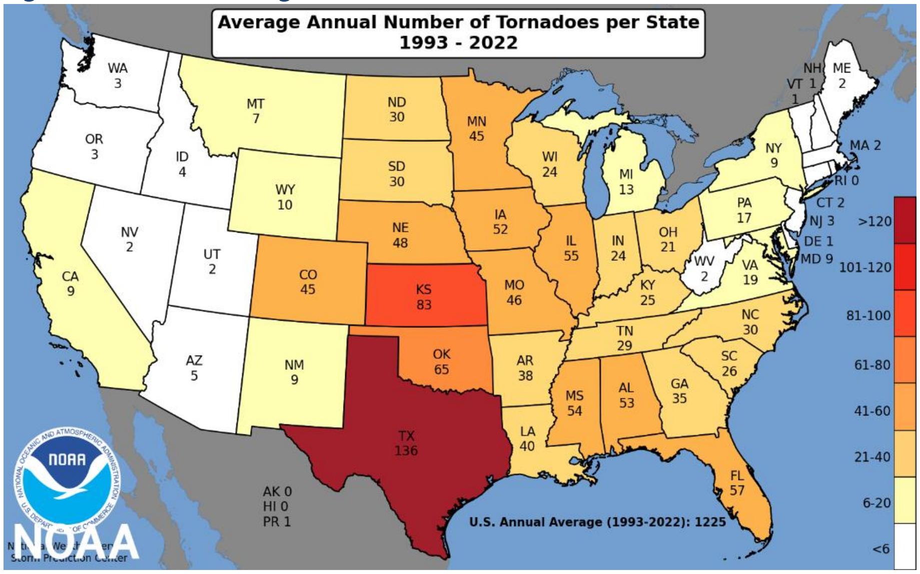


Source: FEMA, 2012

Tornadoes

The peak of the tornado season is April through June, with the highest concentration of tornadoes in the central United States ([NOAA-NCEI, 2023]). The potential for a tornado strike is about equal across locations in New Jersey, except in the northern section of the State which typically has steeper terrain and therefore is less likely to experience tornadoes. Figure 4.10-2 shows the annual average number of tornadoes between 1993 and 2022, which is three for New Jersey.

Figure 4.10-2 Annual Average Number of Tornadoes in the United States, 1993 to 2022



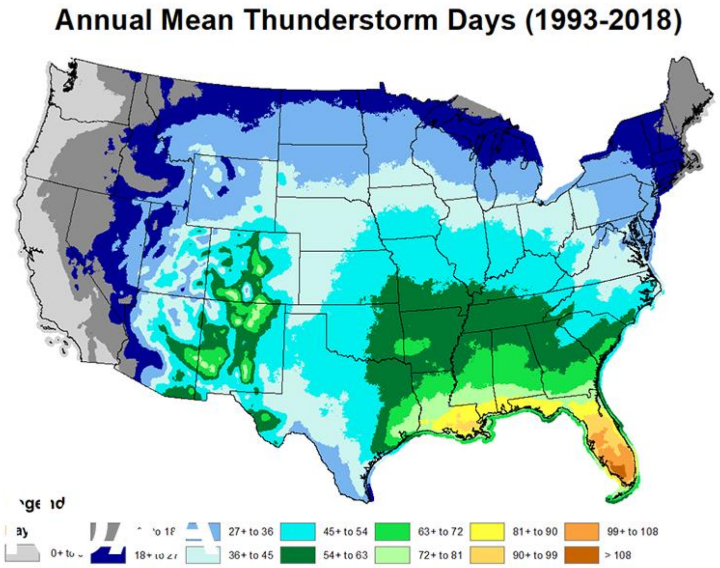
Source: NOAA, 2023b

Thunderstorms

Thunderstorms affect relatively small, localized areas rather than large regions like winter storms and hurricane events. There are three basic ingredients which must be present for a thunderstorm to occur: moisture, instability and lifting. Although they happen across the entire country, atmospheric conditions in the Southeast and Great Plains regions are ideal for generating these powerful storms. Figure 4.10-3 shows the average number of thunderstorm days throughout the United States, which illustrates that New Jersey experiences between 27 to 36 thunderstorm days each year in the majority of the state, and 18 to 27 thunderstorm days along the Atlantic coast (NOAA, 2023a). It is important to note that observational methodology of thunderstorms has varied over the years. In many cases, the number of thunderstorm days dropped by as much as 50% from the past to present periods, though this was not apparent at all Mid-Atlantic stations (ONJSC Rutgers University 2013a).

Thunderstorms spawned in Pennsylvania and New York State often move into New Jersey, where they usually reach maximum development during the evening hours. The interior and northern regions of the State have about twice as many thunderstorms as the coastal zone. The conditions most favorable to thunderstorm development occur between June and August, with July being the peak month for all weather stations in New Jersey.

Figure 4.10-3 Annual Mean Thunderstorm Days

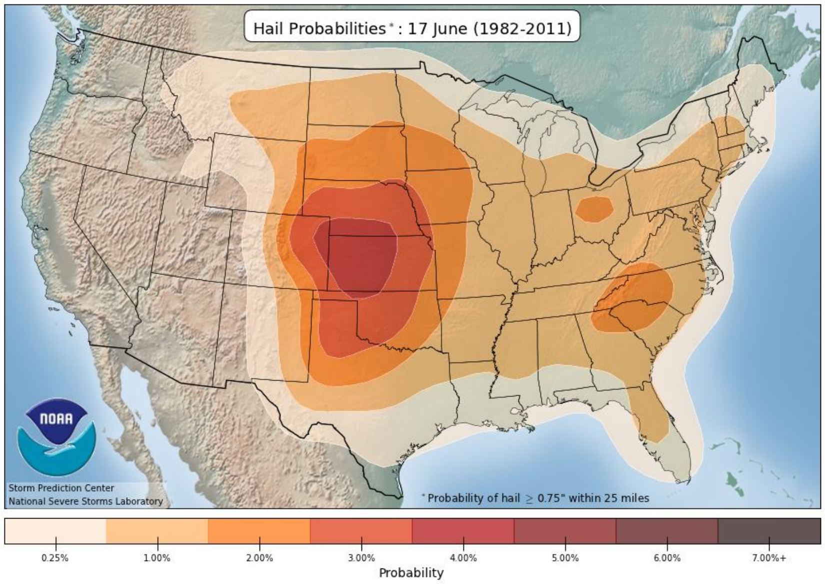


Source: NOAA, 2023a

Hailstorms

Hail occurs most frequently in the Southern and Great Plains states; however, since hail occurs with thunderstorms, the possibility of hail damage exists throughout the entire United States (Federal Alliance for Safe Homes, 2006). NOAA's National Severe Storms Laboratory (NSSL) has generated estimates of the likelihood of severe weather hazards in the United States. Figure 4.10-4 illustrates the chance of hail events occurring within 25 miles of any point. In New Jersey, the figure shows a 1.0% chance for most of the state, with a 0.25% chance for most of the coastal areas and the southeast. The June 17th timeframe was chosen as it is the time that New Jersey has the highest collective risk for hail, according to this data. After this point, the probability of hail events steadily decreases until it largely disappears over winter. It then steadily increases throughout the Spring until reaching the highest risk during the Summer.

Figure 4.10-4 Threat of Hail Event s (0.75-inch diameter or greater) in the United States, 1982 to 2011



Source: NSSL, 2013

Extent

High Winds

The extent of a severe storm is largely dependent upon sustained wind speed. Straight-line winds, winds that come out of a thunderstorm, in extreme cases, can cause wind gusts exceeding 100 mph. These winds can accompany hail and thunderstorms and cause damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado (Northern Virginia Regional Commission [NVRC], 2006). The following table provides the descriptions of winds used by the NWS.

Table 4.10-1 NWS Wind Descriptions

Descriptive Term	Sustained Wind Speed (mph)
Strong, dangerous, or damaging	≥40
Very Windy	30-40
Windy	20-30
Breezy, brisk, or blustery	15-25
None	5-15 or 10-20
Light or light and variable wind	0-5

Source: NWS, 2010

Windstorms have been known to cause damage to utilities. The predicted wind speed given in wind warnings issued by the NWS is for a one-minute average; gusts may be 25% to 30% higher. The NWS issues advisories, watches, and warnings for winds. A wind advisory is defined as sustained winds 25 to 39 mph and/or gusts of 46 to 57 mph. Issuance is normally site-specific. High wind advisories, watches, and warnings are products issued by the NWS when wind speeds may pose a hazard or are life threatening. The criterion for each of these varies from state to state (NWS, 2010).

Tornadoes

The Enhanced Fujita (EF) Scale was developed in 2008 to address limitations with the previously used Fujita (F) Scale (NOAA 2008). It is used to assign tornadoes a 'rating' based on estimated wind speeds and related damage. When tornado-related damage is surveyed, it is compared to a list of Damage Indicators (DI) and Degree of Damage (DOD), which help better estimate the range of wind speeds produced by the tornado. From that, a rating is assigned, similar to that of the F-Scale, with six categories from EF0 to EF5, representing increasing degrees of damage. This new scale considers how most structures are designed (NOAA, 2008). Table 4.10-2 displays the EF-Scale.

Table 4.10-2 Enhanced Fujita Damage Scale

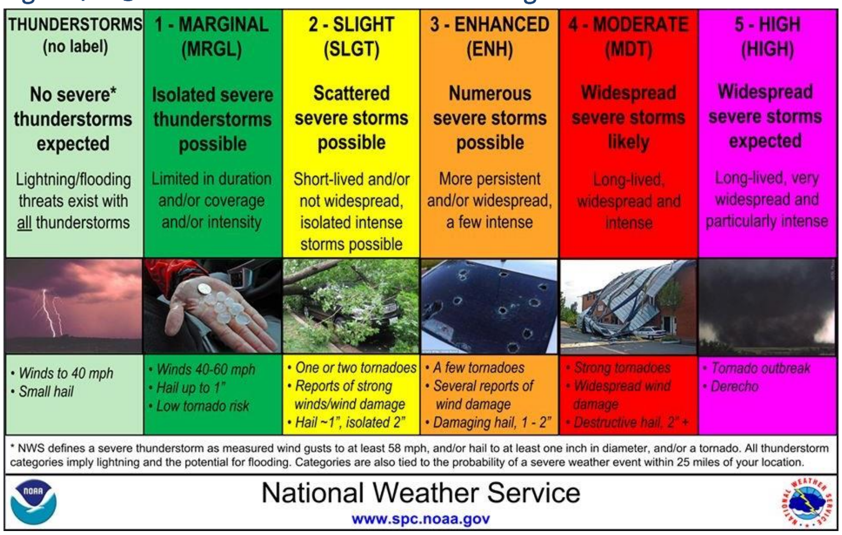
EF Scale Number	Wind Speed (MPH)	F-Scale Number	Type of Damage Possible
EF0	65–85	F0-F1	Minor damage: Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. Confirmed tornadoes with no reported damage (i.e., those that remain in open fields) are always rated EF0.
EF1	86-110	F1	Moderate damage: Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	111–135	F1-F2	Considerable damage: Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
EF3	136–165	F2-F3	Severe damage: Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some distance.
EF4	166–200	F3	Devastating damage: Well-constructed houses and whole frame houses completely leveled; cars thrown, and small missiles generated.
EF5	>200	F3-F6	Extreme damage: Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 m (300 ft.); steel reinforced concrete structure badly damaged; high-rise buildings have significant structural deformation.

Source: SPC, 2011

Thunderstorms

Severe thunderstorms were defined in the United States as having either tornado, gusts at least 58 mph, or hail at least 0.75-inch in diameter. Figure 4.10-5 below showcases how the National Weather Service categories the risks associated with severe thunderstorms.

Figure 4.10-5 NWS Severe Thunderstorm Risk Categories



Hailstorms

Hail occurs with thunderstorm events. The size of hail is estimated by comparing it to a known object. Most hailstorms are made up of a variety of sizes, and only the very largest hail stones pose serious risk to people, when exposed. Table 4.10-3 shows the different sizes of hail and the comparison to real-world objects.

Table 4.10-3 Hail Size

Size	Inches in Diameter
Pea	0.25 inch
Marble/mothball	0.50 inch
Dime/Penny	0.75 inch
Nickel	0.875 inch
Quarter	1.0 inch
Ping-Pong Ball	1.5 inches
Golf Ball	1.75 inches
Tennis Ball	2.5 inches
Baseball	2.75 inches
Teacup	3.0 inches
Grapefruit	4.0 inches
Softball	4.5 inches

Source: NOAA 2012

4.10-3 PREVIOUS OCCURRENCES AND LOSSES

FEMA Disaster Declarations

Between 1954 and 2023, FEMA declared that the State of New Jersey experienced 15 severe storm-related disasters (DR) or emergencies (EM) classified as one or a combination of the following disaster types: severe storms, high tides, flooding, high winds, heavy rain, hail, tornadoes, and mudslides. Generally, these disasters cover a wide region of the State; therefore, they can impact many counties. However, not all counties were included in the disaster declarations as determined by FEMA (FEMA, 2023).

Table 4.10-4 identifies known severe storm events that have affected New Jersey and were declared a FEMA disaster since 2010. This table provides information on the FEMA disaster declarations for severe storms, including the disaster number, disaster type, declaration and incident dates, and counties included in the declaration.

Table 4.10-4 Severe Weather-Related FEMA Disaster Declarations (2010 to 2023)

Disaster Number	Disaster Type	Incident Period	Atlantic	Bergen	Burlington	Camden	Cape May	Cumberland	Essex	Gloucester	Hudson	Hunterdon	Mercer	Middlesex	Monmouth	Morris	Ocean	Passaic	Salem	Somerset	Sussex	Union	Warren	Impacted # of Counties
DR-1897	Severe Storms and Flooding	3/12/2010 - 4/15/2010	X	X	X		X	X	X	X			X	X	X	X	X	X		X		X		15
DR-4033	Severe Storms and Flooding	8/13/2011						X		X									X					3
DR-4048	Severe Storm	10/29/2011		X			X		X			X		X				X		X	X	X	X	10
DR-4070	Severe Storms and Straight-Line Winds	6/30/2012	X					X											X					3
DR-4231	Severe Storm	6/23/2015	X		X	X			X															4

Source: FEMA, 2023

Historical Events Summary

Many sources provided historical information regarding previous occurrences and losses associated with severe storm events throughout New Jersey. Numerous sources were reviewed for this Hazard Management Plan (HMP), therefore, loss and impact information for many events could vary depending on the source. Table 4.10-5 includes significant historical severe weather events that have occurred since 2010. To be considered significant, the event had a fatality had a high number of power outages and/or property damage. This table does not include hailstorms (see Table 4.10-6).

Table 4.10-5 Significant Historical Severe Weather Events Since 2010

Event Date(s)	Event Type	Counties Affected	Description
1/25/2010	Strong Winds	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Middlesex, Ocean, Salem, Somerset	Strong to high southerly winds affected central and southern New Jersey in the morning of January 25. Peak wind gusts averaged around 55 mph, with the strongest winds in the southern half of the state. About 80,500 homes and businesses lost power. Most power was restored by the next afternoon. The high winds also caused structural and property damage in Cumberland and Gloucester Counties.
3/13/2010	High Winds	Statewide	Strong to high winds downed thousands of trees and tree limbs, hundreds of telephone poles. Over half a million utility customers throughout the state lost power. Dozens of homes were damaged by fallen trees, a few other homes were damaged by the high winds themselves and crane damage occurred in

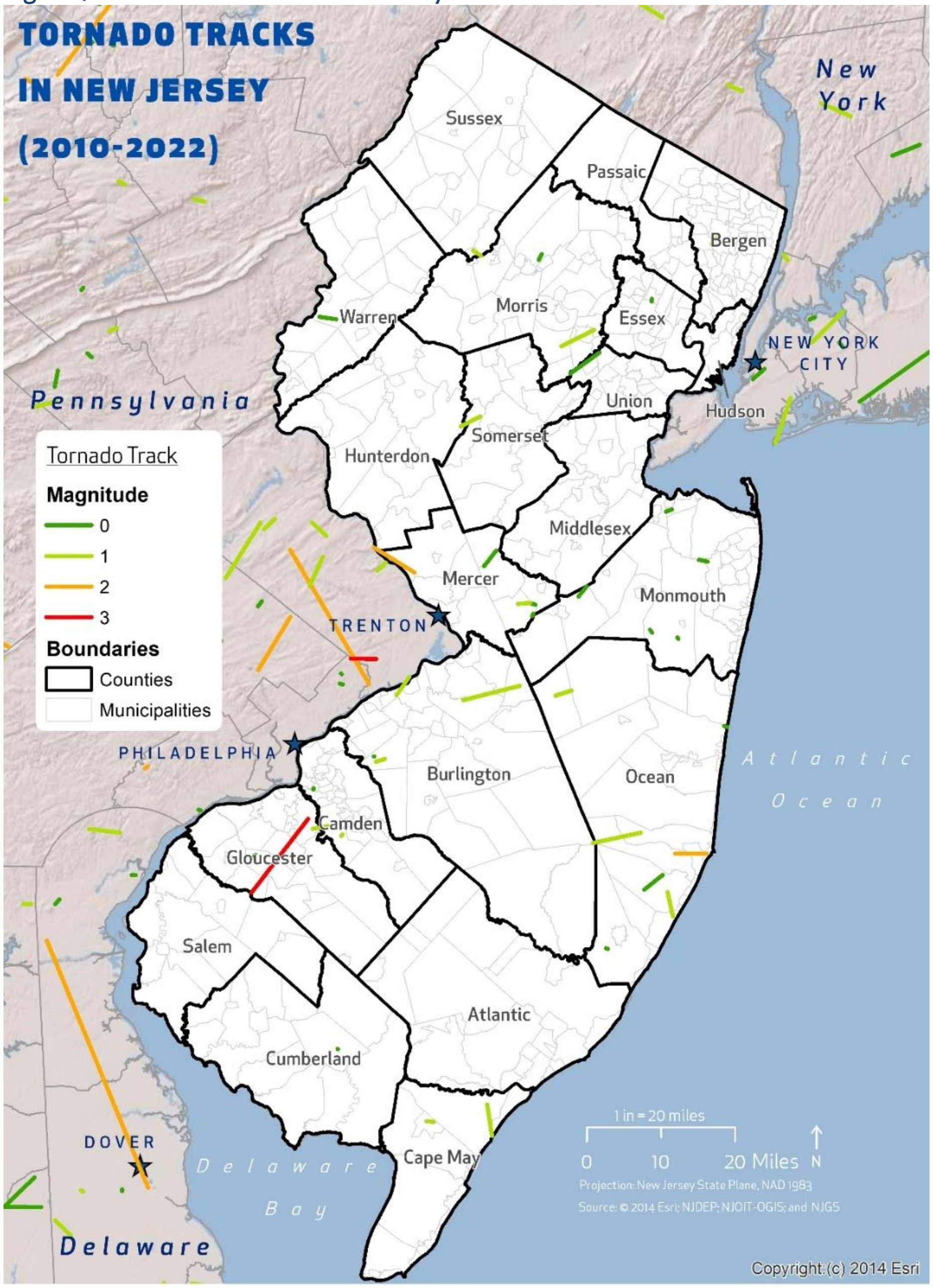
Event Date(s)	Event Type	Counties Affected	Description
			Atlantic City. There were three reported injuries. A 78-mph wind gust was reported at Robbins Reef at 7:18 pm.
6/24/2010	Severe Thunderstorm, Lightning	Atlantic, Burlington, Cumberland, Gloucester, Salem	Severe thunderstorms caused considerable tree damage during the afternoon into the early evening on June 24, across the southern third of New Jersey and claimed the life of one woman and injured two other persons in Burlington County. About 130,000 PSE&G and 65,000 Atlantic City Electric customers lost power. A lightning strike caused an apartment fire at the Campus Crossings Apartments in Glassboro.
7/14/2010	Lightning	Burlington	A 46-year-old and a 37-year-old man camping in Rancocas State Park were injured after being struck by lightning.
7/19/2010	Severe Thunderstorm	Bergen, Camden, Monmouth	A lee side trough triggered and maintained a line of severe thunderstorms across central and southern New Jersey in the morning of July 19. A 49-year-old man was struck and killed by lightning on Linden Avenue in Middletown. A lightning strike set the attic of a house on fire on Monmouth Parkway in Middletown Township and struck an attached garage on a house along Colonial Road in Emerson.
12/18/2010	High Winds	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Salem, Somerset, Sussex, Warren	Strong to high west to northwest winds affected New Jersey in the evening of January 18 into the evening of January 19. Peak wind gusts averaged around 55 mph. The winds tore down trees, tree limbs, and wires, and caused power outages. Most of the highest winds and damage occurred in the central and southern part of the state. About 22,000 homes and businesses lost power.
7/3/2011	Severe Thunderstorm, Lightning	Atlantic, Hunterdon, Middlesex, Monmouth, Ocean, Sussex	A warm front acted as a focus for strong to severe thunderstorms in the early morning of July 3 in northwestern New Jersey and in the late afternoon and early evening of July 3 across central New Jersey. A 54-year-old male was struck and killed by lightning while ducking under a tree during a thunderstorm to light a cigar in Hammonton.
7/29/2011	Severe Thunderstorm, Lightning	Atlantic, Burlington, Mercer, Monmouth, Ocean	An approaching cold front helped trigger strong to severe thunderstorms across central and northern New Jersey in the early evening on July 29. Hardest hit were Sussex, Burlington and Ocean Counties. About 37,000 PSE&G customers lost power. A pair of lightning strikes caused house fires in Willingboro Township. A lightning strike started an attic fire at a house on Melissa Court in Moorestown. A lightning strike started a fire at an occupied structure at the intersection of Ford Road and U.S. Route 9 in Howell Township.
8/1/2011	Severe Thunderstorm, Lightning	Atlantic, Burlington, Camden, Cumberland, Gloucester, Monmouth, Salem	An approaching cold front triggered strong to severe thunderstorms mainly across the southern half of New Jersey in the late afternoon and early evening on August 1. A 32- year-old man was struck and seriously injured by lightning while on a beach in Sandy Hook.
9/15/2011	Lightning	Atlantic County	A 40-year-old male construction worker was killed, and two others were injured after they were struck by lightning while working on the Revel Casino Project in Atlantic City off of Connecticut Avenue.
3/12/2014	High Winds	Statewide	The strong pressure gradient (difference) between an intensifying strong low-pressure system and a high-pressure system in the Ohio Valley caused high to strong northwest winds to occur in New Jersey. Peak wind gusts averaged around 50 mph, with some gusts as high as around 60 mph. The high winds toppled a tree that killed one man in Sussex County.
6/29/2012	Derecho ("The Ohio Valley/Mid-Atlantic Derecho of June 2012")	Southern New Jersey	This event produced the all-time highest recorded June or July wind gusts at several official observing sites, in addition to widespread, significant wind damage. Five million people lost power from Chicago to the mid-Atlantic coast and 22 people were killed. In New Jersey, the storms produced continuous damage that extended east across the Delaware Bay to Atlantic City, where a 74-mph wind gust was reported. Two children were killed in Salem County.
7/28/2012	Severe Thunderstorm,	Atlantic, Burlington, Cape May, Cumberland, Mercer,	Pulse-type severe thunderstorms caused scattered wind damage in New Jersey in the afternoon and evening of July 28. Over 43,000 homes and businesses

Event Date(s)	Event Type	Counties Affected	Description
	Lightning	Middlesex, Monmouth, Morris, Salem, Warren	lost power in the state. A lightning strike and ensuing fire damaged a house on West 25th Avenue in North Wildwood.
8/9/2012	Severe Thunderstorm	Atlantic, Camden, Cumberland, Gloucester, Salem	A storm knocked out power to thousands and killed two people. Atlantic County, Vineland and other New Jersey towns and counties declared states of emergency, which restricted travel in some areas, so crews could clear debris and assess damage caused by the storm. The hardest counties were: Atlantic, Camden, Cumberland, Gloucester, and Salem Counties in Southern New Jersey.
8/15/2012	Lightning	Cumberland, Monmouth, Passaic, Sussex	A 41-year-old male was struck and died the next day from a lightning strike while fishing with his 10-year-old son on Takanassee Lake Beach in Long Branch. His son was not injured.
12/26/2012	High Winds	Atlantic, Burlington, Cape May, Mercer, Monmouth, Ocean	An intense low-pressure system brought strong to high northeast winds into central and eastern New Jersey mainly during the evening on December 26. Peak wind gusts reached hurricane force gusts in Ocean County. The strong to high winds caused some structural damage as well as knocking down trees, tree limbs, and wires and causing power outages. Jersey Central Power and Light reported about 7,000 of its customers lost power in Ocean and Monmouth Counties. Peak wind gusts included 74 mph in Brick (Ocean County), 70 mph in Tuckerton and Barnegat (Ocean County), 68 mph in Harvey Cedars (Ocean County), 61 mph in Sandy Hook (Monmouth County), 58 mph in Monmouth Beach (Monmouth County), 57 mph in Oceanport (Monmouth County), 54 mph in Florence (Burlington County), Point Pleasant and Seaside Heights (Ocean County), 51 mph at the Atlantic City International Airport (Atlantic County), 49 mph in West Cape May (Cape May County), 48 mph in Oceanville (Atlantic County) and 46 mph in Trenton (Mercer County) and the Marina in Atlantic City (Atlantic County). Overall, the State experienced $150,000 in property damages.
8/13/2013	Tornado - EF0	Ocean	A complex of showers and thunderstorms produced both wind damage and flash flooding across southern new Jersey. The wind damage included an EF0 tornado in Manahawkin (Stafford Township in Ocean County). An isolated severe thunderstorm then occurred during the evening of the 13th in Morris County. Cloud-to-ground lightning strikes peaked at 6,000 per hour as this complex moved through New Jersey. The thunderstorms caused about 14,500 homes and businesses to lose power on the 13th.
7/2/2014	Severe Thunderstorm, Lightning	Bergen, Burlington, Camden, Essex, Hunterdon, Mercer, Sussex, Warren	A weakening approaching cold front triggered a series of strong to severe thunderstorms. Hardest hit was Hunterdon County with multiple municipalities that reported downed trees and wires. There was $1,030,000 of property damage.
7/25/2016	Tornado - EF1	Hunterdon	A trough of low pressure led to the development of afternoon and evening showers and thunderstorms which became severe in spots and produced locally heavy rains. 40,000 were left without power across the state.
6/9/2021	Thunderstorm, Lightning	Burlington, Mercer, Monmouth, Ocean	A man in his 70s was struck and killed by lightning at Burlington Country Club. This was the first documented case of a fatal lightning strike in the United States in 2021.
8/30/2021	Thunderstorm, Lightning	Ocean	A few thunderstorms developed over eastern New Jersey. Seven individuals were struck by lightning in South Seaside Park, with one fatality.
9/1/2021	Tornado - EF3	Gloucester	The tornado touched down near Harrisonville, NJ doing mostly damage to trees and limbs before moving northeast and producing more significant damage to trees with many trees uprooted as well as serious structural damage to a number of homes. Several homes had exterior walls completely collapsed, several homes lost roofs and upper story walls, one home had only a few interior walls remaining, and one home was destroyed. Vehicles were tossed around and moved, and damage from flying debris was observed in several spots. The tornado continued to move to the northeast to |where multiple trees had trunks snapped and most of the barns and storage buildings

Event Date(s)	Event Type	Counties Affected	Description
			at multiple commercial farms were completely destroyed along with two large grain silos. In addition, the tornado produced complete deforestation with nearly 100 percent of the trees in a thickly wooded area snapped. The tornado also reached its maximum width at this location and was estimated to be around 400 yards wide. The consistency of the |damage along the path of the tornado in this area was EF-3 in the middle of the circulation, with EF-2 along the edge of the circulation. Damage was estimated at $5,000,000 and there were two reported injuries.

Sources: NOAA-NCDC, 2016; SPC, 2013; ONJSC Rutgers University, 2013, Source: NCEI 2023; Chang 2012; Giambusso 2012

Figure 4.10-6 Tornado Tracks in New Jersey Since 2010



Hailstorms

Hailstorms, like thunderstorms, occur as a routine part of severe weather in New Jersey. There are at least a few incidences each year, but they are minor. New Jersey exhibits a relatively low potential for significant hail events, based on previous records.

Many sources provided historical information regarding previous occurrences and losses associated with hail events throughout the State, so loss and impact information for many events could vary depending on the source. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP.

Hailstorms in New Jersey that occurred through February 2023 are summarized in this plan update. Table 4.10-6 summarizes the events that have occurred since 2010 by county, as hailstorms likely overlapped with many of the thunderstorm events detailed above. The table may not include all incidents. There were no deaths or injuries associated with these hailstorm events.

Table 4.10-6 Hailstorm Events Summary, 2010 to 2023

County	Number of Reported Incidents	Property Damage	Crop Damage
Atlantic	24	10, 000	$10,000
Bergen	47	$0	$0
Burlington	68	$1,000	$0
Camden	37	$0	$0
Cape May	15	$0	$0
Cumberland	17	$0	$0
Essex	8	$0	$0
Gloucester	15	$0	$0
Hudson	6	$0	$0
Hunterdon	14	$0	$0
Mercer	29	$0	$0
Middlesex	26	$0	$0
Monmouth	40	$0	$0
Morris	32	$5,000	$0
Ocean	47	$5,000	$0
Passaic	8	$0	$0
Salem	8	$0	$0
Somerset	13	$0	$0
Sussex	24	$0	$0
Union	4	$0	$0
Warren	13	$0	$0
Total	**495**	**$21,000**	**$10,000**

Source: NCEI, 2023

Power Outages

Power outages are defined as any interruption or loss of electrical service caused by disruption of power transmission caused by accident, sabotage, natural hazards, or equipment failure (also referred to as a loss of power or power outage). Power failures in New Jersey are usually localized and are usually the result of a natural hazard event. Power disruption can lead to significant consequences, including service disruption, disruption to infrastructure operations, and loss of heat or cooling that can cause further disturbance or injury.

Severe weather can cause power outages primarily due to high velocity winds. High winds can occur on their own or during a storm or tornado and can directly damage power equipment by toppling utility poles along with causing downing of tree limbs which can damage exposed power lines. Additional causes of power outage during severe weather events can include hail which has the potential to cause damage to electrical power equipment, or lightning which can cause electrical surges in equipment leading to an outage.

4.10-4 PROBABILITY OF FUTURE OCCURRENCES

High Wind

High wind events will occur regularly as part of severe weather events in the State. As noted in the previous occurrences section, high wind events occur annually, and in most cases several times per year across the State.

Tornadoes

Tornadoes occur approximately one to three times per year in New Jersey. Generally, these events will be rather minor and will not cause significant damage.

Thunderstorms

Like high windstorms, thunderstorms occur in regular intervals as part of normal weather systems in New Jersey. During the summer months some thunderstorms may be severe and could cause significant damage. Thunderstorms often result in other severe hazards such as hail and lightning and can occur in conjunction with damaging winds.

Hailstorms

Hailstorms occur regularly but not at the frequency or intensity of thunderstorms across the State. Furthermore, damaging storms that produce golf ball or larger sized hail do not occur every year in New Jersey like they do in the central United States.

Potential Effects of Climate Change

Detecting trends and developing future projections for extreme weather events such as tornadoes, severe thunderstorms, high winds, and hail is difficult because they occur over much shorter time periods and smaller areas than other extreme phenomena such as heat waves, droughts, and even tropical cyclones (NCA, 2018). However, many extreme weather events are expected to grow in frequency and severity over the coming years (NJDEP, 2020).

Modeling studies consistently suggest that the frequency and intensity of extreme weather events including thunderstorms, tornadoes, and high winds in the Eastern United States could increase as a result of increased occurrence of climate conditions related to air moisture and temperature which support the formation of convective storms (NCA, 2018).

4.10-5 VULNERABILITY ASSESSMENT

Vulnerable Jurisdictions

A review of the historic record indicates that all counties have experienced severe weather events. Further, all counties identified severe weather as a hazard of concern in their hazard mitigation plans, as summarized in Table 4.10-7. In addition to the rankings created by the counties, the table includes the Hazard Risk Rating data from the National Risk Index. The ratings are relative to other jurisdictions and based on an equation that accounts for expected annual loss, social vulnerability, and community resilience. Organization of hazards does not align perfectly between the NRI and County HMPs or among the counties themselves. For example, some may group many different hazards under the umbrella of severe weather while other counties may choose to address hazards individually or categorize them differently.

Table 4.10-7 Severe Weather Risk Rankings

County	Hailstorm		Lightning		Strong Winds	Severe Weather	Severe Summer Weather	Tornado	
	NRI Hazard Risk Rating	Ranking of Hazard by County HMP	NRI Hazard Risk Rating	Ranking of Hazard by County HMP	NRI Hazard Risk Rating	Ranking of Hazard by County HMP	Ranking of Hazard by County HMP	NRI Hazard Risk Rating	Ranking of Hazard by County HMP
Atlantic	Relatively Low	Low	Relatively High	Low	Relatively High	Not Profiled	Not Profiled	Relatively Low	Medium
Bergen	Relatively Low	Profiled, Not Ranked	Relatively High	Not Ranked	Very High	Profiled, Not Ranked	Not Profiled	Relatively Moderate	Profiled, Not Ranked
Burlington	Very Low	High	Relatively High	Not Profiled	Very High	High	Not Profiled	Relatively Moderate	High
Camden	Relatively Low	Low	Relatively Moderate	Low	Relatively High	Not Profiled	Low	Relatively Moderate	High
Cape May	Very Low	Low	Relatively Moderate	Low	Relatively High	Low	Low	Relatively Low	Low
Cumberland	Relatively Low	Not Ranked	Relatively Moderate	Not Profiled	Relatively High	Not Profiled	High	Relatively Low	Not Profiled
Essex	Very Low	Low	Relatively Moderate	Not Profiled	Very High	Low	Not Profiled	Relatively High	Low
Gloucester	Relatively Low	High	Relatively Low	High	Relatively High	High	Not Profiled	Relatively Moderate	High
Hudson	Very Low	Low	Relatively Moderate	Low	Relatively High	Low	Not Profiled	Relatively Moderate	Low
Hunterdon	Relatively Low	Low	Relatively Moderate	Not Profiled	Very High	Low	Not Profiled	Relatively Low	Low
Mercer	Relatively Low	Low	Relatively Moderate	Not Profiled	Very High	Low	Not Profiled	Relatively Moderate	Low
Middlesex	Relatively Low	Medium	Relatively Moderate	Not Profiled	Very High	Medium	Not Profiled	Relatively High	Medium
Monmouth	Relatively Low	Not Ranked	Relatively High	Low	Very High	Not Profiled	Not Profiled	Relatively Low	Medium
Morris	Relatively Low	High	Relatively Moderate	High	Very High	High	Not Profiled	Relatively Moderate	High
Ocean	Very Low	Not Profiled	Relatively High	Not Profiled	Very High	Not Profiled	Not Profiled	Relatively Low	Low
Passaic	Relatively Low	Low	Relatively High	Not Profiled	Very High	Low	Not Profiled	Relatively Moderate	Low
Salem	Relatively Low	Not Profiled	Relatively Low	Not Profiled	Relatively High	Not Profiled	Medium	Relatively Low	Not Profiled
Somerset	Relatively Low	High	Relatively Moderate	High	Very High	Not Profiled	Not Profiled	Relatively Moderate	High
Sussex	Very Low	Not Profiled	Relatively Moderate	Not Profiled	Relatively High	Low	Not Profiled	Relatively Low	Not Profiled
Union	Very Low	Not Profiled	Relatively Low	Low	Relatively High	Not Profiled	Not Profiled	Relatively Moderate	Medium
Warren	Relatively Low	High	Relatively Moderate	High	Relatively High	High	Not Profiled	Relatively Low	High

Sources: FEMA NRI (accessed June 2023), County Hazard Mitigation Plans (accessed June 2023)

Built Environment

To understand risk, the assets exposed to hazards must be identified. Certain areas are more vulnerable to specific severe weather events than others due to geographic location and local weather patterns. For severe weather, the entire State of New Jersey is exposed. Therefore, all State assets are potentially vulnerable.

Table 4.10-8 shows estimated potential annual losses (EAL) for severe weather (hailstorm, lightning, strong winds, and tornado) by county in the state of New Jersey. Total building EAL was derived from FEMA's National Risk Index while EAL for state owned assets was calculated using Replacement Cost Value for state owned facilities per county derived from LBAM data and Expected Annual Loss Rate for Buildings by county provided by the NRI.

Table 4.10-8 Estimated Potential Annual Losses for Severe Weather

County	Hailstorm		Lightning		Strong Winds		Tornado	
	Total Buildings	State-Owned Assets	Total Buildings	State-Owned Assets	Total Buildings	State-Owned Assets	Total Buildings	State-Owned Assets
Atlantic	$764.61	$5.22	$86,637.04	$591.61	$3,151,028.16	$21,516.94	$472,377.70	$3,225.65
Bergen	$196,288.07	$176.21	$33,545.82	$30.12	$563,134.96	$505.54	$3,908,166.56	$3,508.48
Burlington	$88.47	$0.57	$207,974.34	$1,336.53	$8,472,436.27	$54,447.29	$1,920,425.14	$12,341.43
Camden	$80,740.20	$397.90	$3,182.74	$15.68	$1,863,416.91	$9,183.13	$1,933,361.17	$9,527.82
Cape May	$15,114.97	$45.49	$9,178.43	$27.63	$1,763,640.58	$5,308.37	$481,496.07	$1,449.25
Cumberland	$16,589.34	$356.24	$657.72	$14.12	$1,636,818.07	$35,149.05	$562,109.45	$12,070.74
Essex	$1,973.23	$12.59	$5,311.22	$33.89	$576,481.13	$3,678.06	$3,220,189.16	$20,545.45
Gloucester	$52,314.74	$92.30	$20,414.49	$36.02	$3,978,332.62	$7,018.73	$1,419,459.93	$2,504.27
Hudson	$984.12	$3.30	$1,952.76	$6.55	$380,880.93	$1,277.59	$1,652,252.13	$5,542.15
Hunterdon	$50,764.58	$331.38	$29,999.31	$195.83	$4,905,683.80	$32,023.59	$1,210,909.96	$7,904.64
Mercer	$98,170.48	$3,254.83	$126,357.93	$4,189.39	$10,172,415.87	$337,265.58	$1,605,804.20	$53,240.30
Middlesex	$3,615.84	$11.89	$65,489.15	$215.41	$17,255,919.64	$56,759.98	$4,653,896.90	$15,308.08
Monmouth	$1,725.49	$4.93	$118,899.07	$340.01	$12,070,310.34	$34,517.30	$1,076,186.38	$3,077.56
Morris	$1,020.28	$3.18	$82,721.96	$258.16	$655,511.00	$2,045.69	$3,054,056.28	$9,530.98
Ocean	$616.45	$1.77	$90,717.90	$260.17	$6,392,564.52	$18,333.10	$713,204.93	$2,045.39
Passaic	$91,200.36	$270.50	$87,774.06	$260.34	$278,285.28	$825.41	$1,838,160.56	$5,452.07
Salem	$36,682.44	$181.29	$11,728.88	$57.97	$1,538,744.94	$7,604.68	$370,548.15	$1,831.30
Somerset	$38,739.94	$99.63	$141,224.53	$363.18	$4,789,317.47	$12,316.41	$2,265,908.68	$5,827.11
Sussex	$29,406.60	$80.12	$16,196.63	$44.13	$1,648,950.37	$4,492.81	$761,418.40	$2,074.60
Union	$1,441.97	$2.56	$2,513.43	$4.46	$535,258.47	$949.17	$1,644,023.19	$2,915.33
Warren	$34,402.23	$95.59	$2,141.24	$5.95	$1,989,843.53	$5,528.92	$786,459.68	$2,185.23
Total	**$752,644.41**	**$5,427.49**	**$1,144,618.65**	**$8,287.15**	**$84,618,974.86**	**$650,747.34**	**$35,550,414.62**	**$182,107.83**

Source: FEMAs NRI, NJOMB, 2023

Critical Facilities

Critical facilities are important for ensuing the day-to-day functioning of a society. These facilities include utilities, hospitals, and schools, financial and cultural institutions, and others. They are also important in emergency response; thus, it is vital that in the event of a disaster they continue to operate. Table 4.10-9 depicts the number of critical facilities by category which are located within areas at risk from tornado.

Table 4.10-9 Critical Facilities at Risk from Tornado

County	Communications	Energy	Food, Water, Shelter	Hazardous Materials	Health and Medical	Safety and Security	Transportation	Financial	Cultural
Atlantic	-	-	-	-	-	-	1	-	-
Bergen	60	3	48	398	33	138	10	33	1876
Burlington	143	30	107	597	195	401	40	57	18821
Camden	143	25	172	745	253	547	85	64	10494
Cape May	-	-	-	-	-	-	-	-	-

County	Communications	Energy	Food, Water, Shelter	Hazardous Materials	Health and Medical	Safety and Security	Transportation	Financial	Cultural
Cumberland	4	-	2	3	3	5	2	48	53
Essex	241	44	116	1852	323	910	178	145	13440
Gloucester	65	17	40	415	130	307	32	48	3000
Hudson	135	17	42	901	86	260	130	56	2384
Hunterdon	14	3	20	70	15	49	8	11	1581
Mercer	189	29	20	655	175	1	33	78	7729
Middlesex	264	62	89	1619	341	422	93	184	3379
Monmouth	26	5	7	59	16	778	3	5	889
Morris	124	22	107	568	191	51	23	90	4890
Ocean	12	1	7	9	6	444	-	-	260
Passaic	75	9	32	595	114	9	19	48	1636
Salem	14	3	16	29	10	326	3	11	849
Somerset	117	25	106	557	172	25	35	79	4511
Sussex	-	-	-	-	-	-	-	-	-
Union	86	37	102	1216	229	606	125	130	5366
Warren	2	-	1	8	5	5	1	1	81
Total	1714	332	1035	10296	2297	5675	821	1040	81239

Source: HIFLD, 2006, 2007, 2012, 2014, 2017, 2018, 2019, 2020, 2021, 2022; NJOGIS, 2019, 2020; NJ TRANSIT, 2021; PANYNJ, 2023; USDOT, 2022; NOAA, 2022

Bridges

Bridges are a critical node in our transportation infrastructure. Landslide has the potential to cause damage to bridges, possibly even resulting in collapse. Table 4.10-10 below shows the number of bridges in each county that are vulnerable to tornado. A total of 3,908 bridges across the state are considered at risk from tornado.

Table 4.10-10 Bridges at Risk from Tornado

County	Number of Bridges
Atlantic	2
Bergen	58
Burlington	288
Camden	239
Cape May	-
Cumberland	6
Essex	499
Gloucester	216
Hudson	110
Hunterdon	114
Mercer	406
Middlesex	548
Monmouth	65
Morris	311
Ocean	14
Passaic	200
Salem	34
Somerset	385
Sussex	-
Union	406
Warren	7
Total	3908

Source: USDOT, 2022; NOAA, 2022

Lifeline Impacts

FEMA created the eight Community Lifelines to contextualize information from incidents, communicate impacts in plain language, and promote a more unified effort across a community that focuses on stabilizes these lifelines during response. More information on these lifelines can be found in Section 4.1: Risk Assessment Overview. Table 4.10-11 showcases the most likely lifelines to be impacted by severe weather, including a short description of anticipated impacts.

Table 4.10-11 Lifelines Most Likely Impacted by Severe Weather

Lifeline Categories	Notable Impacts
Safety and Security	Community safety may be threatened due to potential direct harm from severe weather impacts and compounding effects on administration of services. Transportation infrastructure issues may directly impact the abilities of law enforcement, fire service, search and rescue, and other government services.
Food, Hydration, Shelter	Severe weather can cause damage to structures and water utility infrastructure, while the food supply chain may be disrupted due to damage to agricultural production or impacts on transportation infrastructure.
Health and Medical	Potential Impacts to the Health and Medical lifeline consist of damage to physical and transportation infrastructure. Medical facilities can be impacted due to power disruptions or damage to structures from severe, patient movement and medical supply chains can be impacted by dangerous conditions on roadways.
Energy	Severe weather has the potential to cause direct damage to energy infrastructure and its ability to provide power to the grid. High winds, tornado, hailstorms, and lightning could all topple or damage power lines resulting in a loss of power.
Communications	Many types of communications equipment are impacted by power failures or destruction of communication lines which could occur because of severe weather. Wi-Fi and cellular data infrastructure can be crippled in such cases leaving many without access to communication lifelines.
Transportation	Anticipated impacts present a causal relationship for the Transportation lifeline in response and recovery due to direct damage to infrastructure and dangerous road conditions, including decreased visibility such as during a hail or thunderstorm. Additionally high winds and tornadoes can topple trees creating hazardous conditions. Lightning can impact rail service. These impacts can lead to a range of cascading effects on other community lifelines.
Hazardous Materials	Hazardous Materials facilities could be impacted by power disruptions due to effects to energy infrastructure. Transport of hazardous materials can be impacted by transportation infrastructure issues and dangerous road conditions including the potential for spills or releases.

High Winds

Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. High-rise buildings are also vulnerable structures. Mobile homes are the most vulnerable to damage, even if tied down, and offer little protection to people inside.

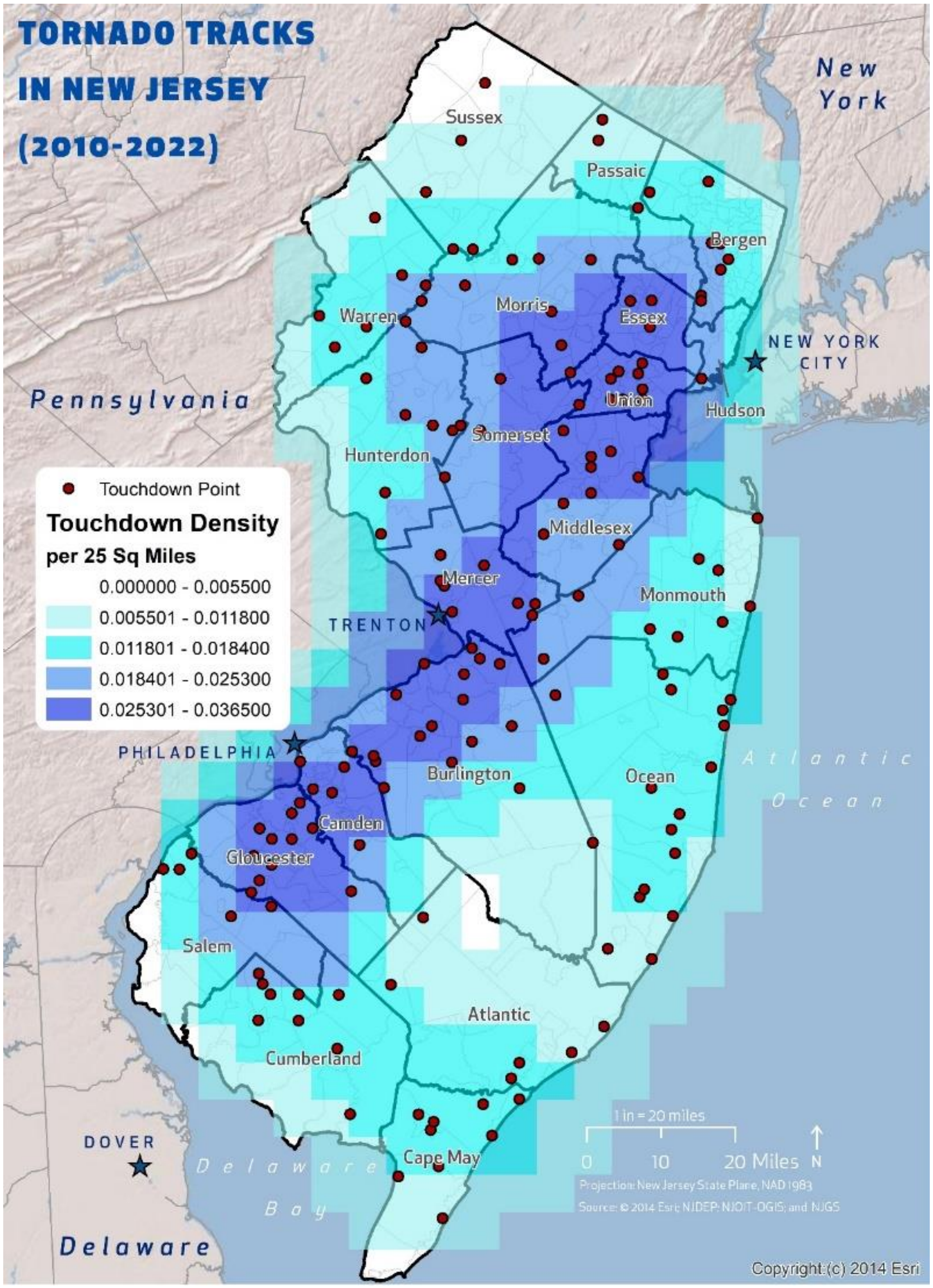
Damage to buildings is dependent upon several factors including wind speed and duration and building construction. Refer to Section 4.9: Hurricane, Nor'easter, Tropical Storm for a presentation on potential wind losses associated with high winds.

Tornado

Tornado risk and vulnerability is based on probability of occurrence of past events. As shown in Figure 4.10-7 below, the density per 25 square miles indicates the probable number of tornado touchdowns for each 25-square mile cell within the contoured zone that can be expected over a similar period of record (approximately 60 years). The highest frequency of touchdowns has occurred in a southwest to northeast band across the State. The frequency of tornado touchdowns in New Jersey is heavily biased toward areas where the population density is greatest.

Based on previous occurrences of tornado touchdowns, generally the Interstate 95 corridor in New Jersey may be more vulnerable to tornado activity than other areas. New development proximate to this corridor has the potential to increase the number of people vulnerable to the hazards associated with tornadoes.

Figure 4.10-7 Total Tornado Events per 25-Square Miles in New Jersey



Source: NOAA, 2022

Tornado events are typically localized, whereas high wind and thunderstorm events can be more widespread. The impacts of tornadoes on the environment may include severe damage to complete devastation to buildings, vegetation, and anything in its path.

To determine the vulnerability of State buildings to tornadoes, a spatial analysis was conducted using the historic tornado touch-down density. The number of State buildings in the zones of greatest historical tornado touch-down density (greater than 0.02) are presented in Tables 4.10-12 and 4.10-13 by county and agency.

Table 4.10-12 State Buildings in the Zones of Greatest Historical Tornado Touch-Down Density by County

County	Number of State Facilities
Atlantic	2
Bergen	3
Burlington	261
Camden	76
Essex	103
Gloucester	46
Hudson	21
Hunterdon	134
Mercer	665
Middlesex	315
Monmouth	53
Morris	152
Ocean	7
Passaic	48
Salem	52
Somerset	138
Union	48
Warren	4
Total	**2,128**

Source: NJOMB, 2023; NOAA, 2022

Table 4.10-13 State Buildings in the Zones of Greatest Historical Tornado Touch-Down Density by Agency

Agency	Number of State Facilities
Agriculture	10
Banking And Insurance	1
Chief Executive	2
Children and Families	71
Community Affairs	5
Corrections	427
Education	54
Environmental Protection	417
Health	210
Higher Education	1
Human Services	31
Inter-Departmental	1
Judiciary	58
Juvenile Justice Commission	142
Labor and Work Force Development	28
Law And Public Safety	11
Legislature	6

Agency	Number of State Facilities
Military And Veterans Affairs	101
Miscellaneous Commissions	1
Motor Vehicles Commission	66
Personnel	2
State	18
State Police	88
Transportation	290
Treasury	87
Total	**2,128**

Source: NJOMB, 2023; NOAA, 2022

Thunderstorms

Agricultural losses can be devastating due to lightning and resulting fires. The counties with the amount of high value crop types have the highest potential loss due to storms. Refer to Section 3.0: State Profile and Section 4.16: Crop Failure for additional details on New Jersey Agriculture, historic crop failure events and losses.

All State-owned and -leased buildings may be exposed to the effects of thunderstorms. Thunderstorms will often be accompanied by high winds and sometimes hail. Losses related to thunderstorms primarily will be structural when falling or projectile debris impacts state-owned buildings. Lightning can be responsible for damages to buildings; cause electrical, forest and/or wildfires; and damage infrastructure such as power transmission lines and communication towers. Of particular concern is radio towers used by the first responder community that are frequently struck by lightning. Current modeling tools are not available to estimate specific losses for this severe weather type.

Hailstorms

Hail causes considerable damage to United States crops and property and occasionally causes death to farm animals. All counties are considered vulnerable to the effects of hailstorms, but those with farmland and high agricultural yields are more likely to be impacted. According to the 2017 United States Department of Agriculture's Agricultural Census, the counties with the greatest number of farms are: Burlington (915 farms); Hunterdon (1,604 farms); Monmouth (838 farms); Sussex (1,008 farms) and Warren (918 farms) (United States Department of Agriculture, 2017). Refer to Section 3.0: State Profile and Section 4.16: Crop Failure for additional details on New Jersey Agriculture, historic crop failure events and losses.

Similar to thunderstorms, hailstorms may affect all State-owned and -leased buildings across New Jersey. Damages will result from the hail stones themselves and will have a specific impact on roofs of state facilities. The extent of damage will depend on the size and scope of the hailstorm. Current modeling tools are not available to estimate specific losses for this severe weather type.

Population and Economy

For the purposes of this 2024 Plan update, the entire population of New Jersey is exposed to severe weather events. Residents may be displaced or require temporary to long-term sheltering due to severe weather events. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on several factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

The entire population of the State is considered exposed to high wind events. High wind events may threaten safety, damage buildings, and impact the economy, including loss of business function, damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Recovery and clean-up costs can also be costly and impact the economy as well.

Overall, all 21 Counties are vulnerable to thunderstorms. Lightning strikes primarily occur during the summer months. People outside are considered at risk and more vulnerable to a lightning strike than those inside a shelter. This could be particularly true for the State's shore community, as many lightning strikes occur at the beach.

Ecosystems & Natural Assets

High Winds

Winds and waves are the forces that cause coastal sand dunes to change. Natural dunes are dynamic and change in response to erosion from storm events and recover via wind- and wave-driven sediment transport between storm events (NOAA, 2021).

Over time, tree develop strength and flexibility, known as wind firmness; however, windstorms can exceed a tree's wind firmness. When this happens, tree can break or blow over. Root damage can make trees more susceptible to fungi and insects and wound (debarking) can make trees more susceptible to disease or insect pests. Disturbed forestland is also more vulnerable to wildfire, pests, and invasive species (American Forest Foundation, n.d.a).

Tornadoes

Tornadoes have the potential to devastate forests due to powerful winds and associated flooding and hail. Trees can break from wind or hail damage; this has a secondary impact of making the tree more vulnerable to fungi. Tornadoes also cause bending, root damage, and wounds (debarking) and their aforementioned secondary vulnerabilities. Disturbed forestland is also more vulnerable to wildfire, pests, and invasive species (American Forest Foundation, n.d.b).

Thunderstorms

Lightening associated with thunderstorms can ignite forest fires (NJDEP, 2020). Strong, straight-line winds and hail are associated with thunderstorms; their impacts to ecosystems and natural assets also apply.

Hailstorms

Significant hailstorms can kill wildlife and livestock. For information on how hail can cause crop damage, see the Population and Economy above.