5.10 SEVERE WEATHER

SECTION 5.10 SEVERE WEATHER

5.10.1 HAZARD DESCRIPTION

Severe weather events in New Jersey are very common and can occur at any time. The severe weather profile includes high winds, tornadoes, thunderstorms, hailstorms, and extreme temperatures. The United States Natural Hazards Statistics provides statistical information on fatalities, injuries, and damages caused by weather-related hazards. These statistics were compiled by the Office of Services and the National Climatic Data Center (NCDC) from information contained in in the publication *Storm Data*. This data includes statistics on cold, flood, heat, lightning, tornado, tropical cyclone, wind, and winter storm events. Details regarding high winds, tornadoes, thunderstorms, hailstorms, and extreme temperatures (heat and cold) are discussed below.

High Winds

High winds, other than tornadoes, are experienced in all parts of the United States. Areas that experience the highest wind speeds are coastal regions from Texas to Maine, and the Alaskan coast; however, exposed mountain areas experience winds at least as high as those along the coast (FEMA, 1997; Robinson, 2013). In New Jersey, the northwest ridge tops most often experience the highest winds in the State, followed by the coastal locations (Robinson, 2013). Wind begins with differences in air pressures. It is rough horizontal movement of air caused by uneven heating of the earth's surface. Wind occurs at all scales, from local breezes lasting a few minutes to global winds resulting from solar heating of the earth. Effects from high winds can include downed trees and power lines, and damages to roofs, windows, etc. (Ilicak, 2005). The following table provides the descriptions of winds used by the NWS.

Table 5.10-1 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 mph

Extreme windstorm events are associated with extra-tropical and tropical cyclones, winter cyclones, severe thunderstorms, and accompanying mesoscale offspring such as tornadoes and downbursts. Winds 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 experienced often 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 and often has isolated gusts exceeding 75 mph. This means that trees generally fall, and debris is blown in one direction. 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 (ONJSC Rutgers University, 2013a).

Tornadoes

Tornadoes are nature's most violent storms and can cause fatalities and devastate neighborhoods in seconds. A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 250 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 typically move at speeds between

30 and 125 mph and can generate internal winds exceeding 300 mph. 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 September/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. Thunderstorms form from the equator to as far north as Alaska. These storms occur most commonly in the tropics. Many tropical land- based locations experience over 100 thunderstorm days each year (Pidwirny, 2007). Although thunderstorms generally affect a small area when they occur, they have the potential to become dangerous due to their ability in generating tornadoes, hailstorms, 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).

The rising air in a thunderstorm cloud causes various types of frozen precipitation to form within the cloud, which includes very small ice crystals and larger pellets of snow and ice. The smaller ice crystals are carried upward toward the top of the clouds by the rising air while the heavier and denser pellets are either suspended by the rising air or start falling towards the ground. Collisions occur between the ice crystals and the pellets, and these collisions serve as the charging mechanism of the thunderstorm. The small ice crystals become positively charged while the pellets become negatively charged, resulting in the top of the cloud becoming positively charged and the middle to lower part of the storm becoming negatively charged. At the same time, the ground below the cloud becomes charged oppositely. When the charge difference between the ground and the cloud becomes too large, a small amount of charge starts moving toward the ground. When it nears the ground, an upward leader of opposite charge connects with the step leader. At the instant this connection is made, a powerful discharge occurs between the cloud and ground. The discharge is seen as a bright, visible flash of lightning (NOAA, 2012). Thunder is the sound caused by rapidly expanding gases in a lightning discharge (NWS, 2009c).

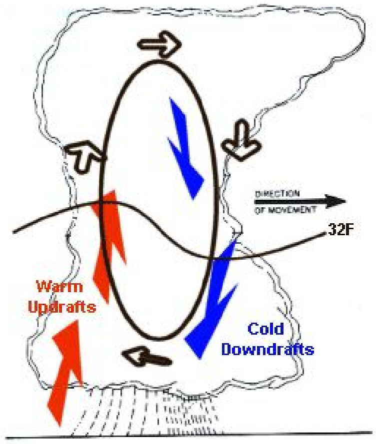
In the United States, an average of 300 people are injured and 80 people are killed by lightning each year. Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes. An estimated 100,000 thunderstorms occur each year in the United States, with approximately 10% of them classified as severe. 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 two inches in diameter (NWS 2010). Figure 5.10-1 illustrates the process that occurs in hail formulation.

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

Figure 5.10-1 Hail Formation



Source: NOAA 2012

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.

Extreme Temperatures

Extreme temperature includes both heat and cold events, which can have significant impact to human health, commercial/agricultural businesses, and primary and secondary effects on infrastructure (e.g., burst pipes and power failures). What constitutes as extreme cold or extreme heat can vary across different areas of the United States, based on what the population is accustomed to.

New Jersey has four well-defined seasons. The seasons have several defining factors, with temperature one of the most significant. Extreme temperatures can be defined as those that are far outside the normal ranges for the season. The average temperatures for New Jersey are listed in Table 5.10-2.

Table 5.10-2 Average Temperatures in New Jersey

Month	30 Year Normal	Mean Temperature	Median Temperature	Minimum Temperature	Maximum Temperature
January	30.7	29.8	29.8	18.7	41
February	33.4	30.8	30.9	17.2	40.4
March	40.8	39.4	39.1	30.4	49.8
April	50.9	49.7	49.4	43.8	55.9
May	60.5	60.1	60	53.1	66
June	69.8	68.8	68.9	63.1	73.9
July	74.6	73.8	73.6	69.4	78.4
August	73	71.9	71.8	66.2	76.9
September	65.8	65.3	65.2	60.2	70.8
October	54.5	54.2	54.2	47.7	62.1
November	45.2	43.5	43.4	36.6	49.6
December	35.2	33.5	33.8	22.7	48
Annual	52.9	51.7	51.6	47.8	55.9

Source: ONJSC Rutgers University, 2017

In New Jersey, temperatures fall below freezing on as many as 150 days each year in the coldest portions of the northwest portion of the State, while less than 75 days below freezing occur along the southern coast. The average lies between 90 and 100 days over two-thirds of the State. Minimal temperatures during the three core winter months of December, January, and February average below freezing (≤32°F) over the entire State, with the exception of some southern coastal locations in December. Generally, the minimal temperature averages 20°F during these months, with the exception of northwest, where January and February averages can drop into the teens. March temperatures run in the upper 20°F to low 30°F in the northern half of the State and the low to mid 30°F in the southern portion. The Pinelands are somewhat colder than the adjacent coast and southwest farmland, and an urban heat island bias was identified near Newark (ONJSC Rutgers University, 2013d).

Lows equal to or below 20°F occur on more than 60 days annually in the northwest, while only one-third of that number are found in southern coastal locations. A majority of the State experiences these temperatures on 20 to 30 days of the year. Below 0°F lows, on average, occur only a day or two a year over most of the State. Exceptions are the northwest where as many as six days or slightly more, on average, exhibit these temperatures (ONJSC Rutgers University, 2013).

The following are some of the lowest temperatures recorded for the period from 1893 to 2018:

- Atlantic City International Airport: -11 °F (February 1979)
- Atlantic City Station: -4°F (January 1893)
- Newark: -8°F (January 1985)

Extreme cold events are when temperatures drop well below normal in an area. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered “extreme cold.” Extreme cold temperatures are generally characterized in temperate zones by the ambient air temperature dropping to approximately 0ºF or below (Centers of Disease Control and Prevention [CDC] 2005).

Exposure to cold temperatures, whether indoors or outside, can lead to serious or life-threatening health problems such as hypothermia, cold stress, frostbite or freezing of the exposed extremities such as fingers, toes, nose, and ear lobes. Hypothermia occurs when the core body temperature is <95ºF. If persons exposed to excessive cold are unable to generate enough heat (e.g., through shivering) to maintain a normal core body temperature of 98.6ºF, their organs (e.g., brain, heart, or kidneys) can malfunction. When brain function deteriorates, persons with hypothermia are less likely to perceive the need to seek shelter. Signs and symptoms of hypothermia (e.g., lethargy, weakness, loss of coordination, confusion, or uncontrollable shivering) can increase in severity as the body's core temperature drops (CDC 2005).

Extremely cold temperatures often accompany a winter storm, which can cause power failures and icy roads. Although staying indoors as much as possible can help reduce the risk of car crashes and falls on the ice, individuals may also face indoor hazards. Many homes will be too cold—either due to a power failure or because the heating system is not adequate for the weather. The use of space heaters and fireplaces to keep warm increases the risk of household fires and carbon monoxide poisoning (CDC 2007).

Excessive summer temperatures in New Jersey are often identified through counts of days with maximum temperatures greater than or equal to 90°F and greater than or equal to 100°F. Interior lowlands of the State have the largest number of such days, experiencing, on average, 20 to 30 days of greater than or equal to 90°F. Fewer than 10 days of temperatures greater than or equal to 90°F occur each summer along the coast and at higher elevations. Days when temperatures are equal to or greater than 100°F are rare throughout New Jersey and average one day or less each year (ONJSC Rutgers University 2013d).

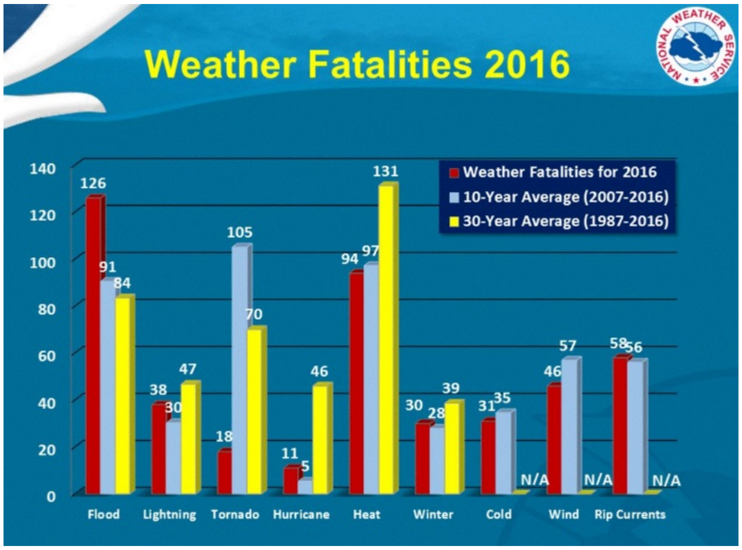
The following are some of the highest temperatures recorded for the period from 1893 to 2018:

- Atlantic City International Airport: 106°F (June 1967)
- Atlantic City Station: 104°F (August 1918)
- Newark: 108°F (August 2001)

Conditions of extreme heat are defined as summertime temperatures that are substantially hotter and/or more humid than average for a location at that time of year (CDC 2009). An extended period of extreme heat of three or more consecutive days is typically called a heat wave and is often accompanied by high humidity (NWS 2005). There is no universal definition of a heat wave because the term is relative to the usual weather in a particular area. The term heat wave is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century (Meehl and Tebaldi 2004). A basic definition of a heat wave implies that it is an extended period of unusually high atmosphere-related heat stress, which causes temporary modifications in lifestyle and which may have adverse health consequences for the affected population (Robinson, 2000). A heat wave is defined has three consecutive days of temperatures ≥90°F.

NOAA indicates that extreme heat is the number one weather-related cause of death in the United States. On average, excessive heat claims more lives each year than floods, lightning, tornadoes, and hurricanes combined. In 2012, New Jersey reported one heat-related fatality (NOAA 2012). As seen in Figure 5.10-2, heat had the highest average of weather related fatalities nationally in 2012 (155 fatalities), with one of those fatalities occurring in New Jersey.

Figure 5.10-2 Weather Fatalities for 2016 in the U.S.



Source: NWS, 2016

Urbanized areas and urbanization creates an exacerbated type of risk during an extreme heat event, compared to rural and suburban areas. As defined by the United States Census Bureau, urban areas are classified as all territory, population, and housing units located within urbanized areas and urban clusters. The term urbanized area denotes an urban area of 50,000 or more people. Urban areas under 50,000 people are called urban clusters. The United States Census delineates urbanized area and urban cluster boundaries to encompass densely settled territory, which generally consists of:

- A cluster of one or more block groups or census blocks each of which has a population density of at least 1,000 people per square mile at the time.
- Surrounding block groups and census blocks each of which has a population density of at least 500 people per square mile at the time.
- Less densely settled blocks that form enclaves or indentations or are used to connect discontinuous areas with qualifying densities (United States Census 2003).

As these urban areas develop and change, so does the landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist are now impermeable and dry. These changes cause urban areas to become warmer than the surrounding areas. This forms an 'island' of higher temperatures (United States Environmental Protection Agency [EPA] 2009).

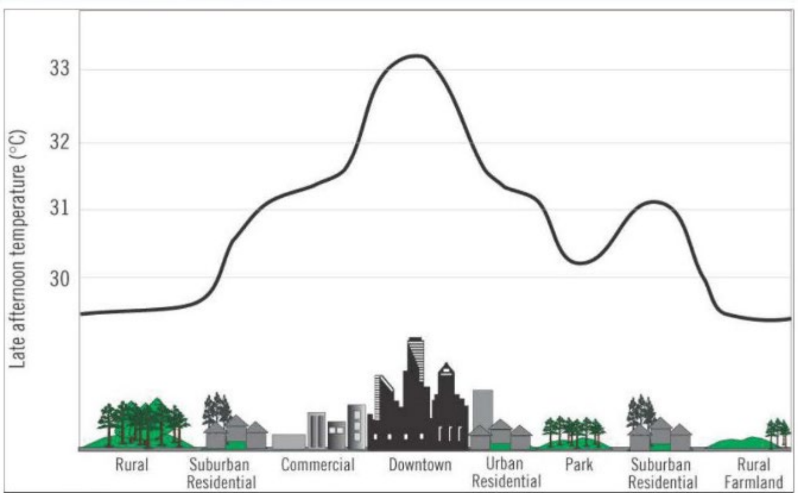
The term 'heat island' describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with more than one million people can be between 1.8ºF and 5.4ºF warmer than its surrounding areas. In the evening, the difference in air temperatures can be as high as 22ºF. Heat islands occur on the surface and in the atmosphere. On a hot, sunny day, the sun can heat dry, exposed urban surfaces to temperatures 50ºF to 90ºF hotter than the air. Heat islands can affect communities by increasing peak energy demand during the summer, air conditioning costs, air pollution and greenhouse gas emissions, heat- related illness and death, and water quality degradation (EPA 2010 and 2011). Detailed information regarding the effects of heat islands is described below.

- Elevated summer temperatures increase the energy demand for cooling. Research has shown that for every 1ºF, electricity demand increases between 1.5% and 2%, starting when temperatures reach between 68ºF and 77ºF. Urban heat islands increase overall electricity demand, as well as peak demand. This generally occurs during hot, summer afternoons when homes and offices are running cooling systems, electricity, and appliances. During extreme heat events, the demand for cooling can overload systems and require utility companies to institute controlled brownouts or blackouts to prevent power outages (EPA 2011).

- Urban heat islands raise the demand for electricity during the summer. Companies that provide the electricity generally rely on fossil fuel power plants to meet the demand. This can lead to an increase in air pollution and greenhouse gas emissions. The primary pollutants include sulfur dioxide (SO_2), nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and carbon dioxide (CO_2). These could all contribute to future global climate change. Elevated temperatures can also directly increase the rate of ground-level ozone formation. Ground-level ozone is formed when NOx and volatile organic compounds (VOC) react to the presence of sunlight and hot weather (EPA, 2011).
- Increased temperatures and higher air pollution levels can affect human health by causing discomfort, respiratory difficulties, heat cramps and exhaustion, heat stroke, and mortality. Heat islands can also intensify the impact of heat waves. High risk populations are at particular risk from extreme heat events (EPA, 2011).
- Urban areas often have many buildings and paved areas. During the hot summer months, high pavement and rooftop surface temperatures can heat storm water runoff. Pavements that are 100ºF can elevate initial rainwater temperature from approximately 70ºF to over 95ºF. The heated stormwater usually becomes runoff and drains into storm sewers and raises water temperatures of streams, rivers, ponds, and lakes. Water temperature affects aquatic life. Rapid temperature changes in aquatic ecosystems from storm water runoff can be stressful and sometimes fatal to aquatic habitats (EPA, 2011).

Figure 5.10-3 below illustrates an urban heat island profile. The graphic demonstrates that heat islands are typically most intense over dense urban areas. Further, vegetation and parks within a downtown area may help reduce heat islands (EPA, 2008).

Figure 5.10-3 Urban Heat Island Profile



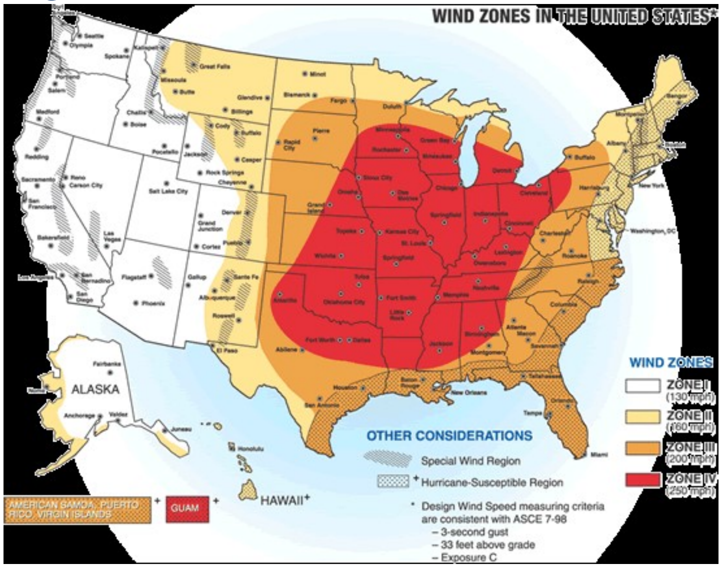
Source: EPA 2008

5.10.2 LOCATION

High Winds

Figure 5.10-4 indicates how the frequency and strength of windstorms impacts the United States and the general location of the most wind activity. This is based on 40 years of tornado data and 100 years of hurricane data, collected by FEMA. States located in Wind Zone IV have experienced the greatest number of tornadoes and the strongest tornadoes. New Jersey is located within Wind Zone II, which may experience wind speeds up to 160 mph. The entire State is also located within the hurricane-susceptible region. Table 5.10-4 describes the areas affected by the different United States wind zones.

Figure 5.10-4 Wind Zones in the United States

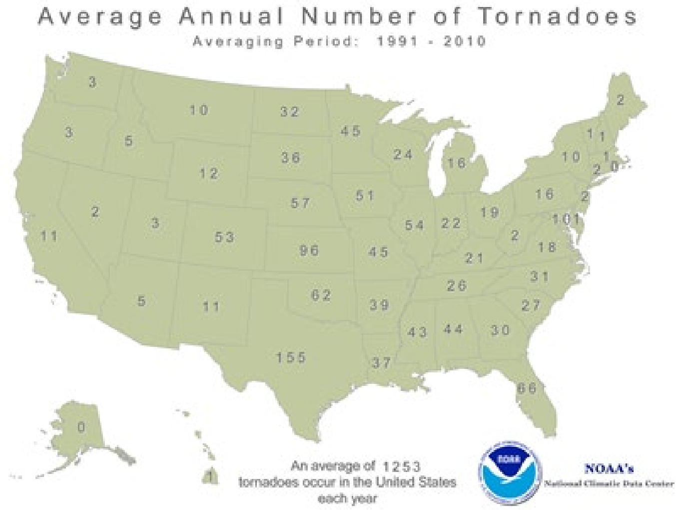


Source: FEMA, 2012 mph

Tornadoes

The United States experiences more tornadoes than any other country. In a typical year, approximately 1,000 tornadoes affect the United States. The peak of the tornado season is April through June, with the highest concentration of tornadoes in the central United States. 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 5.10-5 shows the annual average number of tornadoes between 1991 and 2010. Based on the number of tornadoes that have occurred in New Jersey between 1986 and 2016 (91 events); New Jersey can expect to experience an average of two to three tornadoes each year.

Figure 5.10-5 Annual Average Number of Tornadoes in the United States, 1954 to 2010



Source: NOAA, 2014

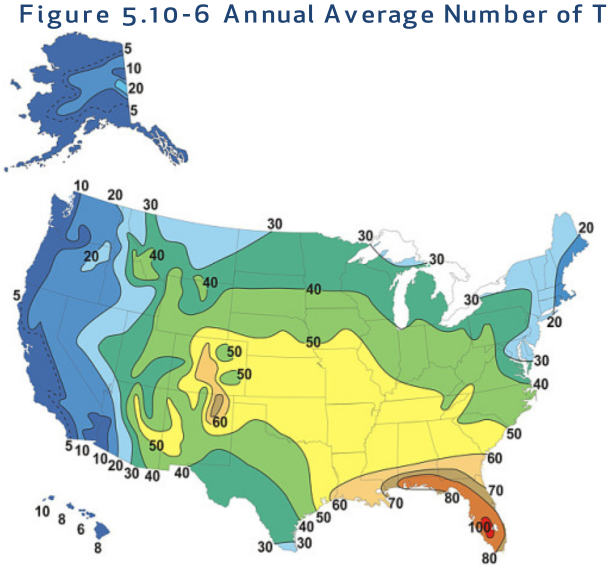
Table 5.10-3 Wind Zones in the United States

Wind Zone	Areas Affected
Zone I (≤130 mph)	All of Washington, Oregon, California, Idaho, Utah, and Arizona. Western parts of Montana, Wyoming, Colorado, and New Mexico. Most of Alaska, except the east and south coastlines.
Zone II (131 - 160 mph)	Eastern parts of Montana, Wyoming, Colorado, and New Mexico. Most of North Dakota. Northern parts of Minnesota, Wisconsin, and Michigan. Western parts of South Dakota, Nebraska, and Texas. All New England States. Eastern parts of New York, Pennsylvania, Maryland, and Virginia. All of New Jersey, Delaware, and Washington, DC.
Zone III (161 - 200 mph)	Areas of Minnesota, South Dakota, Nebraska, Colorado, Kansas, Oklahoma, Texas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, Pennsylvania, New York, Michigan, and Wisconsin. Most or all of Florida, Georgia, South Carolina, North Carolina, Virginia, and West Virginia. All of American Samoa, Puerto Rico, and Virgin Islands.
Zone IV (201 - 250 mph)	Mid United States including all of Iowa, Missouri, Arkansas, Illinois, Indiana, and Ohio and parts of adjoining states of Minnesota, South Dakota, Nebraska, Kansas, Oklahoma, Texas, Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, Pennsylvania, Michigan, and Wisconsin. Guam.
Special Wind Region	Isolated areas in the following states: Washington, Oregon, California, Idaho, Utah, Arizona, Montana, Wyoming, Colorado, New Mexico. The borders between Vermont and New Hampshire; between New York, Massachusetts and Connecticut; between Tennessee and North Carolina.
Hurricane Susceptible Region	Southern United States coastline from Gulf Coast of Texas eastward to include entire state of Florida. East Coastline from Maine to Florida, including all of Massachusetts, Connecticut, Rhode Island, New Jersey, Delaware, and Washington DC. All of Hawaii, Guam, American Samoa, Puerto Rico and Virgin Islands.

Thunderstorms

Thunderstorms affect relatively small localized areas, rather than large regions like winter storms and hurricane events. Thunderstorms can strike in all regions of the United States; however, they are most common in the central and southern states.

Figure 5.10-6 Annual Average Number of Thunderstorm Days in the United States



Source: NWS 2010

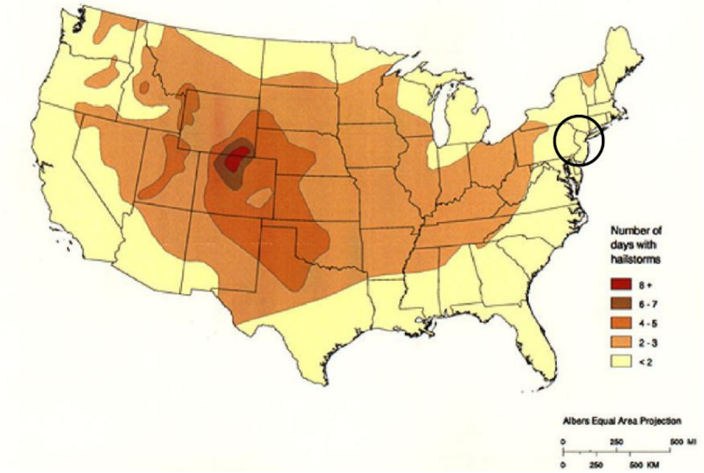
The atmospheric conditions in these regions of the country are ideal for generating these powerful storms. It is estimated that there are as many as 40,000 thunderstorms each day worldwide. Figure 5.10-6 shows the average number of thunderstorm days throughout the United States. The most thunderstorms are seen in the southeast states, with Florida having the highest incidences (80 to over 100 thunderstorm days each year). Figure 5.10-6 illustrates that locations in New Jersey experience between 20 and 30 thunderstorm days each year (NWS 2009d; NWS 2010).

Thunderstorms spawned in Pennsylvania and New York State often move into northern New Jersey, where they usually reach maximum development during the evening hours. This region of the State has 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.

Hailstorms

Hail causes nearly $2 billion in crop and property damages, on average, each year in the United States. Hail occurs most frequently in the southern and central plain states; however, since hail occurs with thunderstorms, the possibility of hail damage exists throughout the entire United States (Federal Alliance for Safe Homes, 2006). Figure 5.10-7 indicates that New Jersey experiences less than two hailstorms a year, on average.

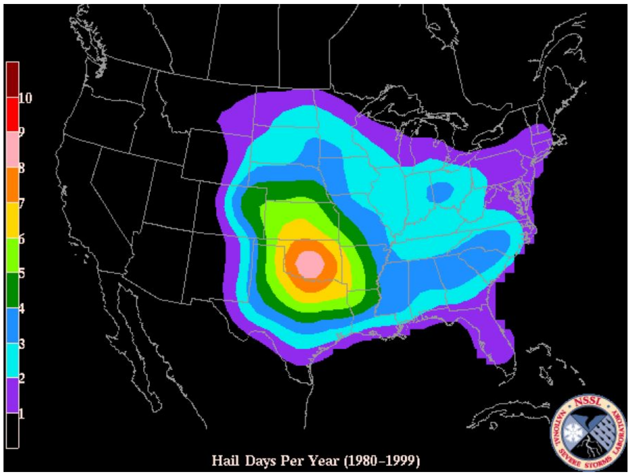
Figure 5.10-7 Annual Frequency of Hailstorms in the United States



Source: FEMA, 1996
Note: The circle represents the approximate location of New Jersey

NOAA's National Severe Storms Laboratory (NSSL) started a project that estimates the likelihood of severe weather hazards in the United States. Severe thunderstorms were defined in the United States as having either tornadoes, gusts at least 58 mph, or hail at least 0.75-inch in diameter. Figure 5.10-8 illustrates the average number of days per year of hail events occurring within 25 miles of any point. In New Jersey, the figure shows an average of one to two days per year of hail events at least 0.75-inch diameter.

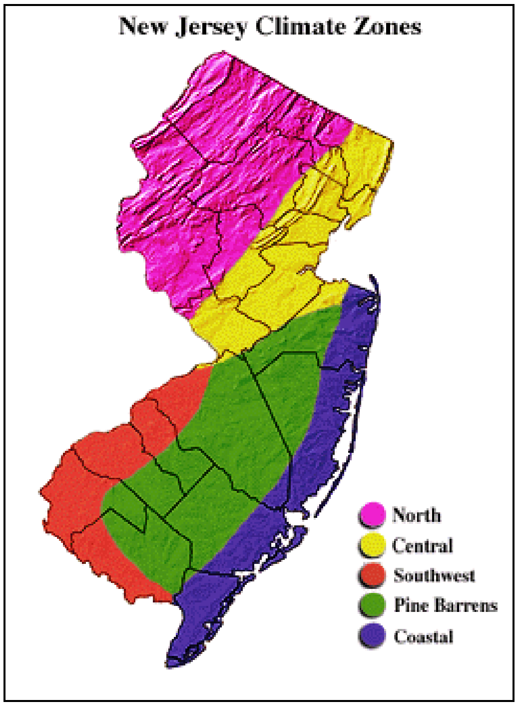
Figure 5.10-8 Total Annual Threat of Hail Events (0.75-inch diameter or greater) in the United States, 1980 to 1999



Source: NSSL, 2003

Extreme Temperatures

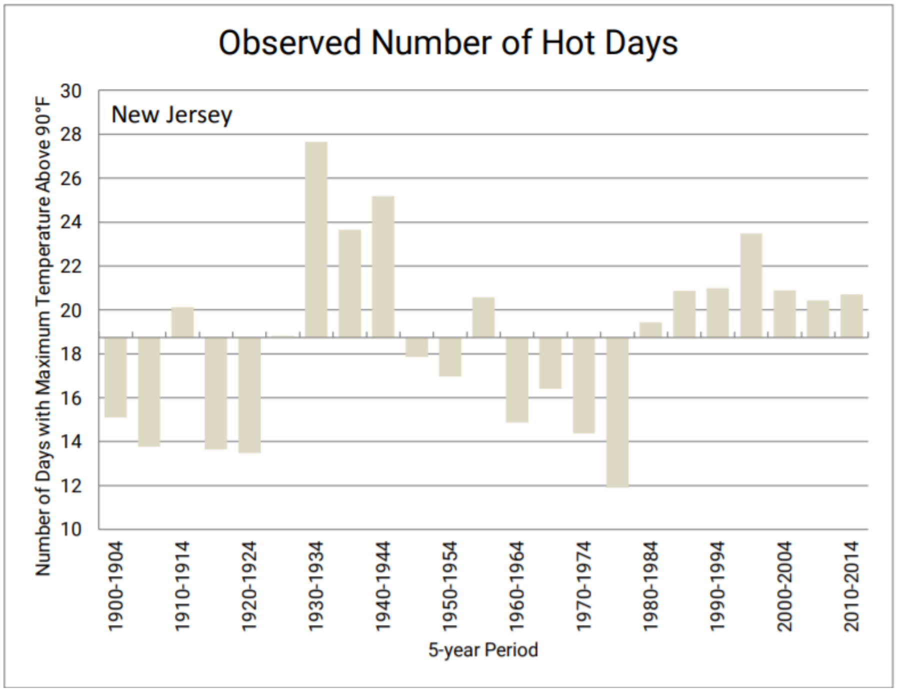
The location of extreme temperatures throughout the State are further identified below. For a discussion regarding drought locations, refer to Section 5.4 (Drought). According to the ONJSC, New Jersey has five distinct climate regions. Elevations, latitude, distance from the Atlantic Ocean, and landscape (e.g. urban, sandy soil) produce distinct variations in the daily weather between each of the regions. The five regions include: Northern, Central, Pine Barrens, Southwest, and Coastal. Further descriptions regarding each of the climate divisions can be found in Section 4 State Profile.



According to 2017 NOAA National Centers for Environmental Information, State Summaries 149—NJ, "New Jersey's geographic position in the mid-latitudes often places it near the jet stream, particularly in the late fall, winter, and spring. This gives the state its characteristic changeable weather… New Jersey's climate is characterized by moderately cold and occasionally snowy winters and warm, humid summers" (Jennifer Runkle, Kenneth E. Kunkel). The report continues to state the annual temperatures in New Jersey have increased approximately 3°F since the beginning of the 20th century, where nine of the ten hottest years on record have occurred since 1990, with 2012 as the hottest year on record at the time of the report. The observed number of days with maximum temperatures above 90°F between 1900 and 2014 are displayed in Figure 5.10-9 "Observed Number of Hot Days" (maximum temperature above 90°F), Figure 5.10-10 "Observed Number of Very Hot Days" (maximum temperature above 95°F), and Figure 5.10-10 "Observed Number of Extremely Hot Days" (maximum temperature above 100°F).

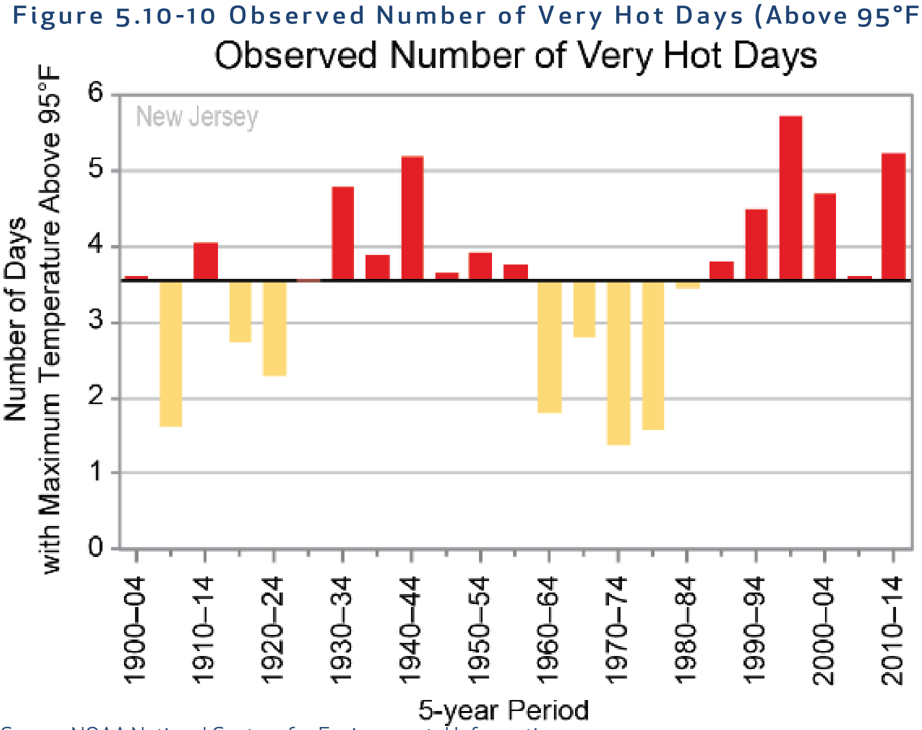
In 2018, the National Climatic Data Center (NCDC) in Trenton, NJ published two preliminary Climate Summaries for the years 2015 and 2017, which list the number of days in each year with a maximum temperature greater than 90°F. In 2015, the number of days with maximum temperature greater than 90°F was 27, 11.2 above the normal value; in 2017, 17 days had a maximum temperature greater than 90°F, 1.5 above the normal value.

Figure 5.10-9 Observed Number of Hot Days (Above 90°F)



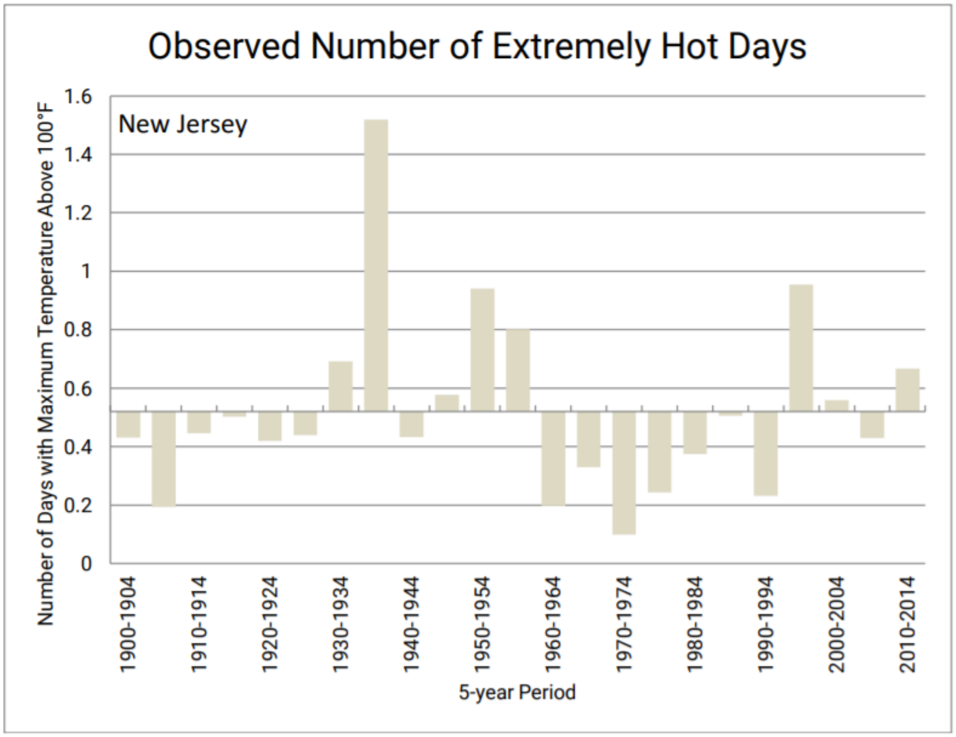
Source: NOAA National Centers for Environmental Information

Figure 5.10-10 Observed Number of Very Hot Days (Above 95°F)



Source: NOAA National Centers for Environmental Information

Figure 5.10-11 Observed Number of Extremely Hot Days (Above 100°F)



Source: NOAA National Centers for Environmental Information

Locations that are more prone to heat include inland urban areas. Cities are the most susceptible to the stresses of heat waves. Urban areas tend to have the largest populations and therefore, amplify the effects of heat. ONJSC conducted a study from 1997 to 2010 on summer heat at the NWS observing station located at Newark Liberty International Airport. The frequency of hot days, those with a maximum air temperature of 90°F or greater, or a heat index of that magnitude, was recorded during the study. Conditions were observed and recorded daily and hourly and also included information for 100°F. During the 14-year study, there was an average of 26 days each year with maximum temperatures ≥90°F. This ranged from 13 days in 2004, to 54 days in 2010. On average, the heat index was ≥90°F for 30 days each year. The temperature was ≥90°F for 124 hours in an average year, with a maximum of 319 hours in 2010. The average was 197 hours per year for the heat index. On ≥90°F days, the temperature remained at that level for an average of 4.4 hours and the heat index for 6.7 hours. Heat waves were also scrutinized during the ONJSC study. The maximum number of consecutive days of ≥90°F was 14 from July 16 to 29, 2010 (ONJSC Rutgers University 2010).

The NWS Automated Surface Observing Station (ASOS) was installed in 1996 in a grassy field between the outermost runway and the New Jersey Turnpike, roughly opposite of Terminal A of Newark Airport. The terrain in the area is flat and marshy, and there is a drainage canal between the station and the Turnpike. Less than a mile to the east is the Newark Bay and just beyond that is the New York Harbor. The majority of the land within a mile of the airport is covered with pavement or rooftops. Downtown Newark is located several miles to the north, and the City of Elizabeth is located to the south of the ASOS. To the northwest are ridges oriented roughly in a south-southwest to north-northwest direction. They rise to an elevation of approximately 200 feet at 4.5 to 5 miles and to 500 to 600 feet at seven to eight miles. The land up to the ridges is heavily developed urban/suburban (ONJSC Rutgers University 2010).

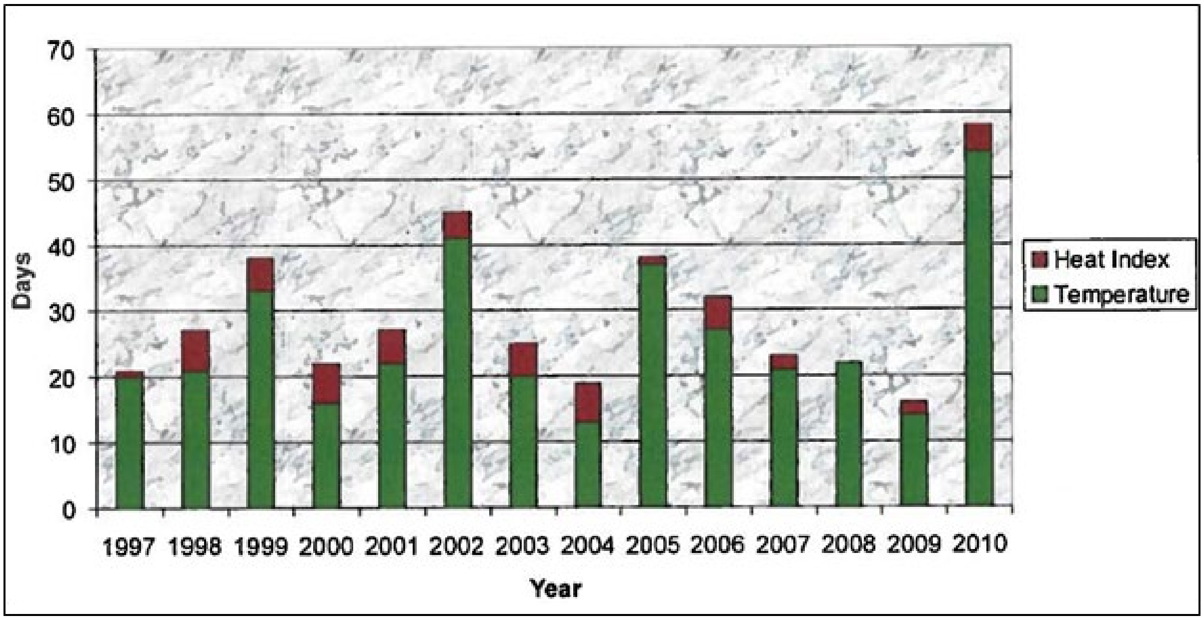
The ASOS weather station records temperature approximately five feet above the grassy surface. While Newark Airport observations date back to the early 1930s, the most recent 14 years were evaluated due to the change in landscape, relocation of the weather station, and the determination that the thermistor at Newark was faulty and read a degree or more too high from June 1992 through November 1994 (ONJSC Rutgers University 2010).

The results from the study provided the following:

- **Maximum temperature ≥90°F** – on average, there were 124 hours ≥90°F annually, with a maximum of 319 hours in 2010 and a minimum of 30 hours in 2004. On average, ≥90°F was reached 26 days each year, with a maximum of 54 days ≥90°F in 2010 and a minimum of 13 days ≥90°F in 2004.
- On days where the temperature was ≥90°F, the average maximum temperature for the day was 93°F, with a maximum of 105°F on August 9, 2001. On days where the temperature was ≥90°F, the average maximum heat index for the day was 95°F, with a maximum temperature of 112°F on July 5, 1999.
- Days where the temperature was ≥90°F, the temperature stayed at ≥90°F for an average of 4.4 hours. The annual maximum was 5.6 hours/day in 1999 and the daily maximum was 15 hours on July 5-6, 1999 and July 5-6, 2010. On days where the temperature was ≥90°F, the heat index was ≥90°F for 2.3 hours longer than the temperature was at or above this mark. The daily maximum was 21 hours on July 5, 1999, August 1, 2006, and August 2, 2006.

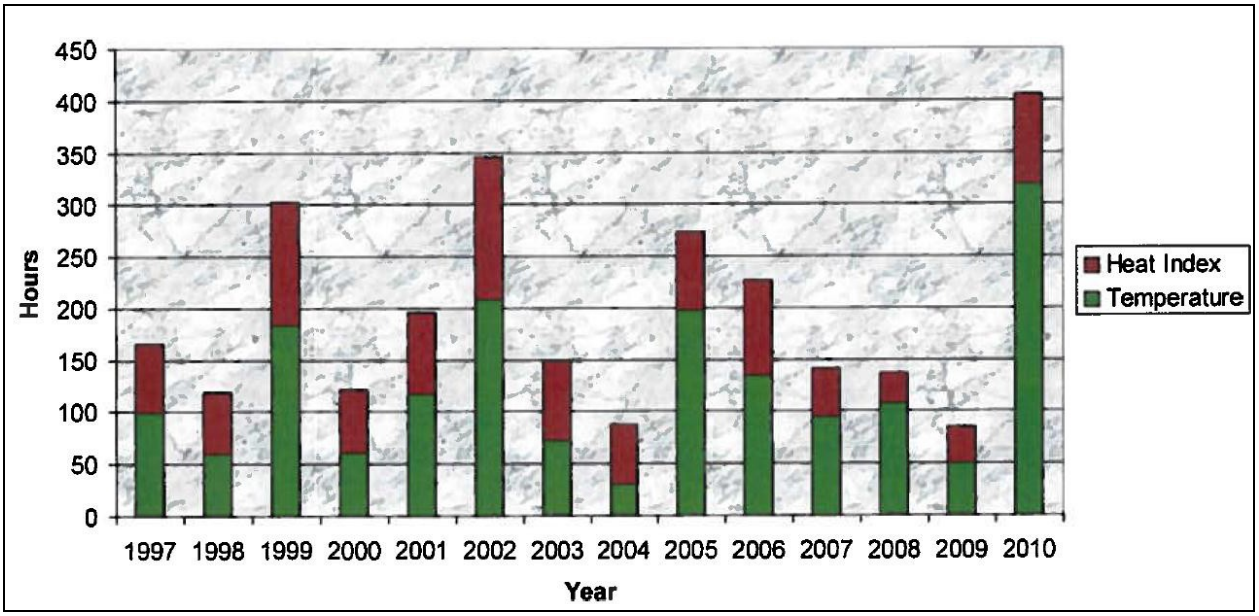
Figure 5.10-12 through Figure 5.10-14 illustrates these observations.

Figure 5.10-12 ≥90°F Days Per Year in Newark, 1997 through 2010



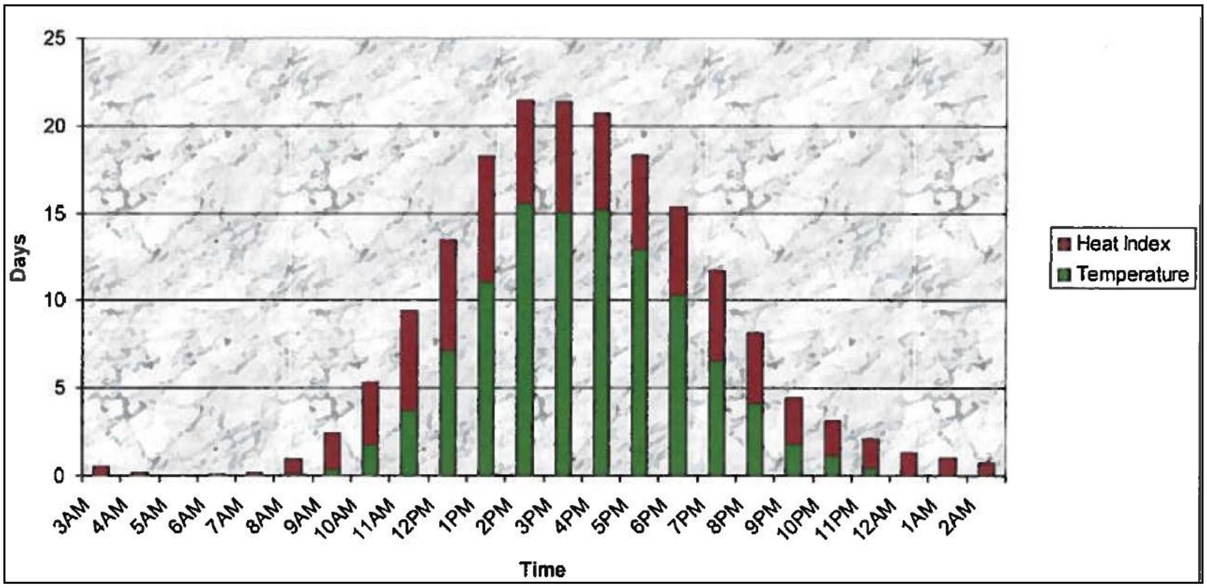
Source: ONJSC Rutgers University 2010

Figure 5.10-13 ≥90°F Hourly Observations Per Year in Newark, 1997 through 2010



Source: ONJSC Rutgers University 2010

Figure 5.10-14 Average Days Per Year ≥90°F by Hour in Newark, 1997 through 2009



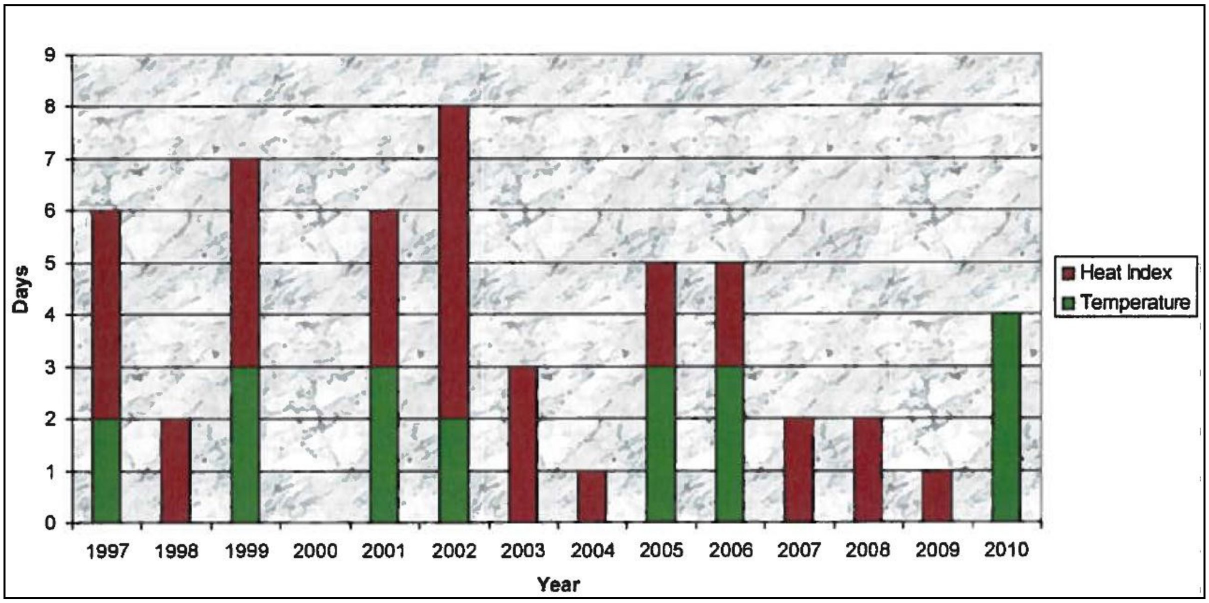
Source: ONJSC Rutgers University 2010

Additional results from the study provided the following:

- **Heat Waves** – on average, heat waves lasted five days, with a maximum of 14 from July 16 to 29, 2010. On average, there were four heat waves per year, with a maximum of seven in 1999 and 2010 and a minimum of zero in 2004. The average duration of heat waves was 93 hours (from the first hourly reading ≥90°F until the last one), with a maximum of 317 hours during the July 2010, heat wave. From the start to the end of heat waves, approximately 26% of hours were spent below 80°F, with a minimum of 4% from August 11 to 14, 2005.
- **Heat Index ≥90°F** – on average, approximately 197 hours were spent with the heat index ≥90°F annually, with a maximum of 406 hours in 2010 and a minimum of 85 hours in 2009. On average, a heat index of ≥90°F was reached on 30 days annually, with a maximum of 58 in 2010 and a minimum of 16 in 2009. On days where the heat index was ≥90°F, the average maximum heat index for the day was 95°F, with a maximum of 112°F on July 5, 1999.
- **Temperatures ≥100°F** – on average, 2.4 hours were spent at ≥100°F annually. The following table summarizes the number of days each year that had temperatures ≥100°F.

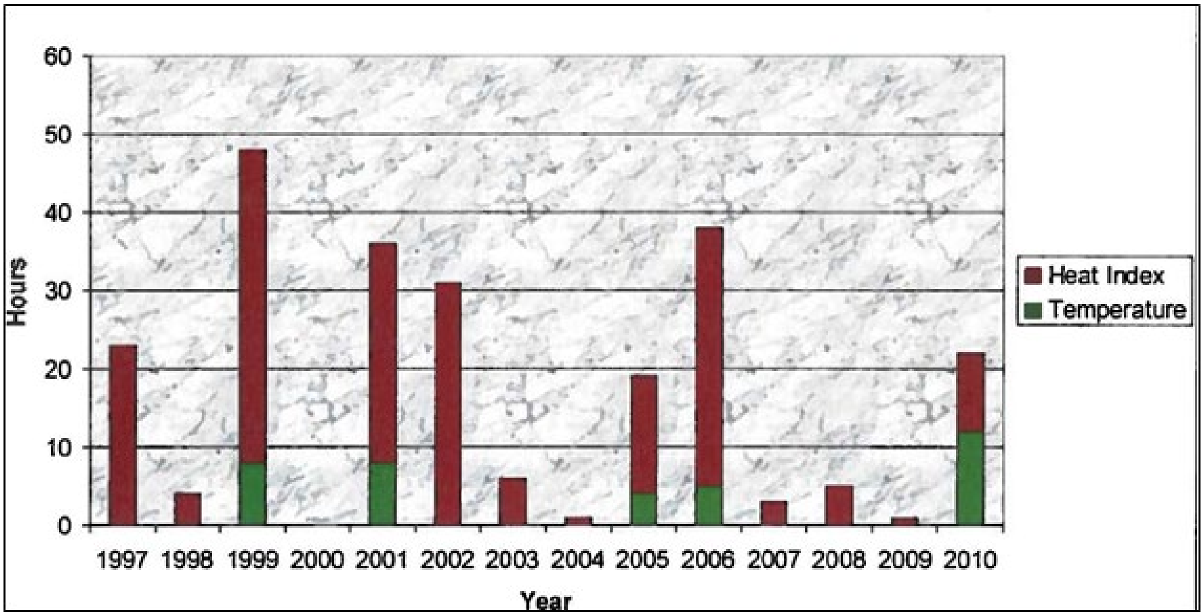
Figure 5.10-15 through Figure 5.10-17 further illustrates these observations.

Figure 5.10-15 ≥100°F Days per Year in Newark, 1997 to 2010



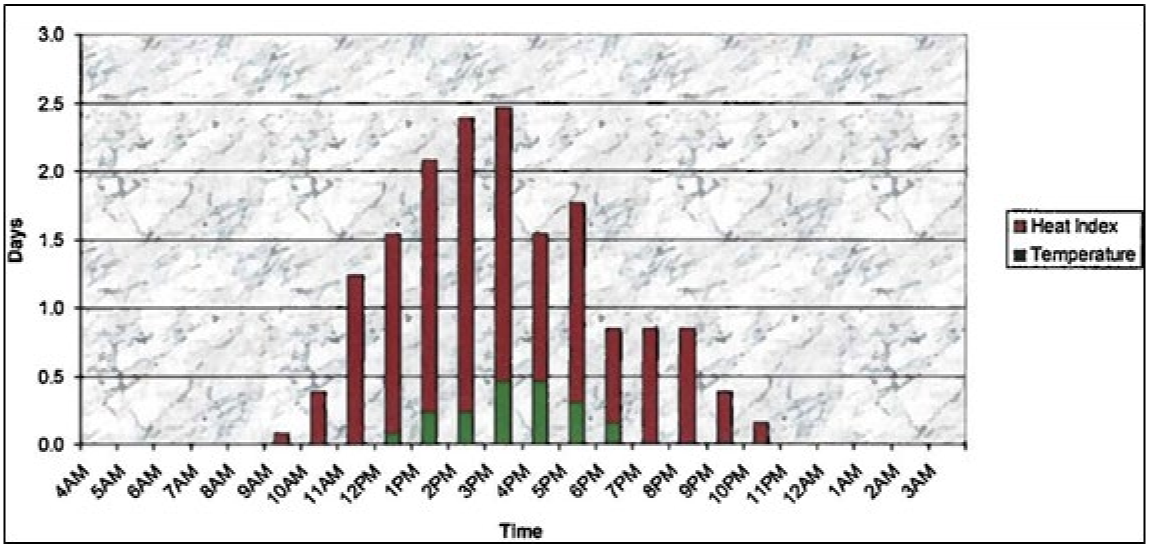
Source: ONJSC Rutgers University

Figure 5.10-16 100°F Hourly Observations by Year in Newark, 1997 to 2010



Source: ONJSC Rutgers University

Figure 5.10-17 Average Days per Year ≥100°F by Hour in Newark, 1997 to 2009

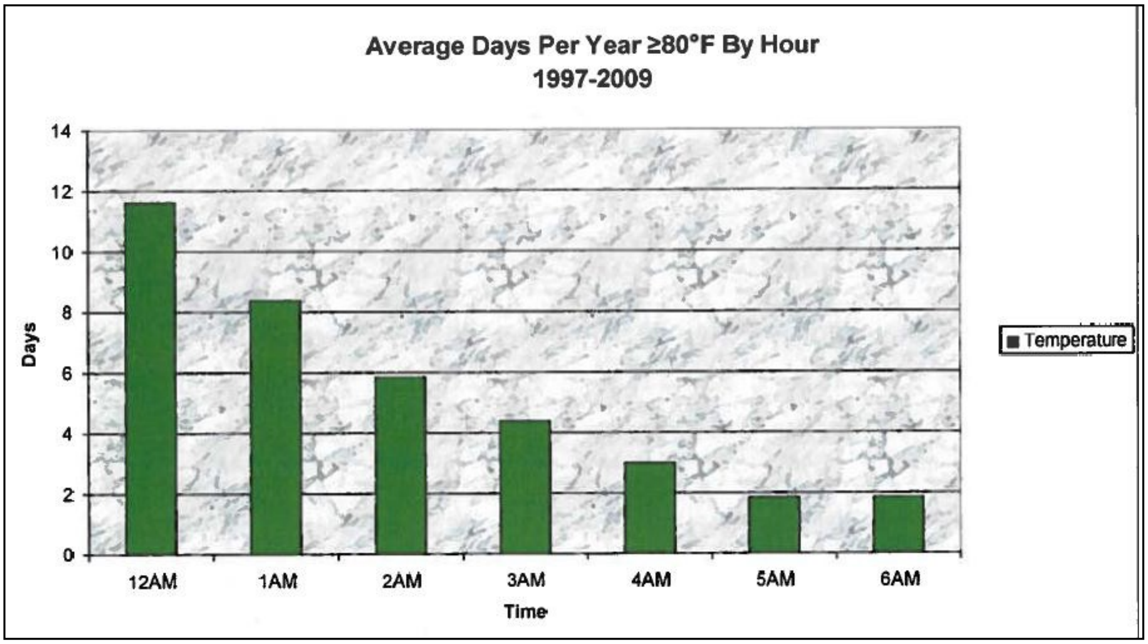


Source: ONJSC Rutgers University

Additional results from the study provided the following:

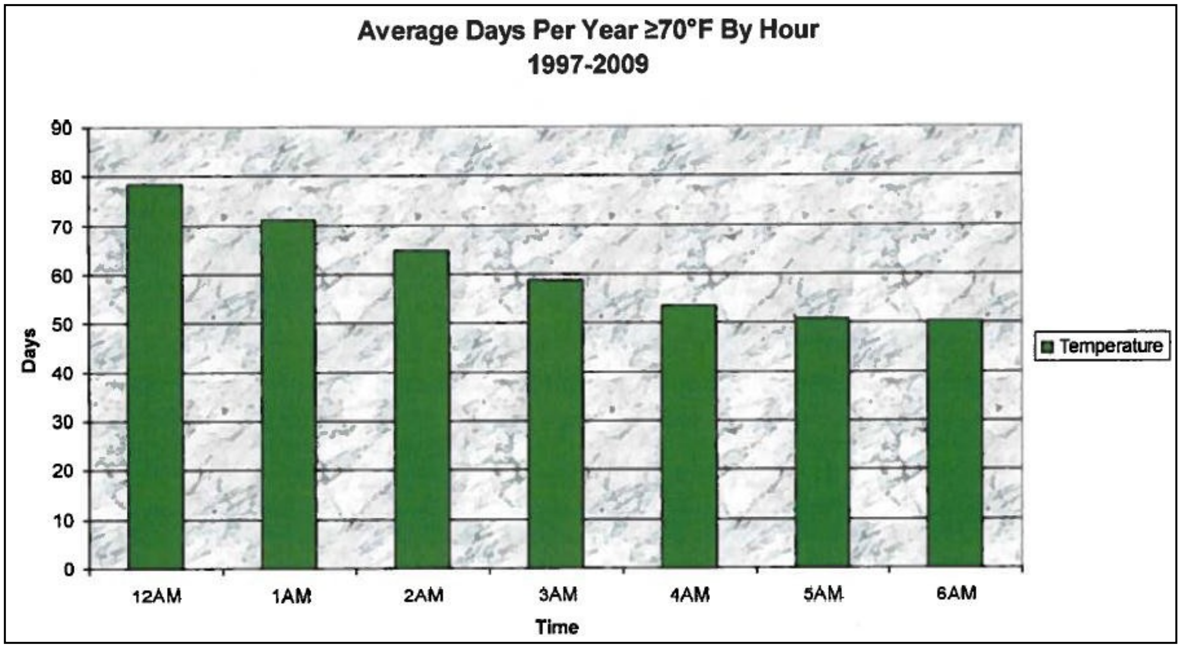
- Warm nighttime temperatures – On average, two days per year had 5 a.m. and 6 a.m. temperatures ≥80°F (Figure 5.10-18) and average of 50 days per year had 5 a.m. and 6 a.m. temperatures ≥70°F (Figure 5.10-19).

Figure 5.10-18 Average Days Per Year ≥80°F by Hour in Newark



Source: ONJSC Rutgers University

Figure 5.10-19 Average Days Per Year ≥70°F by Hour in Newark, 1997 to 2009



Source: ONJSC Rutgers University

NOAA's 2017 state summary for New Jersey graphed the number of days with minimum temperature below 0°F (Figure 5.10-20), where NOAA found a decline in the number of days with a minimum temperature of less than 0°F. NOAA also concluded that "over the past 25 years many more unusually warm months than usually cold months have occurred in the state, so much so that over the period of 2000 – 2015 there were no top five coldest months but 32 top five warmest months" (Jennifer Runkle, Kenneth E. Kunkel).

Figure 5.10-20 Observed Number of Days Below Freezing (Below 32°F)

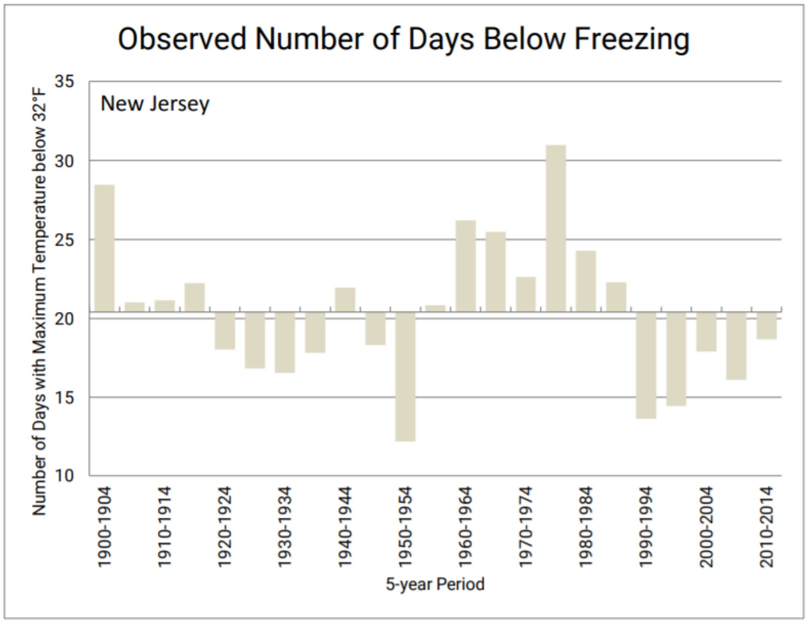
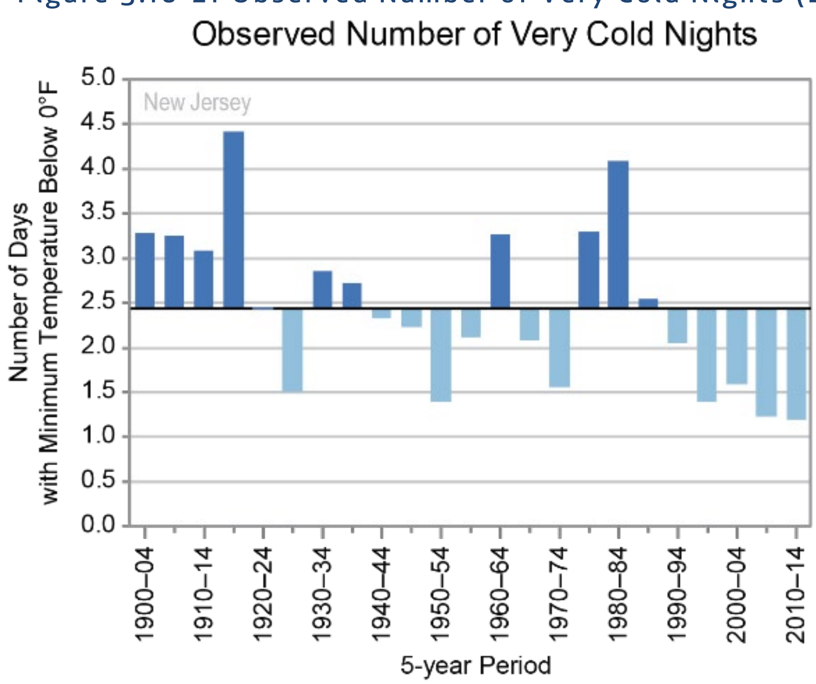


Figure 5.10-21 Observed Number of Very Cold Nights (Below 0°F)

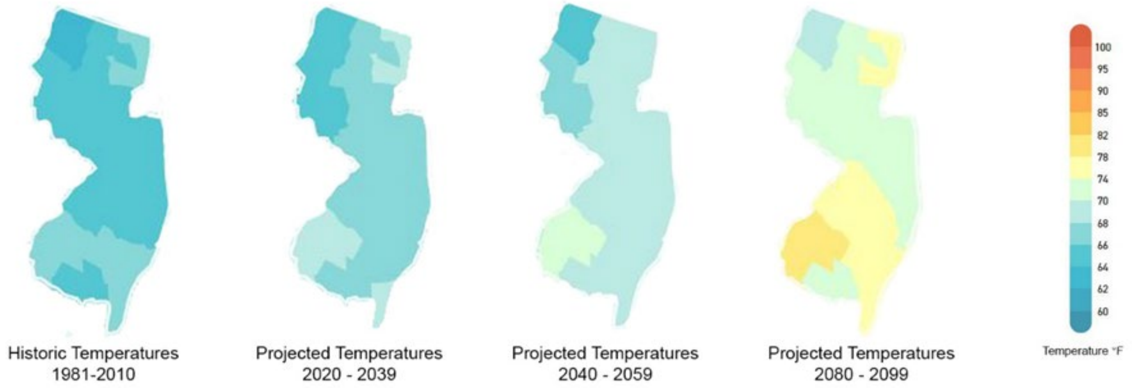


Source for Figure 5.10-20 and Figure 5.10-21: NOAA National Centers for Environmental Information

In the 2018 NCDC preliminary Climate Summary for New Jersey, the number of days in 2015 with a maximum temperature less than 32°F was 27, 10.5 above the normal value. In 2017, 16 days had a maximum temperature less than 32°, 0.5 less than the normal value. Moreover, the number of days in 2015 with minimum temperature of less than 0°F was 2, 1.9 above the normal value, and in 2017 0 days had a minimum temperature less than 0°F, 0.1 less than the normal value.

Climate Impact Lab provides climate projections for the rest of the 21st century based on Coupled Model Intercomparison Project Phase 5 (CMIP5). In this model, the gridded projections were aggregated to regional estimates, which are displayed in Figure 5.21-22.

Figure 5.10-22 Historical and Projected Average Annual Temperatures by County



Source: Climate Impact Map, 2018

5.10.3 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 are most responsible for hailstorm and thunderstorm wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado (Northern Virginia Regional Commission [NVRC], 2006).

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

According to the Tornado Project, the magnitude or severity of a tornado was originally categorized using the Fujita Scale (F-Scale) or Pearson Fujita Scale introduced in 1971, based on a relationship between the Beaufort Wind Scales (B-Scales) (measure of wind intensity) and the Mach number scale (measure of relative speed). It is used to rate the intensity of a tornado by examining the damage caused by the tornado after it has passed over a man-made structure. The F-Scale categorizes each tornado by intensity and area. The scale is divided into six categories, F0 (Gale) to F5 (Incredible) (Edwards 2012). Table 5.10-4 explains each of the six F-Scale categories.

Table 5.10-4 Fujita Damage Scale

F Scale Number	Wind Speed (MPH)	Type of Damage Possible
F0	<73	Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73-112	Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113-157	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	158-206	Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207-260	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown, and large missiles generated.
F5	261-318	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 occur.

Source: Storm Prediction Center (SPC) 2011

Although the F-Scale has been in use for over 30 years, there are limitations to the scale. The primary limitations are a lack of damage indicators, no account of construction quality and variability, and no definitive correlation between damage and wind speed. These limitations have led to the inconsistent rating of tornadoes and, in some cases, an overestimate of tornado wind speeds. The limitations listed above led to the development of the Enhanced Fujita Scale (EF-Scale). The Texas Tech University Wind Science and Engineering (WISE) Center, along with a forum of nationally renowned meteorologists and wind engineers from across the country, developed the EF-Scale (NOAA 2008).

The EF-Scale became operational on February 1, 2007. 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. The EF-Scale was revised from the original F- Scale to reflect better examinations of tornado damage surveys. This new scale considers how most structures are designed (NOAA 2008). Table 5.10-5 displays the EF-Scale and each of its six categories.

Table 5.10-5 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

In the F-Scale, there was a lack of clearly defined and easily identifiable damage indicators. The EF-Scale takes into account more variables than the original F-Scale did when assigning a wind speed rating to a tornado. The EF-Scale incorporates 28 DIs, such as building type, structures, and trees. For each damage indicator, there are eight DODs, ranging from the beginning of visible damage to complete destruction of the damage indicator. Table 5.10-6 lists the 28 DIs. Each one of these indicators has a description of the typical construction for that category of indicator. Each DOD in every category is given an expected estimate of wind speed, a lower bound of wind speed, and an upper bound of wind speed.

Table 5.10-6 EF-Scale Damage Indicators

Number	Damage Indicator	Abbreviation	Number	Damage Indicator	Abbreviation
1	Small barns, farm outbuildings	SBO	15	School - 1-story elementary (interior or exterior halls)	ES
2	One- or two-family residences	FR12	16	School jr. or sr. high school	JHSH
3	Single-wide mobile home (MHSW)	MHSW	17	Low-rise (one to four story) bldg.	LRB
4	Double-wide mobile home	MHDW	18	Mid-rise (five to 20 story) bldg.	MRB
5	Apartment, condo, townhouse (3 stories or less)	ACT	19	High-rise (over 20 stories)	HRB
6	Motel	M	20	Institutional bldg. (hospital, government, or university)	IB
7	Masonry apt. or	MAM	21	Metal building	MBS
8	Small retail building (fast food)	SRB	22	Service station canopy	SSC
9	Small professional (doctor office, branch bank)	SPB	23	Warehouse (tilt-up walls or heavy timber)	WHB
10	Strip mall	SM	24	Transmission line tower	TLT
11	Large shopping mall	LSM	25	Free-standing tower	FST
12	Large, isolated ("big box") retail building	LIRB	26	Free standing pole (light, flag, luminary)	FSP
13	Automobile	ASR	27	Tree - hardwood	TH
14	Automotive service building	ASB	28	Tree - softwood	TS

Source: SPC 2011

Thunderstorms

Observational methodology of thunderstorms has varied over the years. In the 1990s there was the transition to the Automated Surface Observing Stations (ASOS) at NWS and Federal Aviation Administration (FAA) weather stations, mainly situated at airports. With ASOS deployment, an Automated Lightning Detection and Ranging System (ALDARS) took the place of human observers for identifying thunderstorms. Human observations appear to have caused major inconsistencies regarding thunderstorm days based on comparing pre-ASOS records to those gathered since the ASOS network was deployed. 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).

These inconsistencies make it impossible to produce a useful map of thunderstorm days across New Jersey and nearby environs. Based on human observation, approximately 30 thunderstorm days per year occur in this region. This includes some sub-regional aspects, such as there being more inland storms than coastal thunderstorms (ONJSC Rutgers University 2013a).

With time, lightning detection climatology may prove more valuable than the former manual methodology. This should continue to be evaluated as future updates to the hazard mitigation plan are generated (ONJSC Rutgers University 2013a).

Hailstorms
Hail can be produced from many different types of storms. Typically, 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 5.10-7 shows the different sizes of hail and the comparison to real-world objects. Figure 5.10-23 shows a large hailstone.

Table 5.10-7 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
Tea Cup	3.0 inches
Grapefruit	4.0 inches
Softball	4.5 inches

Source: NOAA 2012

Figure 5.10-23 Large Hailstone

Source: New Jersey HMP 2011

Extreme Temperatures
NOAA's heat alert procedures are based mainly on Heat Index values. The Heat Index is given in degrees Fahrenheit. The Heat Index is a measure of how hot it really feels when relative humidity is factored in with the actual air temperature. To find the Heat Index temperature, the temperature and relative humidity need to be known. Once both values are known, the Heat Index will be the corresponding number with both values (Figure 5.10-24). The Heat Index indicated the temperature the body feels. It

is important to know that the Heat Index values are devised for shady, light wind conditions. Exposure to full sunshine can increase heat index values by up to 15°F. Strong winds, particularly with very hot dry air, can also be extremely hazardous (NWS, 2013).

Figure 5.10-24 NWS Heat Index Chart

NWS Heat Index — Temperature (°F); Relative Humidity (%)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution   Extreme Caution   Danger   Extreme Danger

Source: NWS, 2013

Figure 5.10-25 Adverse Effects of Prolonged Exposures to Heat on Individuals

Category	Heat Index	Health Hazards
Extreme Danger	130 °F – Higher	Heat Stroke / Sunstroke is likely with continued exposure.
Danger	105 °F – 129 °F	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Extreme Caution	90 °F – 105 °F	Sunstroke, muscle cramps, and/or heat exhaustions possible with prolonged exposure and/or physical activity.
Caution	80 °F – 90 °F	Fatigue possible with prolonged exposure and/or physical activity.

Source: NWS, 2009

The NWS states that the extent (severity or magnitude) of extreme cold temperatures are generally measured through the Wind Chill Temperature (WCT) Index. Wind Chill Temperature is the temperature that people and animals feel when outside and it is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin's temperature to drop.

On November 1, 2001, the NWS implemented a new WCT Index. It was designed to more accurately calculate how cold air feels on human skin. The table below shows the new WCT Index. The WCT Index includes a frostbite indicator, showing points where temperature, wind speed, and exposure time will produce frostbite to humans. Figure 5.10-26 shows three shaded areas of frostbite danger. Each shaded area shows how long a person can be exposed before frostbite develops (NWS 2013).

Figure 5.10-26 NWS Wind Chill Index

Wind (mph) \ Temperature (°F)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
Calm																		
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

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

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

Effective 11/01/01

Source: NWS 2009b

5.10.4 PREVIOUS OCCURRENCES AND LOSSES

High Winds

Many sources provided historical information regarding previous occurrences and losses associated with thunderstorm events throughout the State of 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. The accuracy of monetary figures discussed is based only on the available information identified during research for this HMP. Table 5.10-8 outlines these wind events in the State but does not include all incidents. Events in the table prior to 2010 were provided by ONJSC.

Table 5.10-8 High Wind Incidents in New Jersey

Event Date(s)	Event Type	Counties Affected	Description
11/20/1989	Derecho	Statewide	A line of thunderstorms formed along a cold front over north-central Pennsylvania in the late afternoon on November 20. The storms built south along the front as it moved across Pennsylvania, southeastern New York State, New Jersey, and adjacent portions of Maryland and Delaware. The squall line produced a continuous swath of damaging wind that extended more than 250 miles from the Allegheny Mountains to the New Jersey coast and Long Island. Maximum wind gusts exceeded 58 mph and there were numerous gusts measuring at greater than 70 mph. In New Jersey, wind gusts of 86 mph were recorded in the southern portion. A steeple was blown off a church in Trenton and a roof was blown off of a high-rise apartment building in Burlington County. A falling tree seriously injured a man in Princeton. Overall, this event caused more than $20 million in damages to Pennsylvania, New Jersey, and New York.

Event Date(s)	Event Type	Counties Affected	Description
9/7/1998	Derechos ("The Labor Day Derechos of 1998")	Northern New Jersey	A derecho formed over western New York State and moved east in the early morning on September 7. Wind damage occurred in much of the area, with some of the worst storm damage occurring in a band across western and central New York State. Along the path of the derecho, tens of thousands of trees were blown down and over 1,000 homes and businesses were damaged. Damage was estimated at approximately $130 million. Many homes and businesses were without power.
1/3/2010	Strong Winds	Statewide	Strong and gusty west to northwest winds occurred for nearly twenty-four hours across New Jersey. Peak wind gusts averaged around 50 mph, with some gusts of 70 mph in the higher terrain of Sussex County. Strong winds downed weak trees, tree limbs, and power lines resulting in power outages. About 1,000 homes and businesses lost power in Monmouth and Ocean Counties.
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 Atlantic City. There were three reported injuries. A 78-mph wind gust was reported at Robbins Reef at 7:18 pm.
12/1/2010	Wind Gusts	Bergen, Passaic	A wind gust to 59 mph was reported at Teterboro airport in the early afternoon of December 1. Strong winds knocked down some trees and tree limbs which caused scattered power outages across the region.
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.
12/26/2010	High Winds	Statewide	Strong to high winds that started in the afternoon of the winter storm on December 26 persisted into the next evening. Peak wind gusts were around 50 mph, except along some shore points and in the higher terrain of Sussex County where gusts reached 60 mph and greater.
2/25/2011	High Winds	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Salem, Somerset, Sussex, Warren	A very strong cold frontal passage produced strong to high winds across New Jersey in the afternoon and early evening of February 25. Peak wind gusts averaged 50 to 60 mph, with most of the highest gusts in the southern half of the state. The winds downed numerous trees, tree limbs, and power lines, and also caused some structural damage.

Event Date(s)	Event Type	Counties Affected	Description
4/16/2011	High Winds	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Salem, Somerset, Sussex, Warren	Strong to high southeast to south winds affected central and southern New Jersey in the afternoon and evening on April 16. Peak wind gusts averaged around 50 to 55 mph with some isolated wind gusts around 60 mph. The highest wind gusts occurred during the evening and the worst reported wind damage occurred in Cumberland County. The strong to high winds coupled with the heavy rain, knocked down weak trees, tree limbs, and wires. The strong to high gradient winds were exacerbated further by isolated severe thunderstorms.
1/13/2012	High Winds	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Salem, Somerset, Sussex, Warren	Strong westerly winds were recorded early in the morning and again later in the day on January 13, across New Jersey, following a cold frontal passage. Peak wind gusts averaged between 45 and 55 mph, resulting in downed tree limbs and isolated power outages. Atlantic City Electric reported about 3,000 of its customers lost power in southern New Jersey.
2/25/2012	Strong Winds	Atlantic, Burlington, Camden, Cape May, Cumberland, Gloucester, Hunterdon, Mercer, Middlesex, Monmouth, Morris, Ocean, Salem, Somerset, Sussex, Warren	Strong winds downed weak trees, tree limbs, and power lines and caused scattered outages. Peak wind gusts included 62 mph in Wantage (Sussex County), 61 mph in Seaside Park (Ocean County), 56 mph in Brick (Ocean 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.
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.

Event Date(s)	Event Type	Counties Affected	Description
1/31/2013	High Winds	Monmouth, Passaic, Union, Essex, Middlesex, Ocean, Camden, Bergen, Hudson	High south winds preceding a strong cold front resulted in areas of damage and disruptions to power.
3/6 and 3/7 2013	High Winds	Southern New Jersey	An intense nor'easter brought strong to high winds across most of central and southern New Jersey.
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.
2/15/2015	High Winds	Statewide	The increasing pressure difference (gradient) between a rapidly intensifying low-pressure system offshore and an arctic high-pressure system moving east from the Great Lakes caused strong to high damaging northwest winds to occur in New Jersey. The highest winds occurred in the southern half of the state and in the higher terrain of Sussex County. In these latter locations, peak wind gusts averaged around 60 mph. In the rest of the northern half of the state, peak wind gusts averaged 45 to 50 mph.
10/2 to 10/4 2015	High Winds	New Jersey Coast	A persistent onshore flow caused periods of heavy rain, strong to high winds, beach erosion, and minor to moderate tidal flooding to occur along the Atlantic coast of New Jersey and into Delaware Bay. The winds peaked on the 2nd.
1/23/2016	High Winds	Statewide	An impulse from the west coast traversed the midsection of the country, then developed into a low-pressure system as it tracked across the Gulf states before intensifying along the Carolina coast into a major nor'easter, producing strong winds and record snowfall in parts of New Jersey.
2/24/2016	High Winds	Statewide	Wind was associated with severe thunderstorms that hit New Jersey. Trees and wires fell down due to the wind.
3/28/2016	High Winds	Essex	High winds occurred behind depending low pressure.
4/3/2016	High Winds	Statewide	The gradient between a low-pressure system and incoming high pressure produced strong winds gusting over 60 MPH in some localities. Numerous trees and wires were reported down.
1/23 to 1/24 2017	High Winds	New Jersey Coast	An area of low pressure over North Carolina on the 23rd strengthened and moved northeast to a location just off the New Jersey Coastline on the morning of the 24th. With a very tight pressure gradient, winds increased ahead of the storm reaching in excess of 50 mph that led to some damage reports.
2/9/2017	High Winds	Cape May	A strong cold front moved through the region with a temperature drop from the 50's and 60's all the way down close to freezing. Low pressure developed along the front with precipitation northwest of the boundary. Gusty winds occurred as the low departed.
2/13/2017	High Winds	Morris, Middlesex, Warren, Sussex, Cape May, Gloucester	High winds blew through the area after a cold frontal passage, enough to lead to downed trees and wires.

Event Date(s)	Event Type	Counties Affected	Description
3/2/2017	High Winds	Southern New Jersey	Pockets of significant wind damage occurred due to thunderstorms. At Ocean City, NJ, a wind gust of 60 MPH was recorded during the afternoon hours of March 1st. 2,500 lost power in Southern NJ. high winds continued behind the system into the 2nd and 3rd with several thousand more-losing power across the state. Top gusts in the early morning hours ranged from 54 mph at Cape May to 58 mph at Sandy Hook along with gusts of 48 mph At Atlantic City International airport and 54 mph in Perth Amboy.
3/14/2017	High Winds	Sussex, Ocean, Cumberland	Low pressure systems across the Ohio Valley and Carolinas phased. This led to a rapidly developing storm which tracked just offshore. Wind, coastal flooding, heavy rain and snow all occurred.

Source: NCDC 2013; ONJSC Rutgers University 2013; SPC 1998; SPC 2012, NOAA NCDC 2018

Tornadoes

Table 5.10-9 displays the annual tornado summary for the State between 1950 and 2012 based on best available data.

Table 5.10-9 Annual Tornado Summary, State of New Jersey, 1951 to 2017

Year	Tornadoes	Deaths	Injuries	Total Damages
1951	1	0	2	$ 25,000
1952	4	0	1	$ 78,000
1953	No incidents reported			
1954	No incidents reported			
1955	1	0	0	N/A
1956	4	0	8	$ 50,000
1957	1	0	0	$ 250,000
1958	3	0	0	$ 277,500
1959	No incidents reported			
1960	5	0	0	$ 302,750
1961	No incidents reported			
1962	3	0	1	$ 500,000
1963	No incidents reported			
1964	6	0	10	$ 775,000
1965	No incidents reported			
1966	No incidents reported			
1967	1	0	0	$ 25,000
1968	No incidents reported			
1969	No incidents reported			
1970	2	0	0	$ 275,000
1971	3	0	0	$ 750,000
1972	No incidents reported			
1973	8	0	12	$ 530,500
1974	2	0	0	$ 250

Year	Tornadoes	Deaths	Injuries	Total Damages
1985	2	0	8	$ 250
1986	1	0	0	$ 250,000
1987	9	0	3	$ 257,500
1988	6	0	1	$ 3,252,500
1989	17	0	2	$ 10,827,500
1990	7	0	11	$ 6,000,000
1991	1	0	0	$ 2,500
1992	4	0	0	$ 500,000
1993	5	0	0	$ 505,000
1994	8	0	0	$10,575,000
1995	5	0	0	N/A
1996	2	0	0	$ 10,000
1997	2	0	0	$ 103,000
1998	3	0	0	$ 2,050,000
1999	2	0	0	$ 100,000
2000	No incidents reported			
2001	2	0	0	$ 1,015,000
2002	No incidents reported			
2003	7	1	2	$ 2,100,000
2004	2	0	2	$ 600,000
2005	No incidents reported			
2006	1	0	0	$ 100,000
2007	No incidents reported			
2008	No incidents reported			

Year	Tornadoes	Deaths	Injuries	Total Damages
1975	3	0	0	$ 25,275,000
1976	1	0	0	$ 250,000
1977	2	0	1	$ 50,000
1978	No incidents reported			
1979	2	0	1	$ 252,500
1980	1	0	0	$ 25,000
1981	3	0	0	$ 250,000
1982	1	0	0	$ 2,500,000
1983	1	0	0	$ 2,500,000
1984	No incidents reported			

Year	Tornadoes	Deaths	Injuries	Total Damages
2009	2	0	0	$ 1,000,000
2010	1	0	0	$ 25,000
2011	4	0	0	$ 250,000
2012	1	0	0	$ 25,000
2013	3	0	0	$ 300,000
2014	No incidents reported			
2015	No incidents reported			
2016	2	0	0	$ 0
2017	1	0	0	$ 0

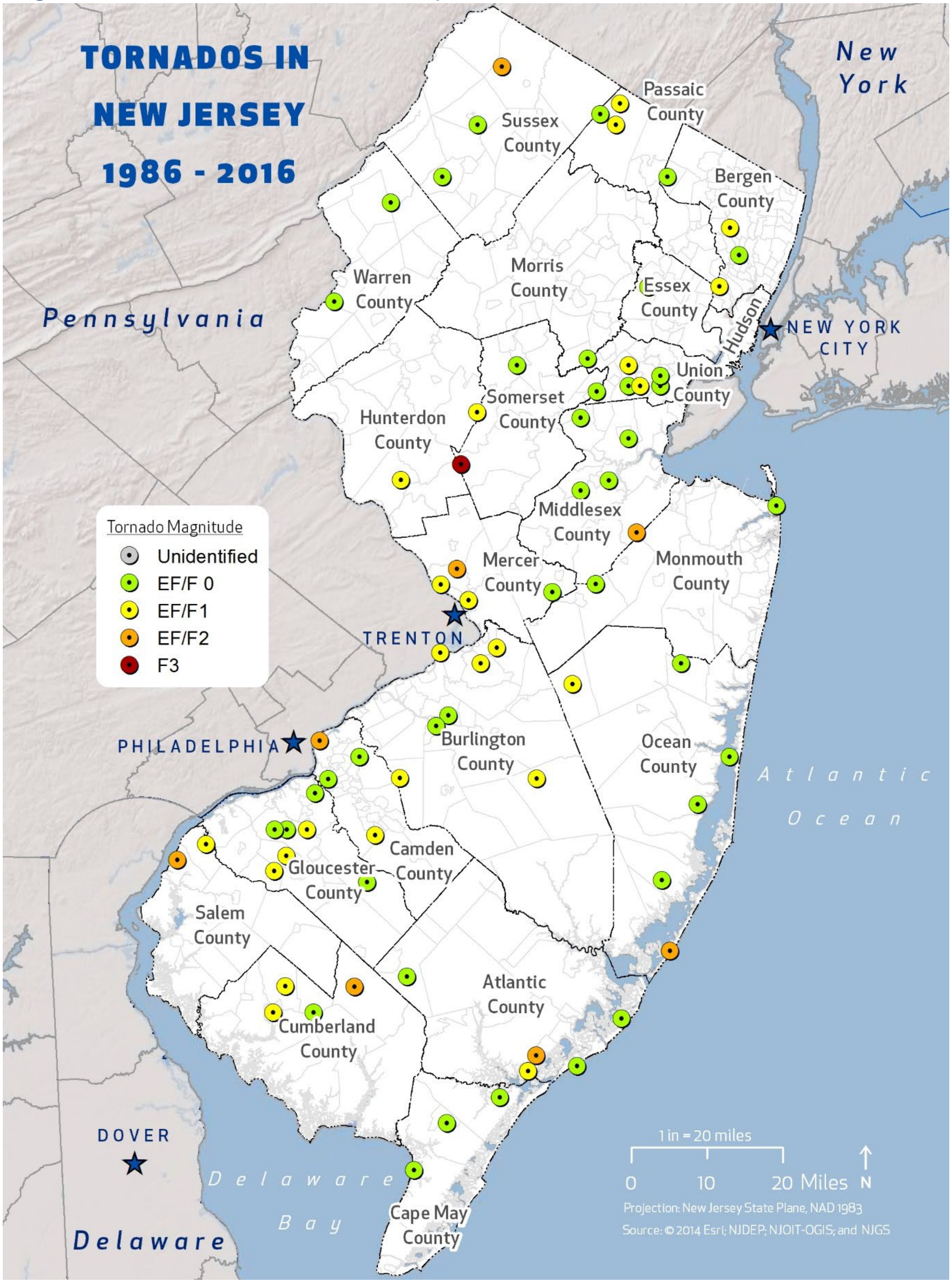
Source: SPC 2012; NOAA-NCDC, 2013; ONJSC Rutgers University, 2013; NOAA, 2016

Over the course of the last 30 years, the State of New Jersey has experienced 90 tornadoes, with an annual frequency of 2.5 per year. Figure 5.10-27 illustrates the locations of tornadoes.

- 6 were EF-0/F-0
- 30 were EF-1/F-1
- 9 were EF-2/F-2
- 1 was EF-3/F-4 and
- 4 were unknown

These tornado events resulted in 77 injuries and one fatality, and they resulted in $78,184,250 in damages. The map figure indicates that northern and western parts of the State experience more tornadoes than southern and coastal areas.

Figure 5.10-27 Tornadoes in New Jersey, 1986 to 2016



Source: NOAA, 2016

Table 5.10-10 Tornado Incidents in New Jersey, 1950 to 2016

Date(s) of Event	Magnitude	Counties Affected	Impacts
4/29/1951	F1	N/A	$25,000 in property damage; two injuries
4/5/1952	F1	N/A	$2,500 in property damage
8/10/1952	F1	N/A	$25,000 in property damage
10/16/1955	F2	N/A	Unknown
5/6/1956	F2	N/A	$25,000 in property damage
7/13/1956	F1	N/A	8 injuries
7/13/1956	F1	N/A	$2,500 in property damage
9/6/1956	F2	N/A	Unknown
11/19/1957	F1	N/A	$250,000 in property damage
6/13/1958	F2	N/A	$250,000 in property damage; one injury
6/13/1958	Unknown	N/A	$2,500 in property damage
7/14/1958	F1	N/A	$25,000 in property damage
4/18/1960	F1	N/A	$250 in property damage
6/24/1960	Unknown	N/A	$25,000 in property damage
7/1/1960	F1	N/A	$2,500 in property damage
7/14/1960	F2	N/A	$250,000 in property damage; six injuries
11/29/1960	Unknown	N/A	$25,000 in property damage
5/24/1962	F2	N/A	$250,000 in property damage; one injury
7/21/1962	F0	N/A	Unknown
8/7/1962	F2	N/A	$250,000 in property damage
3/10/1964	F1	N/A	$250,000 in property damage; five injuries
3/26/1964	F0	N/A	$25,000 in property damage
10/18/1967	F1	N/A	$25,000 in property damage
7/15/1970	F2	N/A	$25,000 in property damage
11/4/1970	F2	N/A	$250,000 in property damage
7/19/1971	F2	N/A	$250,000 in property damage
7/19/1971	F2	N/A	$250,000 in property damage
8/27/1971	F2	N/A	$250,000 in property damage
2/2/1973	F2	N/A	$2,500 in property damage
2/2/1973	F1	N/A	$250 in property damage
2/2/1973	F1	N/A	$250 in property damage
5/28/1973	F3	N/A	$250,000 in property damage
5/28/1973	F3	N/A	$250,000 in property damage; 1two injuries
6/29/1973	F1	N/A	$2,500 in property damage
6/29/1973	F1	N/A	$25,000 in property damage
11/28/1973	F0	N/A	Unknown
4/14/1974	F2	N/A	$250 in property damage
7/24/1974	F1	N/A	Unknown
4/3/1975	F0	N/A	$25,000 in property damage
7/13/1975	F2	N/A	$25 million in property damage
7/13/1975	F1	N/A	$250,000 in property damage
7/7/1976	F1	N/A	$250,000 in property damage

Date(s) of Event	Magnitude	Counties Affected	Impacts
8/10/1977	F0	N/A	$25,000 in property damage; one injury
9/26/1977	Unknown	N/A	$25,000 in property damage
9/6/1979	F1	N/A	$250,000 in property damage; one injury
11/26/1979	F1	N/A	$2,500 in property damage
6/3/1980	F1	N/A	$25,000 in property damage
6/21/1981	F1	N/A	$250,000 in property damage
7/20/1981	F2	N/A	Unknown
10/26/1981	F2	N/A	Unknown
6/29/1982	F2	N/A	$2.5 million in property damage
7/21/1983	F3	N/A	$2.5 million in property damage
9/27/1985	F0	N/A	$250 in property damage
10/5/1985	F1	N/A	8 injuries
9/23/1986	F0	N/A	$250,000 in property damage; eight injuries
7/2/1987	F1	N/A	$250,000 in property damage
7/12/1987	F1	N/A	$2,500 in property damage
7/14/1987	F0	N/A	Unknown
7/21/1987	F2	N/A	$2,500 in property damage
7/26/1987	F0	N/A	Unknown
7/26/1987	F1	N/A	Unknown
8/5/1987	F0	N/A	$2,500 in property damage
5/23/1988	F0	N/A	Unknown
7/20/1988	F1	N/A	Unknown
7/23/1988	F1	N/A	$250,000 in property damage; one injury
8/17/1988	F2	N/A	$2.5 million in property damage
8/17/1988	F0	N/A	$2,500 in property damage
8/17/1988	F2	N/A	$250,000 in property damage
3/18/1989	F1	N/A	$25,000 in property damage
3/18/1989	F1	N/A	$25,000 in property damage
3/18/1989	F1	N/A	Unknown
5/27/1989	F0	N/A	$2,500 in property damage
6/9/1989	F2	N/A	$250,000 in property damage
7/10/1989	F1	N/A	$2.5 million in property damage
7/10/1989	F0	N/A	$2.5 million in property damage
7/10/1989	F0	N/A	$2.5 million in property damage
8/29/1989	F0	N/A	one injury
11/16/1989	F0	N/A	$250,000 in property damage; one injury
11/16/1989	F1	N/A	$250,000 in property damage
11/16/1989	F0	N/A	one injury
11/16/1989	F0	N/A	one injury
11/16/1989	F0	N/A	one injury
11/16/1989	F1	N/A	one injury
11/16/1989	F0	N/A	one injury
11/20/1989	F0	N/A	$2.5 million in property damage

Date(s) of Event	Magnitude	Counties Affected	Impacts
5/10/1990	F0	N/A	$250,000 in property damage
5/10/1990	F2	N/A	$250,000 in property damage
8/13/1990	F0	N/A	Unknown
10/18/1990	F3	N/A	$2.5 million in property damage; eight injuries
10/18/1990	F1	N/A	$250,000 in property damage
10/18/1990	F0	N/A	$2.5 million in property damage; three injuries
10/18/1990	F0	N/A	$250,000 in property damage
8/19/1991	F0	N/A	$2,500 in property damage
6/24/1992	F1	N/A	$250,000 in property damage
7/15/1992	F0	N/A	Unknown
7/31/1992	F1	N/A	$250,000 in property damage
7/31/1992	F1	N/A	Unknown
6/9/1993	F0	N/A	Unknown
6/21/1993	F0	N/A	Unknown
7/10/1993	F0	N/A	Unknown
8/21/1993	F2	N/A	$250,000 in property damage
9/8/1993	F0	N/A	$2,500 in property damage
4/13/1994	F1	N/A	$2.5 million in property damage
5/25/1994	F1	N/A	$2.5 million in property damage
6/29/1994	F1	N/A	Unknown
7/3/1994	F1	N/A	$250,000 in property damage
7/26/1994	F1	N/A	$2.5 million in property damage
8/2/1994	F1	N/A	Unknown
8/17/1994	F1	N/A	Unknown
11/1/1994	F0	N/A	$250,000 in property damage
5/29/1995	F1	N/A	Unknown
7/16/1995	F1	N/A	Unknown
7/16/1995	F1	N/A	Unknown
7/22/1995	F0	N/A	$2.5 million in property damage
10/21/1995	F0	N/A	Unknown
6/22/1996	F0	N/A	Unknown
9/8/1996	F0	N/A	$10,000 in property damage
8/13/1997	F0	N/A	$50,000 in property damage
9/11/1997	F1	N/A	$530,000 in property damage
9/2/1998	F0	N/A	Unknown
9/7/1998	F0	N/A	$1.5 million in property damage
9/7/1998	F1	N/A	$5,500 in in property damage
2/12/1999	F1	N/A	$10,000 in property damage
8/20/1999	F2	N/A	$4.2 million in property damage; one injury
5/27/2001	F2	N/A	$1 million in property damage
7/5/2001	F1	N/A	$10,000 in property damage
7/3/2003	F0	N/A	None
9/23/2003	F1	N/A	$500,000 in property damage

Date(s) of Event	Magnitude	Counties Affected	Impacts
9/23/2003	F1	N/A	$600,000 in property damage
9/23/2003	F1	N/A	$1 million in property damage; two injuries
10/27/2003	F0	N/A	$2,500 in property damage; 1 fatality
10/27/2003	F0	N/A	Unknown
10/27/2003	F0	N/A	Unknown
7/27/2004	F1	N/A	$500,000 in property damage; two injuries
9/28/2004	F0	N/A	$100,000 in property damage
6/2/2006	F0	N/A	$10,000 in property damage
7/29/2009	EF2	Sussex	An EF2 tornado touched down in Wantage Township at about 2:48 p.m. on July 29. It was the first confirmed tornado in Sussex County since August 1990, the first tornado of F2 or EF2 strength ever in the county since records started in 1950 and the first tornado to reach EF2 or F2 strength in New Jersey since the Manalapan tornado of May 27, 2001. The tornado remained on the ground for 6.6 miles before it crossed the border into New York State. Its maximum width was about 100 yards and its highest estimated wind speed was 120 mph. Approximately $800,000 in property damage and $200,000 in crop damage.
7/29/2009	EF2	N/A	$960,000 in property damage
7/29/2009	EF2	N/A	$875,000 in property damage
9/16/2010	EF1	Middlesex, Ocean	An EF1 tornado touched down in Plumsted Township in Ocean County at about 6:05 p.m. on September 16. The tornado remained on the ground for about 2.2 miles. The tornado touched down just north of the intersection of Long Swamp Road and Archertown Road. The tornado traveled east-northeast crossing Ocean County Route 539 and lifted near Hawkins Road or Prospertown-Colliers Mills Road near Colliers Lake. Approximately $25,000 in property damage.
8/9/2011	EF0	Monmouth	An EF0 tornado touched down in Millstone Township in Monmouth County. The tornado initially touched down north of Buono Farm and tracked northeast where it crossed New Jersey State Route 33. Approximately $10,000 in property damage.
8/28/2011	EF0	Mercer	Tropical Storm Irene produced torrential downpour rains that resulted in major flooding and a number of record breaking crests on area rivers, tropical storm force wind gusts with record breaking outages for New Jersey utilities, one confirmed tornado, and a three to five-foot storm surge. There was one confirmed tornado in Mercer County. Overall, $25,000 in property damage.
9/4/2012	EF0	Burlington, Camden	A weak EF0 tornado touched down in Mount Ephraim at 6:31 p.m. on September 4. The tornado initially touched down on the west side of Cleveland Avenue. It then moved east northeast, crossed Jefferson Avenue and lifted as it approached Kings Highway. (County Route 551). Several homes in the area experienced roof damage, mainly from fallen tree limbs.
9/4/2012	EF0	Burlington, Camden	A weak tornado (F0 on the Fujita Scale) touched down in a wooded area between Marne Highway and the Holly Bowl bowling alley in Hainesport Township. It moved east and lifted just before crossing New Jersey State Route 38.

Date(s) of Event	Magnitude	Counties Affected	Impacts
9/4/2012	EF0	Somerset	A weak tornado (F0 on the Fujita Scale) briefly touched down in eastern Bedminster Township on Miller Lane near the split of U.S. Routes 202 and 206. The tornado remained on the ground for only a couple of tenths of a mile before it lifted in a wooded area east of the public works building in the township.
7/1/2013	EF0	Union	A passing upper level impulse, coupled with a stationary front just to the west, triggered an isolated severe thunderstorm in Union County that produced a tornado and a microburst.
8/13/2013	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.
10/7/2013	EF1	Bergen	A passing cold front triggered a line of severe thunderstorms that moved through Northeast New Jersey. The line also spawned a tornado in Bergen County.
7/14/2016	EF0	Warren	A trough of low pressure ahead of a cold front led to the development of several clusters of showers and thunderstorms. Some of these thunderstorms became severe producing damaging winds and even a tornado in Warren County. A 53-mph wind gust was measured at the Morristown Municipal Airport. Several thousand were left without power, mainly in Morris and Warren Counties.
7/25/2016	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.

Source: NOAA-NCDC, 2016; SPC, 2013; ONJSC Rutgers University, 2013

Thunderstorms

Thunderstorms occur regularly in New Jersey, primarily during the summer months. Of particular concern are the effects of lightning strikes to individuals and homes in the State. Most areas receive between 25 and 30 thunderstorms each year.

Many sources provided historical information regarding previous occurrences and losses associated with thunderstorm events throughout the State of New Jersey. With so many sources reviewed for the purpose of this HMP, 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 plan research. Table 5.10-11 outlines thunderstorm events between January 2010 and 2018 in the State but does not include all incidents.

Table 5.10-11 Thunderstorm and Lightning Incidents in New Jersey, 2010 to 2017

Date of Event	Event Type	Counties Affected	Impacts
5/14/2010	Thunderstorm	Burlington, Cape May, Cumberland	An Appalachian lee side meteorological trough and an approaching cold front both helped produce thunderstorms,

Date of Event	Event Type	Counties Affected	Impacts
		Gloucester, Monmouth, Ocean	some locally severe, across central and southern New Jersey in the evening of May 14.
5/31/2010	Severe Thunderstorm	Mercer	A severe thunderstorm formed near a warm front in Mercer County in the afternoon and early evening on May 31. A lightning strike caused a power failure at the Lawrence Township Police Department.
6/1/2010	Lightning Strike	Monmouth	The Shores High Rise Condominium (two twelve-story buildings) were evacuated for three days after a lightning strike struck one of the towers and knocked out the sprinkler system pump.
6/24/2010	Severe Thunderstorm	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.
6/28/2010	Lightning Strike	Cape May, Ocean	A lightning strike damaged a chimney in Lavallette. A lightning strike set a pole on fire in Ship Bottom. The combination of lightning strikes and strong winds caused numerous outages on Long Beach Island.
7/10/2010	Lightning Strike	Morris	Lightning struck a power line in Jefferson Township and caused about 2,000 homes to lose power at around 9 a.m.
7/13/2010	Lightning Strike	Monmouth	Two lightning strikes caused about 8,200 homes and businesses to lose power in Ocean Township.
7/14/2010	Lightning Strike	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.
7/23/2010	Thunderstorm	Bergen, Passaic	Severe storms, including an isolated supercell moved southeast into the region. These thunderstorms produced heavy rain and flash flooding and impacted most of Northeast New Jersey.
7/29/2010	Lightning Strike	Ocean	A lightning strike caused two pole fires and power outages on Long Beach Island in Harvey Cedars.
8/12/2010	Thunderstorm	Salem	A shower and thunderstorm complex that moved through the southern part of New Jersey caused a barn fire.
8/16/2010	Thunderstorm	Bergen, Hudson	An approaching cold front triggered isolated severe thunderstorms, which impacted Bergen and Hudson
9/22/2010	Severe Thunderstorm	Hunterdon, Mercer, Middlesex, Monmouth, Somerset, Warren	A complex of showers and strong to locally severe thunderstorms preceding a cold frontal passage caused wind damage mainly in the central and northern part of New Jersey. A lightning strike caused a transformer fire on Easton Avenue in Montgomery Township. A lightning strike caused a transformer fire on Easton Avenue in Montgomery Township.

Date of Event	Event Type	Counties Affected	Impacts
10/11/2010	Severe Thunderstorm	Camden, Morris, Sussex	Severe thunderstorms formed in the evening of October 11, in central and northern New Jersey. Lightning struck the electrical box in the front of one home in Hopatcong and ignited a fire that engulfed the unoccupied dwelling.
2/25/2011	Thunderstorm	Burlington, Camden, Gloucester, Ocean	A strong cold frontal passage in the afternoon of February 25, triggering a squall line of strong to severe thunderstorms that moved through central and southern New Jersey.
4/12/2011	Thunderstorm	Essex	A cold pool of air triggered thunderstorms across northeast New Jersey, with one lightning strike near Newark.
4/16/2011	Thunderstorm	Cape May, Cumberland, Ocean	Thunderstorms that moved across extreme southern New Jersey exacerbated the ongoing strong synoptic scale southeast winds already in place in the evening of April 16 and produced wind damage. In addition, a lightning strike caused damage to a home in Ocean County.
5/30/2011	Lightning Strike	Monmouth	A lightning strike in Brielle downed some wires. Five hundred homes and businesses lost power for six and a half hours.
6/17/2011	Lightning Strike	Middlesex, Monmouth, Somerset	Lightning caused about 8,300 homes and businesses to lose power during the morning in Somerset and Middlesex Counties.
6/24/2011	Severe Thunderstorm	Mercer, Middlesex, Monmouth, Ocean	An approaching cold front triggered scattered strong to locally severe thunderstorms in central New Jersey in the afternoon and early evening of June 24. One person was struck and injured by lightning in Ocean Township. Two people were struck and injured by lightning in Plainsboro Township.
7/3/2011	Severe Thunderstorm	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.
7/6/2011	Severe Thunderstorm	Burlington, Mercer, Middlesex, Monmouth, Ocean	Scattered strong to severe thunderstorms developed along a lee side trough and affected central New Jersey in the late afternoon and early evening on July 6. A lightning strike took down two wires on the property of the Crystal Springs Aquatic Center in East Brunswick Township.
7/7/2011	Severe Thunderstorm	Atlantic, Burlington, Camden, Cape May, Hunterdon, Monmouth, Ocean	A cold front helped trigger numerous severe thunderstorms in the afternoon and into the evening on July 7. A lightning strike started a house fire in Ocean View (Dennis Township). Lightning struck and injured a man standing on a porch during a thunderstorm on Townhouse Lane in Little Egg Harbor Township. For the third time in 2011, the water treatment plant in Allentown Borough was struck by lightning.
7/19/2011	Severe Thunderstorm	Atlantic, Camden, Cumberland, Gloucester, Salem	Strong to locally severe thunderstorms occurred in the late afternoon and into the evening on July 19 in southern New Jersey. Hardest hit by the severe thunderstorms were Cumberland and Gloucester Counties. Lightning struck, and the ensuing fire damaged a home in Folsom Borough. Lightning struck a home in Franklin Township.

Date of Event	Event Type	Counties Affected	Impacts
7/29/2011	Severe Thunderstorm	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	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.
8/9/2011	Severe Thunderstorm	Gloucester, Monmouth, Salem	A warm front helped trigger some strong to locally severe thunderstorms and also one confirmed tornado across central and southern New Jersey in the afternoon on August 9. Lightning struck the television antenna of a home on Ayers Avenue in North Plainfield.
8/14/2011	Thunderstorm	Camden, Cumberland, Monmouth, Salem	In addition to the flash flooding rains, thunderstorms affected New on August 14. A lightning strike and ensuing fire badly damaged a Maxim Road home in Howell.
8/18/2011	Severe Thunderstorm	Cape May, Cumberland, Gloucester, Morris, Ocean, Monmouth	An upper air disturbance coupled with a surface trough helped trigger strong to locally severe thunderstorms from the late afternoon through the night in New Jersey. A house was struck by lightning in Brick Township.
8/19/2011	Severe Thunderstorm	Bergen, Burlington, Camden, Essex, Hunterdon, Mercer, Middlesex, Morris, Passaic, Somerset, Warren	A passing mid-level disturbance triggered severe thunderstorms that produced large hail, damaging winds and lightning strikes across Bergen, Essex, Hudson, and Passaic Counties. Several homes were reported struck by lightning in the town of Bergenfield. A lightning strike ignited a fire at a house on York Street in Lambertville.
8/21/2011	Thunderstorm	Burlington, Monmouth, Morris, Warren	A series of thunderstorms that preceded and accompanied a lee side trough and a cold front produced strong to locally severe thunderstorms mainly during the afternoon in New Jersey. A lightning strike to one of its water towers on Union Lane caused Brielle Borough to declare an emergency on August 21.
9/15/2011	Lightning Strike	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.
6/7/2012	Thunderstorm	Atlantic County	A thunderstorm with small hail started after the outdoor graduation ceremony began at Absegami High School in Galloway Township causing panic as people left the ceremony and made dashes for shelter.

Date of Event	Event Type	Counties Affected	Impacts
6/22/2012	Severe Thunderstorm	Atlantic, Burlington, Cumberland, Hunterdon, Middlesex, Monmouth, Morris, Ocean, Sussex, Warren	Scattered strong to severe thunderstorms developed along a sea breeze front and also ahead of an approaching cold front, producing pockets of very heavy rain and some wind damage across parts of New Jersey. Lightning from a thunderstorm struck and injured a person at Fort Hancock at 2:30 pm on June 22. Lightning struck ten other buildings at the Gateway National Recreational Area at Sandy Hook, but no serious damage was reported.
6/25/2012	Severe Thunderstorm	Mercer, Middlesex, Monmouth, Ocean	An approaching cold front helped trigger strong to locally severe thunderstorms in two waves across central and southern New Jersey. Lightning struck a house on Washington Avenue in Middletown Township. The homeowner smelled an odor after the lightning struck a metal French door.
6/30/2012	Lightning Strike	Atlantic, Cape May, Cumberland, Gloucester, Ocean, Salem	In the early morning hours on June 30, a severe line of storms packing intense lightning and damaging winds swept through Southern New Jersey. The storms, known as derechos, are essentially an intense line of storms characterized by a bowed "C" shape. This particular derecho began in Chicago and grew in intensity as it moved east. The storms packed intense lightning and high winds gusting to 74 miles per hour. The hardest hit counties were Atlantic and Salem where widespread damage was reported.
7/4/2012	Lightning Strike	Burlington, Monmouth, Ocean	Lightning struck a transformer and downed a couple of wires. The downed wires caused a brief fire.
7/7/2012	Severe Thunderstorm	Hunterdon, Middlesex, Monmouth, Ocean, Somerset	A complex of strong to severe thunderstorms moved through the central third of New Jersey in the early evening on July 7. Lightning strikes on Long Beach Island resulted in about 8,000 homes and businesses losing power in Barnegat Light, Loveladies, Harvey Cedars and Beach Haven
7/18/2012	Lightning Strike	Hunterdon, Middlesex, Monmouth, Sussex	A lightning strike and subsequent fire forced the evacuation of six condominium units in the Hunters Crossing Development on Nuthatch Court in Readington Township.
7/23/2012	Lightning Strike	Morris, Somerset, Sussex	A lightning strike injured two campers in Sandyston Township. The bolt struck a pine tree and traveled into the foundation of a cabin at the Lindley C. Cook 4H Camp in Stokes State Forest.
7/24/2012	Lightning Strike	Cape May, Salem	Lightning struck and damaged a transformer in Pennsville Township.
7/28/2012	Severe Thunderstorm	Atlantic, Burlington, Cape May, Cumberland, Mercer, Middlesex, Monmouth, Morris, Salem, Warren	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 lost power in the state. A lightning strike and ensuing fire damaged a house on West 25th Avenue in North Wildwood.
8/1/2012	Lightning Strike	Cape May	A family of four people suffered minor injuries from a lightning strike on the beach in Wildwood off of East Cedar Avenue. They were under a beach umbrella when lightning struck nearby.
8/5/2012	Lightning Strike	Burlington, Middlesex, Monmouth, Sussex	A house was struck by lightning on Madison Avenue. No serious damage or injuries were reported.

Date of Event	Event Type	Counties Affected	Impacts
8/9/2012	Lightning Strike	Hunterdon, Mercer, Middlesex	A lightning strike and ensuing fire damaged an attic of a home under construction on Jefferson Road in Princeton.
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 Strike	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.
9/4/2012	Lightning Strike	Burlington, Camden, Morris, Sussex	A lightning strike caused 700 homes to lose power in Parsippany.
9/7/2012	Lightning Strike	Bergen	A 71-year-old man was injured by lightning at Northern Valley Regional High School.
4/10/2013	Lightning	Somerset	A lightning strike and ensuing fire destroyed a home and left a family homeless on Brahma Avenue in Bridgewater Township. Lightning struck the home's electrical system and sparked a fire resulting in 275.00K of property damage
5/11/2013	Lightning	Passaic, Atlantic	Scattered showers and thunderstorms congealed into a squall line ahead of an approaching cold front during the afternoon. Isolated severe thunderstorms occurred. There was 4.00K of property damage.
5/23/2013	Lightning	Bergen	An approaching pre-frontal trough, ahead of a cold front, triggered thunderstorms over Northeast New Jersey during the afternoon, causing a lightning strike in Bergen County. There was 5.00K of property damage.
6/13/2013	Lightning	Burlington	An early morning low end derecho moved through the region on the 13th which caused strong to severe thunderstorms to develop. There was 1.00K of property damage.
6/24/2013	Lightning	Burlington	An upper air disturbance combined with a hot and humid air mass to produce strong to locally severe thunderstorms. There was 5.00K of property damage.
6/25/2013	Lightning	Hunterdon	Widely scattered pulse type strong to severe thunderstorms affected New Jersey during the second half of the afternoon on the 25th. One person was struck and injured by lightning in Hunterdon County.
7/9/2013	Lightning	Ocean	A couple of thunderstorms developed on the sea breeze front in central New Jersey during the afternoon of the 9th. One person was struck and injured.
7/21/2013	Lightning	Burlington	stalling cold front helped trigger strong thunderstorms during the second half of the afternoon. There was 1.00K of property damage.
7/23/2013	Lightning	Ocean	Thunderstorms produced torrential rain and some wind damage. There was 1.00K of property damage.
8/13/2013	Lightning	Salem, Monmouth	A complex of showers and thunderstorms produced both wind damage and flash flooding across. There was 15.00K of property damage.

Date of Event	Event Type	Counties Affected	Impacts
8/22/2013	Lightning	Morris, Middlesex	A lee side trof helped trigger clusters of showers and thunderstorms during the second half of the morning and afternoon. There was 25.00K of property damage.
9/12/2013	Lightning	Bergen	A line of showers and thunderstorms, with embedded severe thunderstorms, formed along a cold front as it pushed through the Northeast. There was 11.00K of property damage.
5/23/2014	Lightning	Burlington	A lightning strike from a thunderstorm caused a condominium fire in Mount Laurel Township. There was 250.00K of property damage.
6/19/2014	Lightning	Gloucester, Cumberland, Mercer, Atlantic	A low-pressure system that developed along a frontal boundary helped produce clusters of showers and some strong to locally severe thunderstorms. There was 45.00K of property damage.
7/2/2014	Lightning	Essex, Bergen, Mercer	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.
7/3/2014	Lightning	Sussex, Burlington	Strong to severe thunderstorms occurred. About 33,000 homes and businesses lost power throughout the state from the combination of wind damage and lightning strikes. There was 75.00K of property damage, 10K of crop damage.
7/14/2014	Lightning	Ocean, Monmouth, Union, Gloucester	A pair of lines of strong to severe thunderstorms triggered by another lee side trough moved through New Jersey. There was 44.00K of property damage.
7/15/2014	Lightning	Mercer, Burlington, Morris	An approaching cold front helped trigger a series of strong to severe thunderstorms. There was 25.00K of property damage.
7/28/2014	Lightning	Burlington	A weakening line of thunderstorms moved across the Delaware River into New Jersey. While most of the storms were weakening, one thunderstorm became severe and caused wind damage in Burlington County. There was 3.00K of property damage.
10/21/2014	Lightning	Ocean, Monmouth	A slow moving cold front and relatively colder air aloft triggered thunderstorms that produced hail. There was 6.00K of property damage.
6/6/2015	Lightning	Cape May	A lightning strike started a fire at a Middle Township home. No injuries were reported. There was 5.00K of property damage.
6/15/2015	Lightning	Cape May	A lightning strike started a house fire in Seaville. No injuries were reported. There was 10.00K of property damage.
6/23/2015	Lightning	Gloucester	The combination of an unseasonably hot and humid air mass, an approaching cold front and strong winds aloft caused a squall line of severe thunderstorms. There was 5.00K of property damage.
7/15/2015	Lightning	Atlantic	A trough of low pressure ahead of a cold front led to the development of several clusters of showers and thunderstorms. 1.00K of property damage.
7/21/2015	Lightning	Cape May	An approaching cold front triggered scattered thunderstorms.

Date of Event	Event Type	Counties Affected	Impacts
8/11/2015	Lightning	Burlington	Lightning strikes associated with the line of thunderstorms downed wires and struck a residential building. There was 1.50K of property damage.
6/8/2016	Lightning	Somerset	A trough of low pressure moving through the region produced a quick moving line of thunderstorms around noontime. These thunderstorms produced widespread wind damage. There was 1.00K of property damage.
6/28/2016	Lightning	Somerset	A cold front moved eastward into the region. Thunderstorms formed ahead of the cold front and produced hail, strong winds and flash flooding. There was 1.00K of property damage.
7/15/2016	Lightning	Warren, Ocean, Monmouth	A trough of low pressure ahead of a cold front led to the development of several clusters of showers and thunderstorms. There was 5.00K of property damage.
7/18/2016	Lightning	Atlantic	A cold front and associated pre-frontal trough lead to the development of thunderstorms in the afternoon and evening hours. Some of the thunderstorms became severe with damaging winds. There was 0.01K of property damage.
7/25/2016	Lightning	Morris	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. There was 0.01K of property damage.
6/19/2017	Lightning	Ocean	A complex of thunderstorms came through the region during the evening producing high winds and heavy rain. Wind damage occurred in several locations from the thunderstorms. There was 1.00K of property damage.
7/14/2017	Lightning	Gloucester, Ocean, Cape May	Several rounds of thunderstorms moved through the region. There was 0.03K of property damage.
7/19/2017	Lightning	Burlington	A man was struck by lightning from a thunderstorm. There was 0.01K of property damage.
7/29/2017	Lightning	Atlantic	A rare summertime Nor'easter tracked just offshore producing heavy rain, thunderstorms and wind. There was 0.01K of property damage.
8/2/2017	Lightning	Burlington, Middlesex, Warren	A hot and humid airmass with weak boundaries led to slow moving strong to severe thunderstorms. There was 0.05K of property damage.

Source: NCDC 2017; Chang 2012; Giambusso 2012

Hailstorms

Hailstorms, like thunderstorms, occur as a routine part of severe weather in New Jersey. The potential for hail exists all over New Jersey. There are at least a few incidences each year, but they are minor. New Jersey has 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. With so many sources reviewed for the purpose of this HMP, 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.

Hailstorm events in New Jersey that occurred through August 2018 were summarized in this plan update. Table 5.10-12 summarizes the events from the 2014 Plan and incorporates events that have occurred since 2012, by county. The tables may not include all incidents. There were no deaths or injuries associated with these hailstorm events.

Table 5.10-12 Hailstorm Events Summary, 1950 to 2017

County	Number of Reported Incidents	Property Damage	Crop Damage
Atlantic	36	$ 10,000	$ 5,010,000
Bergen	33	$ 0	$ 0
Burlington	66	$ 1,000	$ 0
Camden	30	$ 0	$ 1,500,000
Cape May	18	$ 0	$ 0
Cumberland	23	$ 75,000	$ 0
Essex	21	$ 0	$ 0
Gloucester	29	$ 0	$ 5,000,000
Hudson	14	$ 0	$ 0
Hunterdon	31	$ 0	$ 100,000
Mercer	32	$ 0	$ 0
Middlesex	32	$ 10,000	$ 0
Monmouth	34	$ 0	$ 0
Morris	37	$ 5,000	$ 0
Ocean	46	$ 6,000	$ 0
Passaic	25	$ 0	$ 0
Salem	13	$250,000	$ 5,000,000
Somerset	26	$100,000	$ 1,000
Sussex	30	$ 0	$ 1,000
Union	19	$ 0	$ 0
Total	595	$457,000	$ 16,612,000

Source: NOAA-NCDC 2018

Extreme Temperatures

New Jersey has been experiencing an increase in extreme temperatures across the State. Historically, there has been an increase in temperature during the warmest months in New Jersey, with the majority of the extreme heat months occurring after 1990. Conversely, the months which set records for extreme cold temperatures tended to occur prior to 1930.

Many sources provided historical information regarding previous occurrences and losses associated with extreme temperature events throughout the State. With so many sources reviewed for the purpose of this HMP, 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.

Extreme heat and cold events were summarized for events that occurred between January 2010, and 2018. Table 5.10-13 summarizes the events from data provided by the ONJSC and NOAA and includes events from 2010 to 2017. The table may not include all incidents. The extreme temperature events that occurred from January 2013 through December 2017 show 20 incidences of temperature extremes that occurred Statewide.

Table 5.10-13 Extreme Temperature Events in New Jersey

Date(s) of	Event Type	Counties	Description
7/15/1995	Excessive Heat	Statewide	Heat index reached 128°F in Newark when the temperature reached 103°F and the dew point reached 84°F. There were 16 hours with the heat index ≥100°F, 12 hours of ≥110°F, and three hours of ≥120°F. ONJSC stated that this was the most uncomfortably hot day at Newark since weather observations began to be collected in the early 1930s.
7/5/1999	Excessive Heat	Statewide	The index was ≥100°F for 14 hours, ≥105°F for nine hours, and ≥110°F for four hours. This culminated with the July 4 to 7 period of having 58 hours with a heat index ≥90°F, with never more than four consecutive hours of less than 90°F.
January 27 to 28, 2000	Extreme Cold	Statewide	Temperatures ranged from 9°F to 14°F
May 2 to 4, 2001	Extreme Heat	Statewide	Temperatures ranged from 89°F to 96°F
February 5 to 7, 2007	Extreme Cold	Statewide	Temperatures ranged from -4°F to 12°F
June 26 to 28,	Extreme Heat	Statewide	Temperatures ranged from 92°F to 96°F
July 8 to 10, 2007	Extreme Heat	Statewide	Temperatures ranged from 93°F to 100°F
August 7 to 8,	Extreme Heat	Statewide	Temperatures ranged from 93°F to 101°F
8/25/2007	Extreme Heat	Statewide	Temperatures ranged from 91°F to 94°F
June 7 to 10, 2008	Extreme Heat	Statewide	Temperatures ranged from 92°F to 100°F
July 16 to 22, 2008	Extreme Heat	Statewide	Temperatures ranged from 93°F to 98°F
8/10/2009	Extreme Heat	Statewide	Temperatures ranged from 93°F to 104°F
June 23 to 24, 2010	Extreme Heat	Statewide	Temperatures ranged from 97°F to 99°F
June 27 to 28, 2010	Extreme Heat	Statewide	Temperatures ranged from 95°F to 99°F
July 4 to 7, 2010	Extreme Heat	Statewide	Temperatures ranged from 90°F to 105°F. One fatality was reported from this event. In Newark, four straight days of temperatures ≥100°F (101°F, 102°F, 103°F, and 101°F respectively). This led to 65 consecutive hours of temperatures of ≥80°F. The low temperature on July 6 was 84°F.
1/24/2011	Extreme Cold/Windchill	Statewide	An arctic high-pressure system brought in the coldest air mass of the season to New Jersey. Many places saw morning lows that were the coldest during that winter. Northwest winds produced wind chill factors below zero in most of the State. Sussex County experienced a wind chill of -15°F. Actual low temperatures in the Raritan Basin and northwest New Jersey were below 0°F. Temperatures throughout the State ranged from -14°F in Warren County to 9°F in Cape May County.
July 21 to 24, 2011	Heat Wave	Statewide	One of the most oppressive heat waves since July 1995. It caused two deaths and hundreds of heat-related injuries. Many locations had high temperatures that were in excess of 100°F. July 22 was the hottest, with heat index values of 110°F to 120°F. Many counties and municipalities opened cooling centers for its residents. Temperatures ranged from 100°F in Cumberland and Cape May Counties, to 106°F in Mercer County.

Date(s) of	Event Type	Counties	Description
3/1/2012	Record Warmth	Statewide	The warmest March in history, breaking nearly 15,000 warm temperature records.
June 20 to 22, 2012	Heat Wave	Statewide	A three-day heat wave occurred throughout the entire State, bringing temperatures between 94°F and 99°F. The heat wave broke dramatically when a series of severe thunderstorms impacted New Jersey.
6/29/2012	Extreme Heat	Statewide	An unseasonably hot and humid day produced high temperatures in the mid to upper 90s in most of New Jersey. Maximum hourly heat indices reached between 100°F and 105°F. High temperatures ranged from 93°F in Hunterdon, Warren, Cape May and Atlantic Counties, to 99°F in Burlington County.
July 2 to 7, 2012	Excessive Heat and High Humidity	Central and Southern New Jersey	Temperatures ranged from 90°F to 101°F between July 2 and 7, peaking on July 7 with high temperatures around 100°F and afternoon hourly heat indices peaking around
July 17 to 18, 2012	Extreme Heat	Statewide	Temperatures ranged from 97°F in Sussex County, to 102°F in Morris, Ocean and Camden Counties.
1/23/2013	Cold/Wind Chill	Central and Northwest New Jersey	The northwest flow behind a departing low-pressure system coupled with one of the coldest air masses of the winter season dropped low temperatures into the single numbers.
July 6 to 7, 2013	Extreme Heat	Central and Southern New Jersey	The first run of hot weather that combined high temperatures in the 90s and more oppressive humidity levels.
July 15 to 20, 2013	Extreme Heat	Statewide	The most oppressive hot spell of the summer season affected New Jersey from July 15th through the 20th. Widespread high temperatures reached into the mid to upper 90s and the most oppressive days (combination of heat and humidity) occurred on the 18th and 19th.
9/11/2013	Extreme Heat	Statewide	An unseasonably hot and humid air mass caused most high temperatures to reach 90F to 95F.
1/4/2014	Cold/Wind Chill	Statewide	A high-pressure system that moved over New Jersey coupled with fresh snow cover from the winter storm on the 2nd and 3rd gave the area one of its coldest winter morning in years. This was the first of three arctic blasts in the state during the month.
1/7/2014	Cold/Wind Chill	Statewide	Some record calendar day low temperatures occurred and combined with strong northwest winds produced wind chill factors as low as 15 to 25 degrees below zero in most areas.
1/22/2014	Cold/Wind Chill	Statewide	Strong northwest winds behind the departing strong low-pressure system coupled with another arctic air mass dropped low temperatures.
6/17/2014	Extreme Heat	Statewide	High temperatures were in the lower to mid-90s were reported. Afternoon heat index values were in the mid-90s.
7/2/2014	Extreme Heat	Statewide	High temperatures in the lower to mid-90s and afternoon heat index values reaching 100 to 105 degrees.
1/7/2015	Cold/Wind Chill	Statewide	The arrival of an arctic air mass brought one of the coldest mornings of the month of January to most of New Jersey. Morning low temperatures were mainly in the single numbers above zero.

Date(s) of	Event Type	Counties	Description
2/13/2015	Cold/Wind Chill	Statewide	Northwest winds that persisted into the morning of the 13th combined with an arctic air mass to produce wind chill factors of around 10 degrees below zero and low temperatures in the positive single numbers.
February 15 to 16, 2015	Cold/Wind Chill	Statewide	The near arrival of the center of the arctic air mass brought some of the lowest wind chills and temperatures of the winter season. This produced wind chill factors as low as around 20 degrees below zero in most of the state.
February 19 to 20, 2015	Cold/Wind Chill	Statewide	The arrival of another arctic air mass brought some of the lowest wind chills as well as the lowest temperatures of the winter season. Actual lowest temperatures on either the 20th or 21st included 17 degrees below zero in Walpack (Sussex County) and 13 degrees below zero in Sussex (Sussex County).
2/24/2015	Cold/Wind Chill	Statewide	The high-pressure system responsible for third and last arctic blast of the month of February arrived in New Jersey on the morning of the 24th. Unlike the two previous arctic outbreaks earlier this month, this one was not accompanied by strong winds during the first half of the day. Air and wind chill temperatures were nearly the same. The calm conditions and snow cover combined to give many locations in northwest New Jersey the coldest morning of the winter season.
6/12/2015	Extreme Heat	Southwest New Jersey	An unseasonably hot and humid air mass caused high temperatures to reach the lower to mid-90s.
6/23/2015	Extreme Heat	Camden, Atlantic, Cumberland, Salem, Burlington, Gloucester	High temperatures reached into the lower to mid-90s and afternoon heat indices of around 100F. In Atlantic County, about 30 people had to be treated for heat exhaustion at the Egg Harbor Township graduation.
July 19 to 20, 2015	Extreme Heat	Statewide	Unseasonably hot and humid weather affected most of New Jersey on the 19th and 20th. High temperatures in most areas reached into the lower to mid-90s both days. The 19th was slightly hotter and more humid overall. The combination of heat and humidity brought afternoon heat index values as high as 100F to 105F on the 19th. These were some of the highest heat index values of the entire summer.
2/14/2016	Cold/Wind Chill	Statewide	Bitter cold temperatures and strong northwest winds associated with an Arctic outbreak combined to create dangerous wind chill temperatures.
7/28/2016	Extreme Heat	Statewide	The State Emergency Operations Center reported 17 heat related illnesses, due to heat exposure. This occurred during the PGA tournament at Baltrusrol Golf Club in Springfield NJ. Temperatures rose to the lower 90s in the afternoon. The combination of these temperatures and high humidity made it feel like the mid-90s.
7/20/2017	Extreme Heat	Statewide	A Bermuda high pressure system ushered in hot and humid weather across the east coast.

Source: NOAA-NCDC 2018; ONJSC Rutgers University 2013

5.10.4.1 FEMA DISASTER DECLARATIONS

Between 1954 and 2018, 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, 2018).

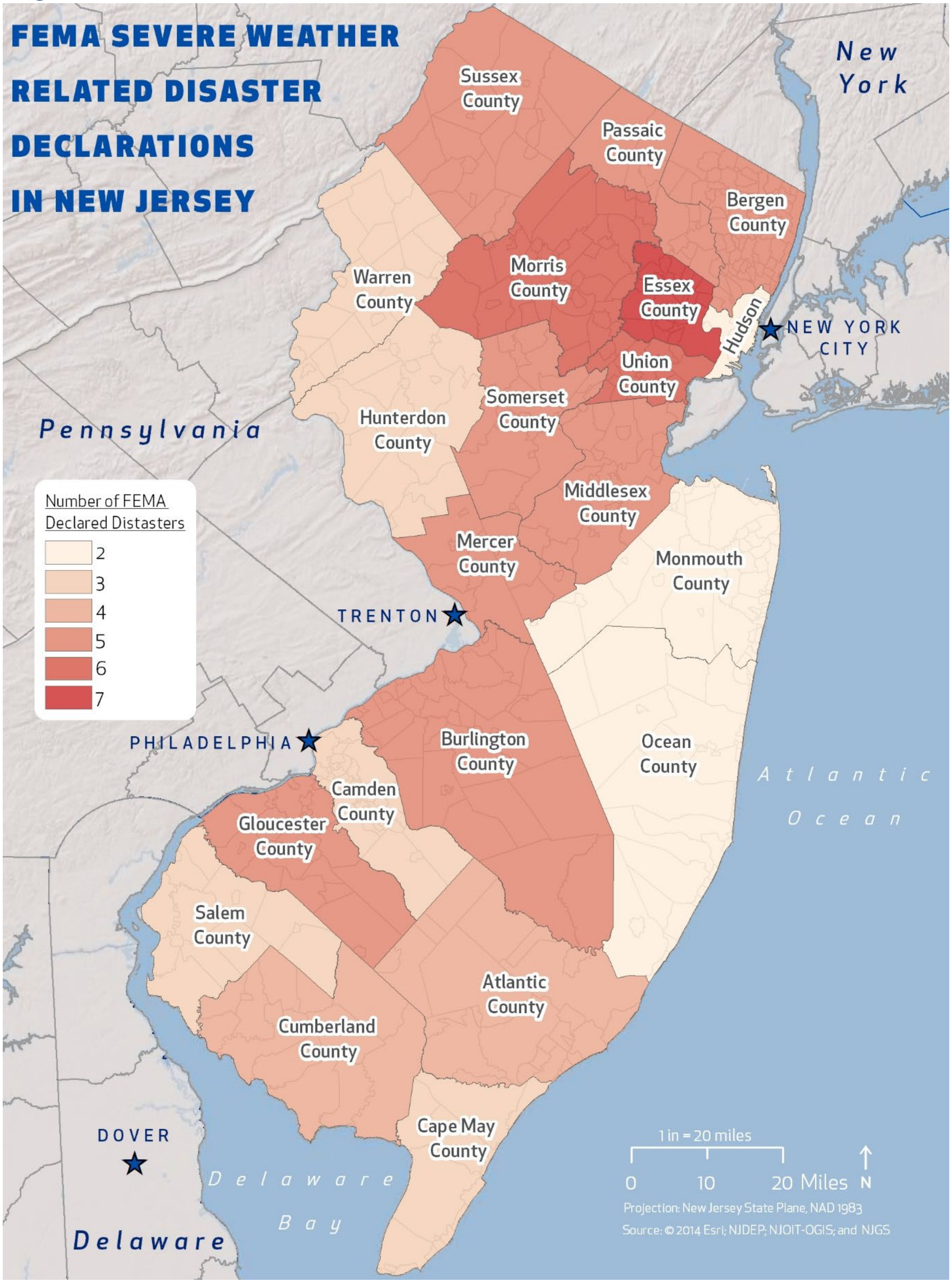
Table 5.10-14 identifies known severe storm events that have affected New Jersey and were declared a FEMA disaster. This table provides information on the FEMA disaster declarations for severe storms, including the disaster number, disaster type, declaration and incident dates, and counties included in the declaration. Figure 5.10-28 illustrates the number of FEMA declared disasters by county. Detailed information about the declared disasters since 2014 is provided in Appendix D of this Plan.

Table 5.10-14 Severe Weather-Related FEMA Disaster Declarations (1954 to 2018)

Disaster Number	Disaster Type	Declaration Date	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 Number of Counties
DR-124	Severe Storms, High Tides, Flooding	3/9/1962	3/9/1962	Unknown																					
DR-402	Severe Storms, Flooding	8/7/1973	8/7/1973							X					X						X		X		4
DR-477	Heavy Rains, High Winds, Hail, Tornadoes	7/23/1975	7/23/1975		X	X			X	X	X			X	X		X		X	X	X	X	X		13
DR-519	Severe Storms, High Winds, Flooding	8/21/1976	8/21/1976	X				X								X		X							4
DR-1145	Severe Storms/Flooding	10/18/1996 – 10/23/1996	11/19/1996									X			X		X				X		X		5
DR-1337	Severe Storms, Flooding, and Mudslides	8/12/2000 – 8/21/2000	8/17/2000														X					X			2
DR-1530	Severe Storms and Flooding	7/12/2004 – 7/23/2004	7/16/2004			X	X																		2
DR-1588	Severe Storms and Flooding	4/1/2005 – 4/3/2005	4/19/2005		X					X	X		X	X			X		X			X		X	9
DR-1653	Severe Storms and Flooding	6/23/2006 – 7/10/2006	7/7/2006										X	X								X		X	4
DR-1694	Severe Storms and Inland Coastal Flooding	4/14/2007 – 4/20/2007	4/26/2007		X	X	X			X	X	X		X	X		X		X		X		X		12
DR-1897	Severe Storms and Flooding	3/12/2010 – 4/15/2010	4/2/2010	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	8/15/2011						X		X									X					3
DR-4048	Severe Storm	10/29/2011	11/30/2011		X			X		X			X		X				X		X	X	X	X	10
DR-4070	Severe Storms and Straight Line Winds	6/30/2012	7/19/2012	X					X											X					3
DR-4231	Severe Storm	7/22/2015	6/23/2015	X		X	X			X															4

Source: FEMA, 2018

Figure 5.10-28 Severe Weather-Related FEMA Disaster Declarations (1954 to 2018)



Source: FEMA, 2018

5.10.5 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 wind storms, 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 occur in conjunction with other severe hazards such as hail and 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 many central United States.

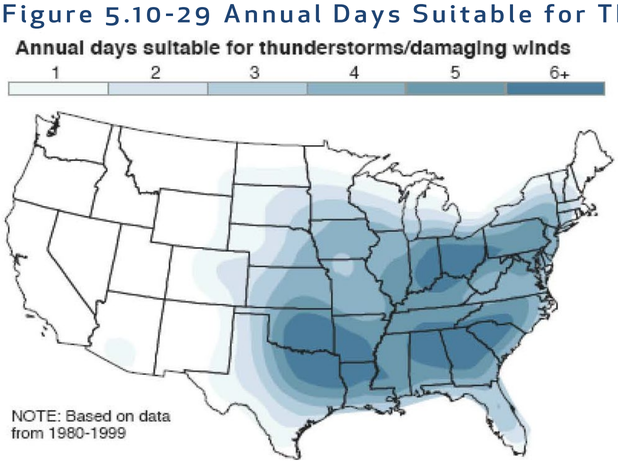
Extreme Temperatures

Extreme temperatures are predicted to occur more frequently as part of regular seasons. Specifically, extreme heat may continue to impact New Jersey and, based upon data presented, may increase in the next several decades. Figure 5.10-3 indicates that many heat records have been set in the last 10 to 15 years. This trend is predicted to continue. On the other hand, record-setting cold temperatures are decreasing. This trend may likely continue.

5.10.5.1 POTENTIAL EFFECTS OF CLIMATE CHANGE

National Aeronautics and Space Administration (NASA) scientists suggest that the United States will face more severe thunderstorms in the future, with deadly lightning, damaging hail, and the potential for tornadoes in the event of climate change. A recent study conducted by NASA predicts that smaller storm events like thunderstorms will also be more dangerous due to climate change (NASA 2007). As prepared by the NWS Figure 5.10-29 identifies those areas, particularly within the eastern United States, that are more prone to thunderstorms, including New Jersey (NWS 2010).

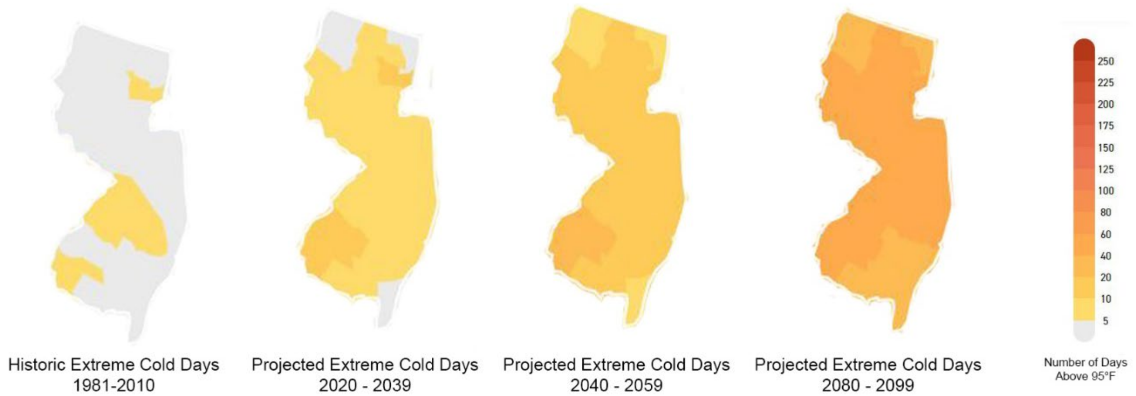
Figure 5.10-29 Annual Days Suitable for Thunderstorms/Damaging Winds



Source: Borenstein, 2007

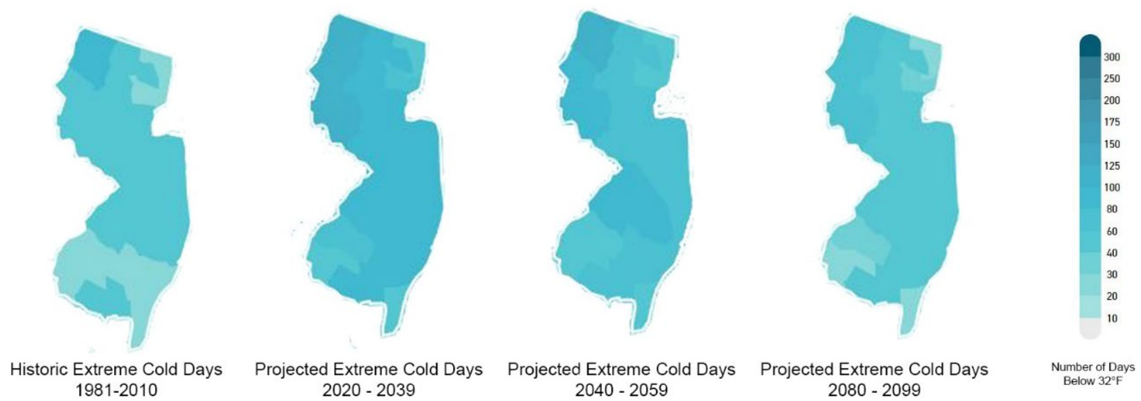
As climate changes, the number of extreme cold and extreme heat events are anticipated to increase. Figure 5.10-30 and 5.10-31 present these projections for number of extreme heat days and number of extreme cold days calculated using the CMIP5 model.

Figure 5.10-30 Historical and Projected Number of Days Above 95 Degrees



Source: Climate Impact Map, 2018

Figure 5.10-31 Historical and Projected Number of Days Below 32 Degrees



Source: Climate Impact Map, 2018

5.10.6 IMPACT ANALYSIS

5.10.6.1 SEVERITY AND WARNING TIME

High Wind

High wind storms cause disruptions to power and have the potential to damage structures in the State. High winds storms also have the potential to knock down tree limbs which subsequently damage power and other utility lines thus contributing to widespread power outages. High wind storms are often accompanied by other events such as thunderstorms, or part of hurricane and tropical storms. The worst-case scenario for a high wind event includes widespread power outages to populated cities and municipalities.

The NWS issues watches and warning for high wind storms and also severe thunderstorms that may cause damaging winds. Additionally, the NWS issues marine weather messages consisting of small craft advisories when conditions are suitable for producing high wind incidents. Like the prediction of thunderstorms and other severe weather events, the NWS can provide accurate forecasts several days prior to an event.

Tornadoes

Tornadoes are nature's most violent storms. They are spawned from thunderstorms and can cause fatalities and devastate a neighborhood in seconds. Winds can reach 300 mph and damage paths can be in excess of one mile wide and 50 miles long. Every state in the United States is at some risk from tornadoes (FEMA 2013).

A tornado watch and warning is issued by the local NWS office. A tornado watch is released when tornadoes are possible in an area. A tornado warning means a tornado has been sighted or indicated by weather radar. The current average lead time for tornado warnings is 13 minutes; however, warning times for New Jersey may be shorter due to the fact that the State experiences smaller tornadoes that are difficult to warn for. Occasionally, tornadoes develop so rapidly, that little, if any, advance warning is possible (NOAA 2013; FEMA, 2013; Robinson 2013).

Thunderstorms

The most common problems associated with severe storms are immobility and loss of utilities. Fatalities are uncommon but can occur due to lightning strikes. Roads may become impassable due to flooding, downed trees, or a landslide. Power lines may be downed due to high winds, and services such as water or phone may be disrupted. Lightning can cause severe damage and injury. Wind storms can be a frequent problem and have caused damage to utilities. Wind storms, as mentioned previously, may occur as part of thunderstorms or independently. 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.

Meteorologists can often predict the likelihood of a severe thunderstorm. This can give several days warning. However, meteorologists cannot predict the exact time of onset, specific location, or the severity of the storm. Some storms may come on more quickly and have only a few hours of warning time.

Hailstorms

The severity of hail is measured by duration, hail size, and geographic extent. All of these factors are directly related to thunderstorms, which creates hail. There is wide potential variation in these severity components. The most significant impact of hail is damage to crops. Hail also has the potential to damage structures and vehicles during hailstorms. The State has a relatively low potential for significant hail events, based on previous records.

Like high wind events and thunderstorms, meteorologists can forecast the potential of hailstorms, often giving several hours of notice that hail may form. In addition, meteorologists can give live updates during severe weather to indicate areas that are experiencing or will experience hail. Since hailstorms often occur as part of other events, such as thunderstorms, forecasts for hailstorms may be available several days in advance.

Extreme Temperatures

The Wind Chill Temperature (WCT) Index is one of the means used to measure the severity of cold temperatures. Wind Chill Temperature is the temperature that people and animals feel, and it is based on the rate of heat loss from exposed skin from the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin's temperature to drop. The severity of extreme heat temperatures are generally measured through the Heat Index. The Heat Index can be used to determine what effects the temperature and humidity can have on the population. Detailed information regarding the WCT and Heat Index is discussed earlier in this section.

Meteorologists can accurately forecast extreme temperature event development and the severity of the associated conditions with several days lead time. These forecasts provide an opportunity for public health and other officials to notify vulnerable populations. For heat events, the NWS issues excessive heat outlooks when the potential exists for an excessive heat event in the next three to seven days. Watches are issued when conditions are favorable for an excessive heat event in the next 24 to 72 hours. Excessive heat warning/advisories are issued when an excessive heat event is expected in the next 36 hours (NWS 2013). Winter temperatures may fall to extreme cold readings with no wind occurring. Currently, the only way to headline very cold temperatures is with the use of the NWS-designated Wind Chill Advisory or Warning products. When actual temperatures reach Wind Chill Warning criteria with little to no wind, extreme cold warnings may be issued (NOAA 2013).

5.10.6.2 SECONDARY HAZARDS

High Winds

The most significant secondary hazard of high wind storms is utility failure resulting from downed power lines and tree branches. As noted, high wind storms can cause localized or regional power outages, thus leading to exposure extreme temperatures for vulnerable populations. An example was the widespread power outages following Superstorm Sandy and the exceptionally cold temperatures which led counties to open additional shelter place for displaced residents. An additional secondary hazard is traffic accidents that may occur when power to traffic control devices is disrupted.

Tornadoes

Like high wind storms, tornadoes have the potential to lead to widespread utility failure, thus exposing vulnerable populations to extreme temperatures. Tornado events may also be accompanied by strong thunderstorms, straight line winds, and hail.

Thunderstorms

Severe thunderstorms, like tornadoes are often accompanied by strong winds and hail. Both of these hazards have the potential to damage critical infrastructure. Additionally, flash flooding, particularly in low lying areas, is a secondary effect of thunderstorms as intense rain often accompanies thunderstorms.

Hailstorms

Hailstorms, like many of the other hazards discussed, are often accompanied by other severe weather. One secondary effect of hailstorms is the damage to critical infrastructure which in turn may lead to utility failure. Additionally, extreme hailstorms impact traffic route and may lead to transportation accidents.

Extreme Temperatures

Prolonged extreme temperatures can radically affect the State and cause numerous secondary hazards. Depending on severity, duration and location; extreme heat events can create or provoke secondary hazards including, but not limited to: dust storms, droughts, wildfires, water shortages, and power outages (FEMA, 2006; CDC, 2006). This could result in a broad and far-reaching set of impacts throughout a local area or entire region. Impacts could include: significant loss of life and illness; economic costs in transportation, agriculture, production, energy and infrastructure; and losses of ecosystems, wildlife habitats, and water resources (Meehl and Tebaldi, 2004; CDC, 2006). Extreme cold temperatures create the conditions for secondary effects such as the possibility of snow, ice, and freezing rain.

The increase in the number of extreme heat days will lead to more heat related illness. Also, with an increase in severe storms there will be an increase in storm water runoff which may be polluted and sicken individuals (Kaplan and Herb, 2012). The effect on public health will likely increase the need for vulnerable population planning and may place heavier burdens on the healthcare system.

5.10.6.3 ENVIRONMENTAL IMPACTS

The environmental impacts of severe weather events, such as thunderstorms and tornadoes, are consistent with impacts of other hazards discussed in this plan (Section 5.8 Hurricane and Tropical Storm and Section 5.9 Nor'easter). A tornado's area of impact tends to be smaller than a thunderstorm, tropical storm or hurricane but their higher wind speeds can cause much more destruction including uprooting trees, buildings and anything in its path. Hailstorm events and prolonged periods of extreme cold temperatures can damage vegetation and crops. Extreme heat events may be associated with drought conditions and impact ground and surface water supplies. A discussion on impacts to water resources is discussed further in Section 5.4 Drought. Both extreme heat and cold temperature events can negatively impact the agricultural industry.

5.10.7 VULNERABILITY ASSESSMENT

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.

5.10.7.1 ASSESSING VULNERABILITY BY JURISDICTION

Historically, severe weather events have impacted all 21 New Jersey counties. All local hazard mitigation plans identified at least one of the severe weather types discussed in this section as a hazard of concern. Refer to Table 5.1-2 in Section 5.1 (State Risk Assessment Overview) for further information on the local mitigation plans.

Of the five-local mitigation plans that ranked risk into high/medium/low categories for this hazard, all considered the severe weather hazard to be high risk. These plans were for the following counties: Cape May, Essex, Hudson, Monmouth, and Somerset counties. If severe weather was not ranked by a local HMP, the jurisdictions identified their most significant hazards using other methods.

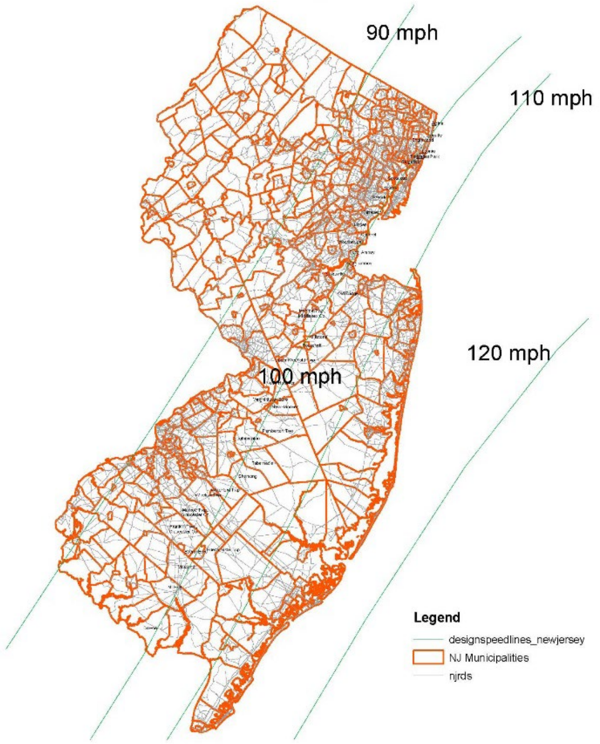
For the purposes of this 2018 Plan update, the entire population of New Jersey is exposed to severe weather events. Residents may be displaced or require temporary to long-term sheltering due to severe weather events. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. The summary below describes the vulnerability for each severe weather type.

High Winds

The entire population of the State is considered exposed to high wind events. Wind speeds for the 50-year mean recurrence interval were determined based on three-second gusts in miles per hour at 33 feet above the ground. Refer to Figure 5.10-32 below. For the 50-year wind event, the portions of the following 12 coastal counties may experience wind speeds greater than 100 miles per hour: Atlantic, Bergen, Burlington, Cape May, Camden, Cumberland, Essex, Hudson, Gloucester, Middlesex, Monmouth, and Union Counties.

According to the Department of Community Affairs, Division of Codes and Standards, the isolines in Figure 5.10-32 should be used to determine the wind loads used for a structure that would be IBC-compliant. Further, Section R301.2.1.1 (design criteria) of the International Residential Code/2006, as it applies to the New Jersey, requires specific construction design requirements in regions where the basic wind speeds equal or exceed 100 mph (NJDCA 2007).

Figure 5.10-32 Wind Load Zones in New Jersey for the 50-Year Mean Recurrence Interval



Source: New jersey Department of Community Affairs, 2009

The continued development of the State will increase the overall vulnerability to severe weather events and more specifically high winds. Any future new or redevelopment in Atlantic, Bergen, Burlington, Cape May, Camden, Cumberland, Essex, Hudson, Gloucester, Middlesex, Monmouth, and Union Counties are vulnerable to winds over 100 mph. The development of new buildings in these areas must meet or exceed the standards in Section R301.2.1.1 of the International Building Code (IBC) which will assist with mitigating future potential damages and losses.

Tornadoes

According to historic record, there have been 144 tornado touch-downs in New Jersey from 1950 to 2012. There has been at least one confirmed tornado touch-down in every county. Table 5.10-15 below summarizes the number of historic confirmed tornado touch-downs in New Jersey from 1950 to 2012. Historically, Burlington County has experienced the greatest number of confirmed tornado touch-downs. However, this is not surprising because geographically it is also the largest county in the State.

Table 5.10-15 Number of Tornado Touch-Downs in New Jersey (1950 – 2016) by County

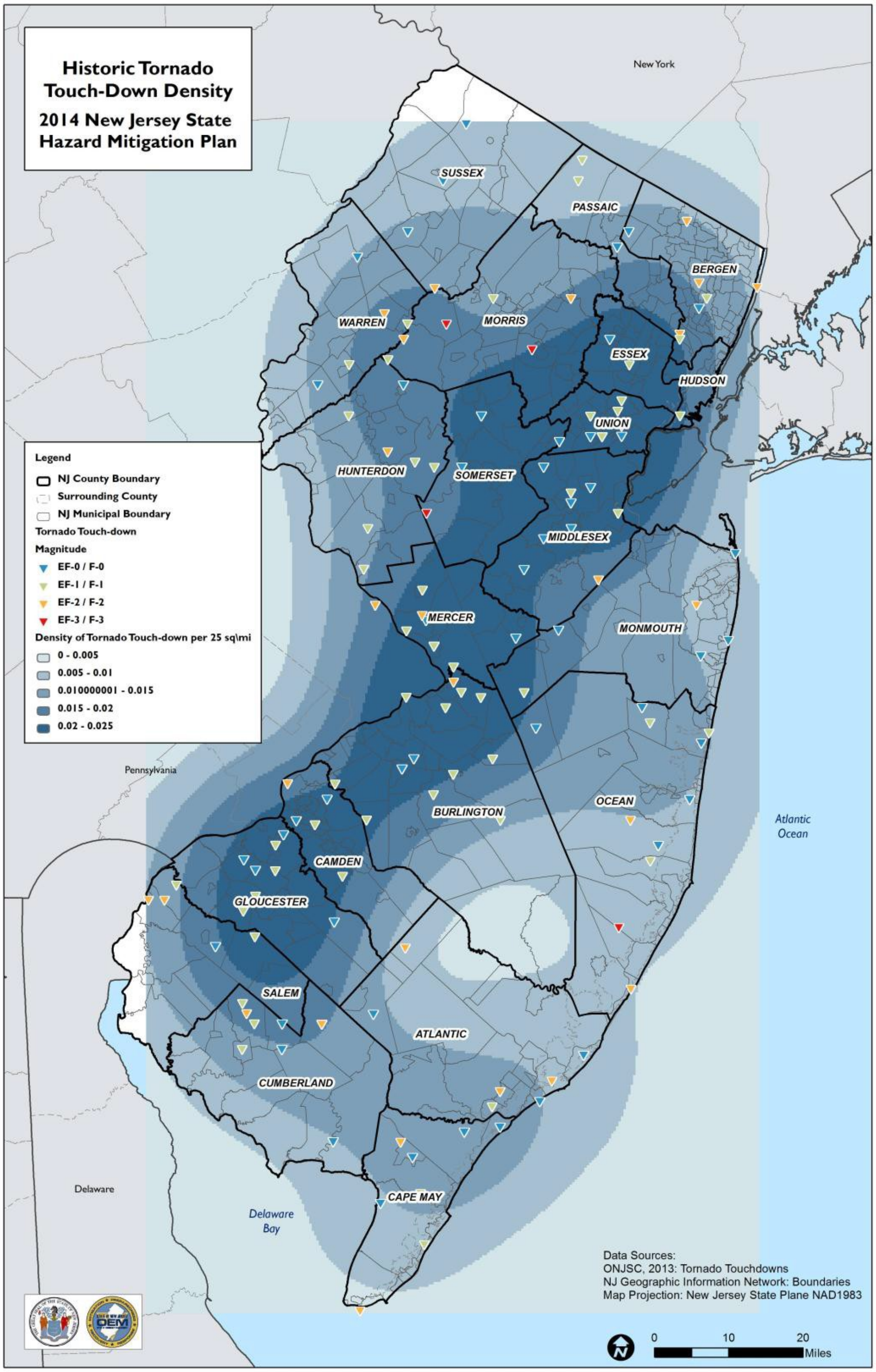
County	Number of Tornado Touch-downs
Atlantic	7
Bergen	9
Burlington	15
Camden	6
Cape May	8
Cumberland	9
Essex	2
Gloucester	8
Hudson	1
Hunterdon	8
Mercer	8
Middlesex	10
Monmouth	6
Morris	6
Ocean	12
Passaic	3
Salem	5
Somerset	4
Sussex	5
Union	11
Warren	6
Total	149

Source: ONJSC Rutgers University, 2013; NOAA, 2016

Tornado risk and vulnerability is based on probability of occurrence of past events. As shown in Figure 5.10-32 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 touch-downs has occurred in a southwest to northeast band across the State. The frequency of tornado touch-downs in New Jersey is heavily biased toward areas where the population density is greatest, as seen in Figure 5.10-33.

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 5.10-33 Total Tornado Events per 25-Square Miles in New Jersey



Source: ONJSC Rutgers University

Thunderstorms

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.

Hailstorms

Hail causes considerable damage to United States crops and property, occasionally causes death to farm animals, but seldom causes loss of human life. 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 2007 United States Department of Agriculture's Agricultural Census, the counties with the greatest number of farms are: Burlington (922 farms); Hunterdon (1,623 farms); Monmouth (932 farms); Sussex (1,060 farms) and Warren (933 farms) (United States Department of Agriculture 2007). Refer to Section 4 (State Profile) for additional statistics on agriculture in New Jersey.

Extreme Temperature

In terms of extreme temperature, both extreme heat and extreme cold were examined. Whether for extreme heat or extreme cold, vulnerable populations include the homeless population, elderly, low income or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads.

As discussed earlier, extreme heat events account for more loss of life than any other weather event. Those at greatest risk are located in urban areas due to the urban heat island effect. Cities are the most susceptible to the stresses of heat waves due to their large populations, which amplify the effects of heat. The population living in urban areas are also at high risk to poor air quality which may accompany extreme heat events.

Rowan University's Geospatial Research Lab compared and displayed the percent impervious surface across the State in 1986 and 2007. According to this study the amount of urban land has been increasing substantially through 2007. The increases in impervious surfaces associated with urban development have the potential to exacerbate the urban heat island effect.

As summarized in Section 4 (State Profile), subsection 4.6.2, there is a growing trend in urbanization and redevelopment in Bergen, Hudson, Essex, Middlesex, Monmouth, Ocean and Union Counties as demonstrated by the increase in building permits and growth compared to the less-developed areas of the State. Development that expands the densely developed urban centers has the potential to increase the vulnerability to extreme heat events due to the heat island effect.

Both extreme heat and cold temperature events can negatively impact the agricultural industry. As summarized in Section 4 (State Profile), New Jersey has more than 10,000 farms that produce products valued at $1 billion annually. The counties with the greatest number of farms were discussed above for the hailstorm severe weather type. Prolonged periods of extreme heat may be associated with drought conditions and impact ground and surface water supplies. A discussion on impacts to water resources is discussed further in Section 5.4 (Drought).

Overall, the northeastern and central areas of the State are more vulnerable to extreme heat events as evidenced by the greater number of 100°F or greater days compared to the northwestern, coastal and southern portions of the State. In terms of extreme cold events, northwestern New Jersey experiences more days of 32°F or colder than the rest of the State.

5.10.7.2 ESTIMATING POTENTIAL LOSSES TO JURISDICTIONS

High Winds

High wind events may threaten life 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.

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.

Table 5.10-16 summarizes the total replacement cost value of the residential general building stock (structure only) in the defined wind zones, by County. This is the default general building stock available in Hazards U.S. – Multi Hazard (HAZUS-MH) Version 4.2. The total structural replacement cost value for residential buildings in the State is greater than $552 billion or approximately 71.6% of all occupancy classes. Refer to Section 5.8 (Hurricanes/Tropical Storms) which includes estimated potential losses to buildings due to high wind speeds associated with historic tropical storm and hurricane events. In summary, Atlantic, Burlington, Cape May, Monmouth and Ocean Counties' residential buildings are the most vulnerable because they are located in the zone for the 50-year recurrence interval with the highest winds (located in the 110 to 120 mph zone).

Table 5.10-16 Estimated Potential Losses to Residential Buildings in Wind Load Zones by County

County	Less than 90 mph		90 - 100 mph		100 - 110 mph		110 - 120 mph	
	RCV	% of Total	RCV	% of Total	RCV	% of Total	RCV	% of Total
Atlantic	$ -	0%	$ 47,178,000	0%	$ 2,929,352,000	17%	$ 14,768,397,000	84%
Bergen	$ 12,533,000	0%	$ 55,853,010,000	88%	$ 7,933,737,000	13%	$ -	0%
Burlington	$ -	0%	$24,784,889,000	89%	$ 3,269,950,000	12%	$ 111,450,000	0%
Camden	$ -	0%	$30,089,736,000	100%	$ 241,150,000	1%	$ -	0%
Cape May	$ -	0%	$ -	0%	$ 161,734,000	1%	$ 12,678,912,000	99%
Cumberland	$ -	0%	$ 5,555,352,000	79%	$ 1,853,584,000	26%	$ -	0%
Essex	$ -	0%	$ 46,181,097,000	100%	$ -	0%	$ -	0%
Gloucester	$ 882,813,000	6%	$ 14,149,939,000	95%	$ 14,933,000	0%	$ -	0%
Hudson	$ -	0%	$ 3,831,479,000	12%	$28,486,360,000	89%	$ -	0%
Hunterdon	$ 9,537,415,000	100%	$ 14,882,000	0%	$ -	0%	$ -	0%
Mercer	$ 366,189,000	2%	$ 22,958,164,000	99%	$ -	0%	$ -	0%
Middlesex	$ -	0%	$ 41,218,609,000	87%	$ 7,154,402,000	15%	$ -	0%
Monmouth	$ -	0%	$ 353,247,000	1%	$ 21,896,119,000	49%	$22,988,654,000	52%
Morris	$25,062,700,000	69%	$ 12,212,841,000	34%	$ -	0%	$ -	0%
Ocean	$ -	0%	$ -	0%	$ 4,019,938,000	11%	$33,663,663,000	91%
Passaic	$ 4,246,553,000	16%	$ 22,829,712,000	85%	$ -	0%	$ -	0%
Salem	$ 1,869,106,000	52%	$ 1,842,625,000	51%	$ -	0%	$ -	0%
Somerset	$ 7,517,043,000	33%	$ 16,265,563,000	71%	$ -	0%	$ -	0%
Sussex	$ 9,749,907,000	100%	$ -	0%	$ -	0%	$ -	0%
Union	$ -	0%	$ 33,128,555,000	100%	$ 125,000	0%	$ -	0%

County	Less than 90 mph		90 - 100 mph		100 - 110 mph		110 - 120 mph	
	RCV	% of Total	RCV	% of Total	RCV	% of Total	RCV	% of Total
Warren	$6,343,325,000	100%	$ -	0%	$ -	0%	$ -	0%
Total	$65,587,584,000	12%	$331,316,878,000	60%	$77,961,384,000	14%	$84,211,076,000	15%

Source: HAZUS-MH 4.2

Tornadoes

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.

An exposure analysis was conducted using the default HAZUS-MH general building stock data. The building data was overlaid with the zone of greatest historical tornado touch-down density (greater than 0.02) in the State. The replacement cost value of buildings (all occupancy types) within this zone are presented in Table 5.10-17. The limitations of this analysis are recognized. Currently, HAZUS-MH does not contain damage functions to estimate potential loss as a result of tornado events. As more current replacement cost data becomes available at the structure level, and probabilistic modeling capabilities become available for tornado events, this section of the plan will be updated with new information. The following Counties have the greatest building replacement cost value located in the zone of greatest touch-down density: Burlington, Camden, Essex, Gloucester, Mercer, Middlesex, Somerset and Union.

Table 5.10-17 Estimated RCV of Buildings in the Greatest Historic Tornado Touch-Downs per Square Mile Zone

County	Total RCV	Total RCV in Greatest Historic Tornado Density	% Total
Atlantic	$ 38,043,171	$ -	0%
Bergen	$ 154,077,482	$ 4,118,290	3%
Burlington	$ 62,700,794	$ 45,949,190	73%
Camden	$ 70,467,051	$ 50,418,110	72%
Cape May	$ 24,665,528	$ -	0%
Cumberland	$ 18,128,613	$ -	0%
Essex	$ 113,124,687	$ 112,053,636	99%
Gloucester	$ 33,534,660	$ 28,373,926	85%
Hudson	$ 82,290,184	$ 19,206,577	23%
Hunterdon	$ 21,720,513	$ -	0%
Mercer	$ 56,194,660	$ 55,272,646	98%
Middlesex	$ 119,947,782	$ 109,959,088	92%
Monmouth	$ 96,235,266	$ 1,261,970	1%
Morris	$ 86,634,810	$ 25,619,706	30%
Ocean	$ 73,559,915	$ 307,181	0%
Passaic	$ 66,705,864	$ 5,963,827	9%
Salem	$ 8,092,037	$ 939,787	12%
Somerset	$ 52,513,253	$ 50,104,465	95%

Sussex	$ 20,979,595	$ -	0%
Union	$ 79,329,736	$ 79,329,736	100%
Warren	$ 14,442,755	$ -	0%
Total	$1,293,388,356	$ 588,878,135	46%

Source: HAZUS 4.2

Thunderstorms

Agricultural losses can be devastating due to lightning and resulting fires. Table 5.10-18 below summarizes the potential monetary loss of crops in each County. The Counties with the amount of high value crop types have the highest potential loss due to storms. Atlantic and Cumberland Counties have the highest amount of potential monetary crop loss. Refer to Section 4 State Profile, Subsection 3, as well as 5.15 Crop Failure for additional details on New Jersey Agriculture, historic crop failure events and losses.

Hailstorms

As discussed above, all Counties are considered vulnerable to the effects of hailstorms, but those with farmland and high agricultural yields are more likely to be impacted. Refer to Section 4.3 State Profile on Agriculture, as well as 5.15 Crop Failure for additional details on New Jersey Agriculture, historic crop failure events and losses.

Extreme Temperature

Extreme heat and cold temperature events can have significant impacts to human health and the local economy. As discussed earlier, extreme heat events account for more loss of life than any other weather event. Those at greatest risk are located in urban areas due to the urban heat island effect. Refer to Section 4 State Profile, Figure 4-8 which displays population density across the State.

Extreme temperature events can lead to power interruption or failure. Business owners may be faced with increased financial burdens due to unexpected repairs such as pipes bursting, higher than normal utility bills or business interruption due to power failure (e.g.., loss of electricity, telecommunications). Increased demand for water and electricity may result in shortages and a higher cost for these resources. Industries that rely on water for business operations and services may be impacted the hardest during extreme heat events (e.g., landscaping businesses). Even though most businesses will still be operational, they may be impacted aesthetically. These aesthetic impacts are significant to the recreation and tourism industry.

As summarized in Section 4 (State Profile), New Jersey has more than 10,000 farms that produce products valued at $1 billion annually. This represents the total potential loss that can be experienced from extreme temperature events. Historic records indicate severe weather such as extreme temperature can damage crops throughout the State. Refer to Section 5.15 (Crop Failure) for additional details on historic events and losses.

5.10.7.3 ASSESSING VULNERABILITY TO STATE FACILITIES

All State buildings are exposed to severe weather events. As the State of New Jersey continues to become more urbanized, the State facilities will need to be developed in locations that will serve the growing population. The summary below describes the vulnerability for each severe weather type.

High Winds

Damage to buildings is dependent upon several factors including wind speed and duration and building construction. Refer to Section 5.8 (Hurricanes/Tropical Storms) for a presentation on potential wind losses associated with high winds. To assess the vulnerability of high winds to State facilities, a spatial analysis was conducted using the four wind load zones. Generally speaking, structures should be designed to withstand the total wind load of the zone in which they are located. Refer to the State Building Code for appropriate reference wind pressures, wind forces on roofs, and other required codes. The State facilities, critical facilities and infrastructure located in each zone are noted in Tables 5.10-18 through 5.10-19. Table 5.10-20 presents only the critical facilities located in the 110 to 120 mph zone.

Approximately two-thirds of the State building inventory is located in zones equal to or less than 100 mph. Cape May, Monmouth and Ocean Counties have the greatest number of State buildings in the 110 to120 mph zone. In terms of critical facilities, schools, fire, EMS and shelters have the greatest number of buildings in the 110 to120 mph zone. It is noted that these facility types also have the largest inventory of buildings included in the analysis.

Table 5.10-18 Number of State-Owned and -Leased Buildings in Wind Load Zones by County

County	Lease	Own	Lease	Own	Lease	Own	Lease	Own
Atlantic	-	-	-	-	7	33	9	38
Bergen	-	-	8	35	-	3	-	-
Burlington	-	-	11	201	-	129	1	3
Camden	-	-	8	61	-	-	-	-
Cape May	-	-	-	-	-	-	5	109
Cumberland	-	-	4	153	1	209	-	-
Essex	-	-	13	61	-	-	-	-
Gloucester	-	6	4	36	-	-	-	-
Hudson	-	-	-	5	7	10	-	-
Hunterdon	3	330	-	-	-	-	-	-
Mercer	-	1	47	342	-	-	-	-
Middlesex	-	-	6	165	1	85	-	-
Monmouth	-	-	-	2	3	43	7	107
Morris	6	85	-	10	-	-	-	-
Ocean	-	-	-	-	-	15	8	80
Passaic	1	9	-	55	-	-	-	-
Salem	3	18	-	34	-	-	-	-
Somerset	-	13	-	22	-	-	-	-
Sussex	5	58	-	-	-	-	-	-
Union	-	-	-	26	-	-	-	-
Warren	3	117	-	-	-	-	-	-
Total	21	637	101	1,208	19	527	30	337

Source: NJOMB 2013

Table 5.10-19 Number of State-Owned and -Leased Buildings in Wind Load Zones by Agency

Agency	Less than 90 mph		90 - 100 mph		100 - 110 mph		110 - 120 mph	
	Lease	Own	Lease	Own	Lease	Own	Lease	Own
Agriculture	-	-	-	-	-	1	-	-
Banking and Insurance	-	-	-	1	-	-	-	-
Chief Executive	1	-	-	-	-	-	-	-
Children and Families	9	4	19	16	6	-	7	20
Community Affairs	2	-	-	1	2	-	-	-
Corrections	-	141	-	344	-	203	3	-
Education	1	1	-	55	-	3	-	-
Environmental Protection	1	130	-	65	2	40	2	70
Health	-	-	1	2	-	-	-	-
Human Services	-	110	1	195	-	89	-	68
Judiciary	-		4		-	-	-	-
Juvenile Justice Commission	-	32	2	46	1	95	-	5
Labor and Work Force Development	-	-	1	1	-	-	2	-
Law and Public Safety	-	-	4	4	-	-	1	1
Legislature	-	-	1	3	-	-	-	
Military and Veterans Affairs	-	27	3	118	-	30	-	82
Miscellaneous Commissions	-	-	1		-	-	-	-
Motor Vehicles Commission	3	7	11	22	3	3	5	9
Personnel	-	-	1	-	-	-	-	-
State	-	-	-	8	-	-	-	1
State Police	4	8	15	56	5	10	9	11
Transportation	-	177	-	263	-	53	-	72
Treasury	-		6	8	-	-	1	-
Total	21	637	70	1,208	19	527	30	339

Source: NJOMB 2013

Table 5.10-20 Number of Critical Facilities Exposed to 110 to 120 mph Wind Loads

County	Total Number	Airport	Special Needs	Communication	Correctional Institutions	Dams	Electric Power	EMS	EOC	Ferry	Fire	Highway Bridges	Highway Tunnels	Light Rail Facilities	Medical	Military	Natural Gas	Oil	Police	Ports	Potable Water	Rail Facilities	Rail Tunnels	School	Shelters	Storage of Critical Records	Wastewater
Atlantic	388	1	15	-	-	19	2	33	1	-	37	9	-	-	6	1	-	-	16	-	1	2	-	71	30	-	2
Bergen	1,148	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burlington	747	1	-	-	-	6	-	1	-	-	2	1	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-
Camden	701	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cape May	229	2	10	-	6	6	-	30	1	1	34	2	-	-	1	1	-	-	14	1	1	-	-	42	58	-	6
Cumberland	251	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Essex	784	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gloucester	346	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudson	493	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hunterdon	328	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercer	538	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Middlesex	816	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Monmouth	905	1	29	-	-	46	-	82	-	1	70	1	-	-	5	1	-	-	34	2	2	11	-	166	31	-	6
Morris	913	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ocean	621	-	43	-	1	66	1	82	1	-	70	5	-	-	9	-	-	-	32	-	2	2	-	188	22	1	3
Passaic	648	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salem	201	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Somerset	539	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sussex	542	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Union	607	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Warren	351	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12,096	5	97	-	7	143	3	228	3	2	213	18	-	-	21	3	-	-	97	3	6	15	-	468	141	1	17

Source: NJOMB 2013

Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day- to-day commuting and goods transport) transportation needs. Utility infrastructure (power lines, gas lines, electrical systems) could suffer damage and impacts can result in the loss of power, which can impact business operations and can impact heating or cooling provision to the population. The impacted population can include the young and elderly, who are particularly vulnerable to temperature-related health impacts. Post- event, there is a risk of fire, electrocution or explosion.

Tornadoes

To determine the vulnerability of State buildings, critical facilities and infrastructure 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 5.10-21 to 5.10-23 by county and agency.

Table 5.10-21 Number of State Buildings in the Greatest Historic Tornado Touch-Downs per Square Mile Zone by County

County	Lease	Own	Total
Atlantic	0	0	0
Bergen	0	0	0
Burlington	8	208	216
Camden	7	17	24
Cape May	0	0	0
Cumberland	0	0	0
Essex	13	61	74
Gloucester	4	31	35
Hudson	2	1	3
Hunterdon	0	0	0
Mercer	47	342	389
Middlesex	13	165	178
Monmouth	0	10	10
Morris	4	22	26
Ocean	0	0	0
Passaic	1	3	4
Salem	0	7	7
Somerset	3	35	38
Sussex	0	0	0
Union	9	26	35
Warren	0	0	0
Total	111	928	1039

Source: NJOMB 2013

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Table 5.10-22 Number of State Buildings in the Greatest Historic Tornado Touch-Downs per Square Mile Zone by Agency

Agency	Lease	Own	Total
Agriculture	-	1	1
Banking and Insurance	-	1	1
Chief Executive	-	-	-
Children and Families	23	11	34
Community Affairs	4	1	5
Corrections	3	319	322
Education	4	51	55
Environmental Protection	21	17	38
Health	1	2	3
Human Services	1	72	73
Judiciary	4	-	4
Juvenile Justice Commission	2	37	39
Labor and Work Force Development	3	1	4
Law and Public Safety	5	4	9
Legislature	1	3	4
Military and Veterans Affairs	2	103	105
Miscellaneous Commissions	-	-	-
Motor Vehicles Commission	14	15	29
Personnel	1	-	1
State	-	8	8
State Police	14	47	61
Transportation	-	227	227
Treasury	8	8	16
Total	111	928	1,039

Source: NJOMB 2013

Table 5.10-23 Number of Critical Facilities in the Greatest Historic Tornado Touch-Downs per Square Mile Zone

County	Total Number	Airport	Special Needs	Communication	Correctional Institutions	Dams	Electric Power	EMS	EOC	Ferry	Fire	Highway Bridges	Highway Tunnels	Light Rail Facilities	Medical	Military	Natural Gas	Oil	Police	Ports	Potable Water	Rail Facilities	Rail Tunnels	School	Shelters	Storage of Critical Records	Wastewater
Atlantic	388	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bergen	1,148	-	-	-	-	-	-	5	-	-	4	-	-	-	-	-	-	-	2	-	2	2	-	14	-	-	-
Burlington	747	-	24	1	1	49	-	46	1	-	44	2	-	6	6	4	-	-	28	-	-	-	-	128	86	-	12
Camden	701	-	25	-	-	67	-	63	1	-	53	1	-	-	4	-	-	-	33	-	-	2	-	160	93	-	-
Cape May	229	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cumberland	251	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Essex	784	2	43	-	2	33	1	57	2	-	63	2	-	17	15	-	-	-	42	3	4	22	-	357	108	1	6
Gloucester	346	-	14	-	-	52	-	33	1	-	44	-	-	-	3	-	-	-	19	-	-	-	-	100	9	-	1
Hudson	493	-	2	-	1	-	1	11	-	-	12	2	-	3	2	-	-	-	5	-	-	1	-	34	21	-	-
Hunterdon	328	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mercer	538	1	25	2	2	87	1	34	3	-	36	-	-	3	12	1	-	-	24	-	3	4	-	151	115	7	6
Middlesex	816	-	28	-	4	35	3	91	2	-	78	5	-	-	10	-	-	1	27	-	6	10	-	288	122	1	4
Monmouth	905	-	-	-	-	15	-	1	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	5	1	-	-
Morris	913	1	16	-	1	25	2	20	-	-	21	-	-	-	3	-	-	-	11	-	-	7	-	71	21	-	6
Ocean	621	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-
Passaic	648	-	-	-	-	3	-	6	-	-	5	-	-	-	-	-	-	-	1	-	4	3	-	11	3	-	-
Salem	201	-	1	-	-	10	-	2	-	-	3	-	-	-	1	-	-	-	1	-	-	-	-	3	4	-	-
Somerset	539	-	28	1	1	87	-	49	1	-	47	-	-	-	5	-	-	-	21	-	2	11	-	145	98	-	3
Sussex	542	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Union	607	-	26	-	1	29	1	53	1	-	45	2	-	-	9	-	-	-	26	5	3	16	-	244	141	-	5
Warren	351	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	12,096	4	232	4	13	493	9	471	12	-	457	14	-	29	70	5	-	1	242	8	24	78	-	1,714	825	9	43

Source: NJOMB 2013

Thunderstorms

All of the 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.

According to NOAA's Technical Paper on *Lightning Fatalities, Injuries, and Damage Reports in the United States from 1959 - 1994*, monetary losses for lightning events range from less than $50 to greater than $5 million. The larger losses are associated with forest fires with homes destroyed and crop loss (NOAA 1997). 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. The total replacement cost value of all state-owned and -leased facilities in the State is approximately $10 billion (structure and contents). Of particular concern is radio towers used by the first responder community that are frequently struck by lightning.

Hailstorms

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. The primary impact of hailstorms is to crops and livestock.

Extreme Temperature

All of the state-owned and -leased buildings are exposed to the extreme temperature hazard. Extreme heat generally does not impact buildings. Extreme heat events can sometimes cause short periods of utility failure commonly referred to as brownouts, due to increased usage from air conditioners, appliances, etc. Similarly, heavy snowfall and ice storms, associated with extreme cold temperature events, can cause power interruption. Backup power or distributed generation is recommended for critical facilities and infrastructure. In terms of utilities and infrastructure, both extreme heat and cold temperature events can cause impacts.

5.10.7.4 ESTIMATING POTENTIAL LOSSES TO STATE FACILITIES

High Winds

As mentioned earlier, all buildings, critical facilities and infrastructure may be exposed and vulnerable to high winds. A spatial analysis was conducted using the four wind load zones and the Land and Building Asset Management System (LBAM) state buildings, and the critical facility inventory to determine the structural replacement cost value in each wind zone for the 50-year mean recurrence interval event (see Figure 5.10-32). Generally speaking, structures should be designed to withstand the total wind load of the zone in which they are located. Refer to the State Building Code for appropriate reference wind pressures, wind forces on roofs, and other relevant codes. Tables 5.10-24 and 5.10-25 list the structural replacement cost value of all State facilities located in each zone by County and Agency, respectively.

The following agencies have the highest State building replacement cost value located in the zone with the maximum wind speeds (110 to 120 mph zone): Department of Children and Families, Department of Corrections, Department of Environmental Protection, Human Services, Juvenile Justice Commission, Military and Veteran Affairs, Motor Vehicles Commission, Department of State, State Police, and Department of Transportation.

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Table 5.10-24 Estimated Potential Loss to State-Owned and -Leased Buildings in Wind Load Zones by County

County	Less than 90 mph		90 - 100 mph		100 - 110 mph		110 - 120 mph	
	Lease	Own	Lease	Own	Lease	Own	Lease	Own
Atlantic	$ -	$ -	$ -	$ -	$13,370,005	$ 21,799,046	$ 131,031,644	$ 13,505,880
Bergen	$ -	$ -	$ 34,121,796	$ 85,849,968	$ -	$ 746,771	$ -	$ -
Burlington	$ -	$ -	$ 76,307,865	$ 320,093,638	$ -	$ 113,655,304	$ 323,273	$ 1,252,718
Camden	$ -	$ -	$ 141,414,541	$ 172,404,799	$ -	$ -	$ -	$ -
Cape May	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,584,257	$ 63,712,640
Cumberland	$ -	$ -	$ 3,524,431	$ 356,599,904	$ 945,573	$ 107,418,708	$ -	$ -
Essex	$ -	$ -	$198,465,073	$ 160,993,164	$ -	$ -	$ -	$ -
Gloucester	$ -	$ 824,429	$ 25,072,915	$ 12,508,550	$ -	$ -	$ -	$ -
Hudson	$ -	$ -	$ -	$ 2,452,809	$41,978,058	$ 38,817,579	$ -	$ -
Hunterdon	$ 3,541,525	$232,064,505	$ -	$ -	$ -	$ -	$ -	$ -
Mercer	$ -	$ 254,676	$385,738,794	$1,405,976,862	$ -	$ -	$ -	$ -
Middlesex	$ -	$ -	$ 18,606,814	$ 272,066,482	$ 7,568,254	$ 58,661,549	$ -	$ -
Monmouth	$ -	$ -	$ -	$ 811,089	$ 7,999,157	$ 28,938,594	$ 14,580,098	$ 72,950,606
Morris	$ 34,821,607	$ 181,561,198	$ -	$ 5,263,728	$ -	$ -	$ -	$ -
Ocean	$ -	$ -	$ -	$ -	$ -	$ 38,208,555	$22,408,626	$ 26,534,632
Passaic	$ 64,799,700	$ 3,653,336	$ -	$ 65,112,172	$ -	$ -	$ -	$ -
Salem	$ 15,267,601	$ 4,083,233	$ -	$ 9,083,368	$ -	$ -	$ -	$ -
Somerset	$ -	$ 4,284,181	$ -	$ 36,626,736	$ -	$ -	$ -	$ -
Sussex	$ 7,318,677	$ 18,539,425	$ -	$ -	$ -	$ -	$ -	$ -
Union	$ -	$ -	$ -	$ 14,280,053	$ -	$ -	$ -	$ -
Warren	$ 9,755,189	$ 45,486,157	$ -	$ -	$ -	$ -	$ -	$ -
Total	$135,504,299	$490,751,140	$883,252,228	$2,920,123,321	$71,861,047	$408,246,106	$170,927,897	$177,956,476

Source: NJOMB 2013

Table 5.10-25 Estimated Potential Loss to State-Owned and -Leased Buildings in Wind Load Zones by Agency

Agency	Less than 90 mph		90 - 100 mph		100 - 110 mph		110 - 120 mph	
	Lease	Own	Lease	Own	Lease	Own	Lease	Own
Agriculture	$ -	$ -	$ -	$ -	$ -	$ 1,438,307	$ -	$ -
Banking and Insurance	$ -	$ -	$ -	$ 41,888,820	$ -	$ -	$ -	$ -
Chief Executive	$ 6,326,688	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Children and Families	$ 96,059,208	$ 1,484,436	$198,040,032	$ 4,955,090	$27,562,382	$ -	$ 24,955,095	$ 11,952,960
Community Affairs	$ 11,145,038	$ -	$ 10,045,108	$ 26,247,441	$22,526,095	$ -	$ -	$ -
Corrections	$ -	$106,918,094	$ 5,686,417	$ 780,483,336	$ -	$ 129,515,990	$ 4,397,087	$ -
Education	$ 885,526	$ 4,540,790	$ 24,928,079	$ 131,560,200	$ -	$ -	$ -	$ -
Environmental Protection	$ -	$ 40,723,792	$ 67,894,941	$ 59,347,757	$ 7,641,226	$ 25,597,541	$ 9,334,284	$ 15,616,242
Health	$ -	$ -	$ 20,584,392	$ 52,632,460	$ -		$ -	$ -
Human Services	$ -	$237,216,398	$ 2,825,013	$ 547,354,087	$ -	$ 71,603,457	$ -	$52,400,639
Judiciary	$ -	$ -	$ 57,010,526	$ -	$ -	$ -	$ -	$ -
Juvenile Justice Commission	$ -	$ 7,391,583	$ 13,222,175	$ 69,008,480	$ -	$ 61,607,211	$ -	$ 1,481,979
Labor and Work Force Development	$ -	$ -	$ 36,200,712	$ 61,327,079	$ -	$ -	$ 3,807,477	$ -
Law and Public Safety	$ -	$ -	$ 119,491,056	$ 111,346,779	$ -	$ -	$ 12,916,988	$ 738,784
Legislature	$ -	$ -	$ 1,953,710	$ 80,588,984	$ -	$ -	$ -	$ -
Military and Veterans Affairs	$ -	$ 44,037,724	$ 1,303,385	$ 338,876,567	$ -	$ 69,350,387	$ -	$ 61,073,217
Miscellaneous Commissions	$ -	$ -	$ 7,825,328	$ -	$ -	$ -	$ -	$ -
Motor Vehicles Commission	$ 7,786,902	$ 5,048,997	$158,906,952	$ 115,042,487	$ 3,113,476	$ 6,717,651	$99,643,424	$ 8,566,797
Personnel	$ -	$ -	$ 4,256,708	$ -	$ -	$ -	$ -	$ -
State	$ -	$ -	$ -	$ 96,143,325	$ -	$ -	$ -	$ 8,265,027
State Police	$ 2,342,275	$ 4,432,666	$ 37,674,219	$ 151,457,068	$ 10,122,078	$ 15,160,036	$ 4,462,204	$ 5,053,013
Transportation	$ -	$38,956,660	$ -	$ 181,104,600	$ -	$ 19,540,097	$ -	$ 22,015,585
Treasury	$ -	$ -	$ 111,264,468	$ 70,758,761	$ -	$ -	$ 11,411,339	$ -
Total	$124,545,636	$490,751,140	$879,113,222	$2,920,123,321	$70,965,257	$400,530,678	$170,927,897	$187,164,243

Source: NJOMB 2013

Tornadoes

An exposure analysis was conducted using the Land and Building Asset Management System (LBAM) State building data and the zone of greatest historical tornado touch-down density in the State. The replacement cost values of the buildings within this zone are presented in Table 5.10-26. Currently, HAZUS-MH does not contain damage functions to estimate potential loss as a result of tornado events. As more current replacement cost data becomes available at the structure level, and probabilistic modeling capabilities become available for tornado events, this section of the plan will be updated with new information. The following Counties have the greatest building replacement cost value located in the zone of greatest touch-down density: Burlington, Camden, Essex, Gloucester, Hudson, Mercer, Middlesex, Monmouth, Morris, Passaic, Salem, Somerset and Union.

Table 5.10-26 Estimated RCV of State Buildings with the Greatest Historic Tornado Touch-Downs per Square Mile

County	Lease	Own	Total
Atlantic	-	-	-
Bergen	-	-	-
Burlington	$ 144,641,366	$ 565,105,052	$ 709,746,419
Camden	$ 267,178,426	$ 23,931,707	$ 291,110,133
Cape May	-	-	-
Cumberland	-	-	-
Essex	$ 396,930,146	$ 277,537,642	$ 674,467,788
Gloucester	$ 50,145,830	$ 24,217,508	$ 74,363,338
Hudson	$ 6,741,931	$ 249,806	$ 6,991,737
Hunterdon	-	-	-
Mercer	$ 771,275,049	$ 2,705,627,970	$ 3,476,903,019
Middlesex	$ 92,348,757	$ 447,393,222	$ 539,741,979
Monmouth	$ -	$ 13,547,532	$ 13,547,532
Morris	$ 43,473,165	$ 22,375,709	$ 65,848,874
Ocean	-	-	-
Passaic	$ 185,413	$ 319,493	$ 504,906
Salem	$ -	$ 1,554,990	$ 1,554,990
Somerset	$ 152,137,964	$ 81,193,734	$ 233,331,698
Sussex	-	-	-
Union	$ 57,259,610	$ 27,997,974	$ 85,257,584
Warren	-	-	-
Total	$ 1,982,317,655	$ 4,191,052,340	$ 6,173,369,996

Source: NJOMB 2013

Thunderstorms

Current modeling tools are not available to estimate specific losses for this severe weather type. As stated earlier, all state buildings, critical facilities, and infrastructure may be vulnerable.

Hailstorms

Current modeling tools are not available to estimate specific losses for this severe weather type. As stated earlier, all state buildings, critical facilities, and infrastructure may be vulnerable.

Extreme Temperatures

Current modeling tools are not available to estimate specific losses for this severe weather type. As stated earlier, all state buildings, critical facilities, and infrastructure may be vulnerable.