4.3.13 Severe Weather

The following section provides the hazard profile (hazard description, location, extent, previous occurrences and losses, probability of future occurrences, and impact of climate change) and vulnerability assessment for the severe weather hazard in Gloucester County.

2021 HMP Update Changes

- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 2015 and 2021.
- A vulnerability assessment was conducted for the severe weather hazard using a more accurate and updated building inventory.

4.3.13.1 Profile

Hazard Description

For the purpose of this HMP Update and as deemed appropriated by the Gloucester County Hazard Mitigation Planning Committee, the severe weather hazard includes high winds, tornadoes, thunderstorms and lightning, derechos, and hail which are defined below.

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 front, cold front, a sea breeze, or a mountain. Thunderstorms form from the equator to as far north as Alaska. Although thunderstorms generally affect a small area when they occur, they have the potential to become dangerous due to their ability to generate tornadoes, hailstorms, strong winds, flash flooding, and lightning.

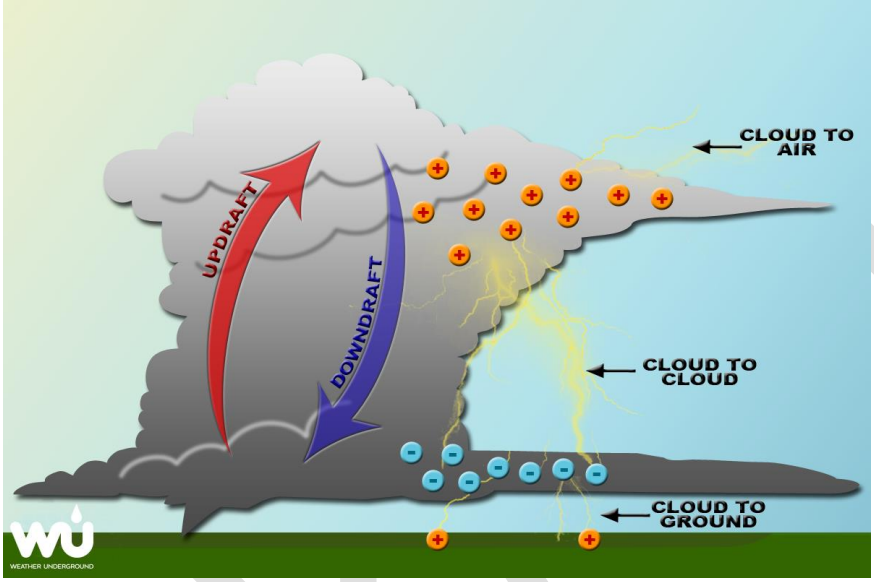
Thunderstorms can lead to heavy rain induced flooding, landslides, strong winds, and lightning. Roads may become impassable from flooding, downed trees or power lines, or a landslide. Downed power lines can lead to loss of utility services, such as water, phone, and electricity. Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes. During the summer, thunderstorms are responsible for most of the rainfall.

Lightning

Lighting is a bright flash of electrical energy produced by a thunderstorm. The resulting clap of thunder is the result of a shock wave created by the rapid heating and cooling of the air in the lightning channel. All thunderstorms produce lightning and are very dangerous. Lightning ranks as one of the top weather killers in the United States, killing approximately 50 people and injuring hundreds each year. Lightning can occur

anywhere there is a thunderstorm. Lightning can be cloud to air, cloud to cloud, and cloud to ground. Figure 4.3.13-1 demonstrates the variety of lightning types.

Figure 4.3.13-1. Types of Lightning

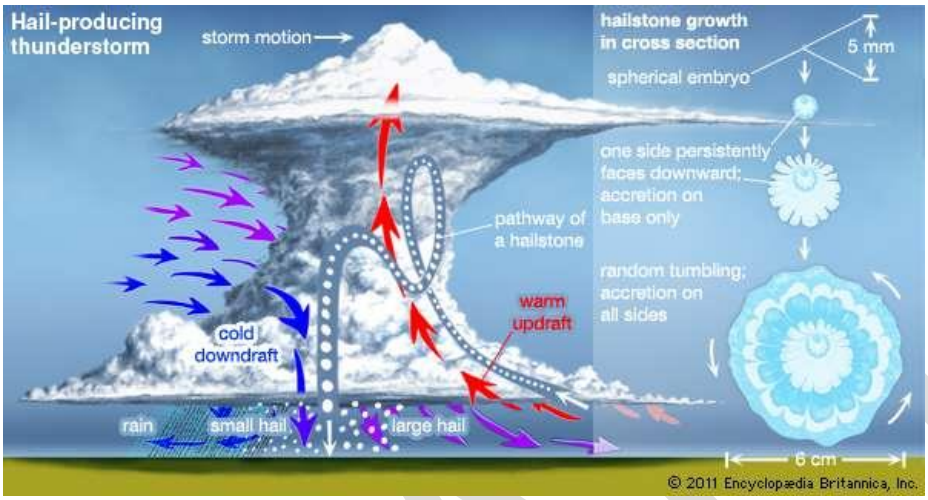


Source: Weather Underground 2021

Hailstorms

Hail forms inside a thunderstorm or other storms with 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 degrees Fahrenheit (°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 2 inches in diameter (NWS 2010). Figure 4.3.13-2 shows how hail is formed within thunderstorms.

Figure 4.3.13-2. Hail Formation in Thunderstorms



Source: Encyclopedia Britannica 2021

Windstorms

Wind begins with differences in air pressures and occurs through 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. High winds are often associated with other severe weather events such as thunderstorms, tornadoes, nor'easters, hurricanes, and tropical storms.

Tornadoes

A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 250 miles per hour (mph). Damage paths can be greater than 1 mile wide and 50 miles long. 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 combined wind speeds (forward motion and speed of the whirling winds) exceeding 300 mph. The lifespan of a tornado rarely is longer than 30 minutes (FEMA 1997). Tornadoes can occur at any time of the year, with peak seasons at different times for different states (NSSL 2013).

Derechos

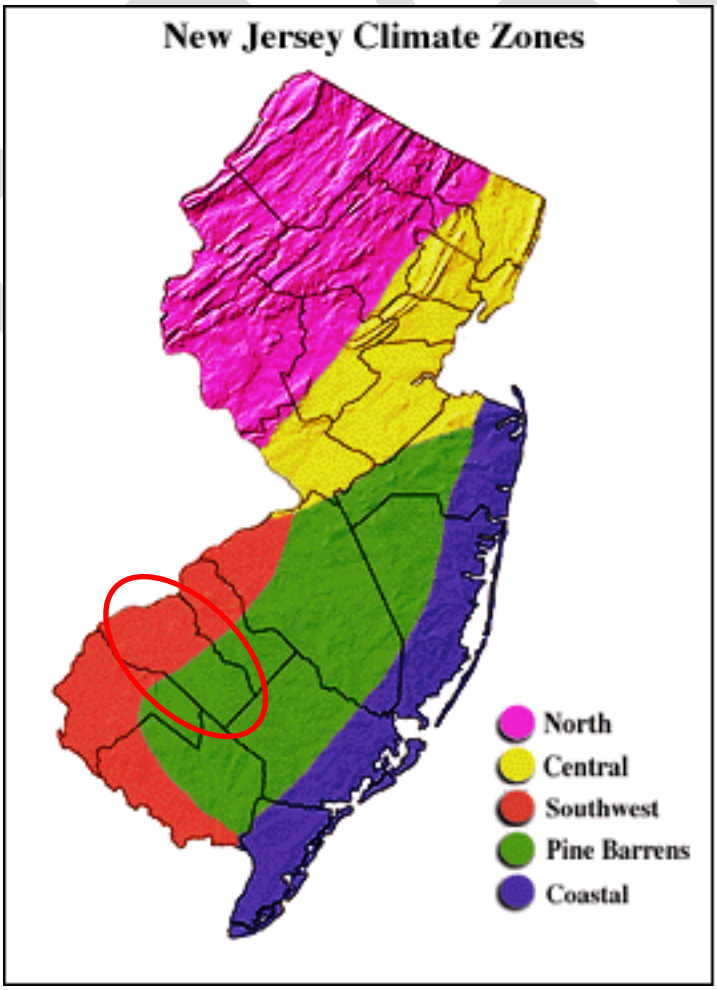
A derecho is a long-lived windstorm that is associated with a rapidly moving squall line of thunderstorms. It produces straight-line wind gusts of at least 58 mph and often has isolated gusts exceeding 75 mph. This means that trees generally fall and debris is blown in one direction. To be considered a derecho, these conditions must persist 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 (ONJSC 2021).

Location

All of Gloucester County is exposed to high wind, tornadoes, thunderstorms and lightning, derechos, and hailstorms. Additionally, all of the County is subject to high winds from severe weather events, especially communities along the Delaware River. According to the FEMA Winds Zones of the United States map, Gloucester County and the entire State of New Jersey is located within Wind Zone II. In this zone, wind speeds can reach up to 160 mph. Additionally, the County is located within a "Hurricane Susceptible Region", meaning Gloucester County is susceptible to hurricanes and other tropical cyclone events.

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 (ONJSC Rutgers University n.d.). Figure 4.3.13-3 depicts these regions. Gloucester County is located within the Southwest and Pine Barrens region.

Figure 4.3.13-3 Climate Regions of New Jersey



Source: Rutgers University Climate Lab 2021

Extent

The extent (severity or magnitude) of a severe storm is largely dependent upon the most damaging aspects of each type of severe weather. This section describes the extent of thunderstorms, lighting, hail, windstorms, and tornadoes in Gloucester County. Historical data presented in Table 4.3.13-1 shows the most powerful severe weather records in Gloucester County.

Table 4.3.13-1. Severe Storm Extent in Gloucester County (1950-2020)

Extent of Severe Storms in Gloucester County	
Largest Hailstone on Record	2 inches
Strongest Tornado on Record	F-2
Highest Wind Speed on Record	56 knots

Source: NOAA-NCEI 2020

High Winds

The following table provides the description of winds used by the NWS during wind-producing events.

Table 4.3.13-2. 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 2009

NWS issues advisories and warnings for winds, which are normally site-specific. High wind advisories, watches, and warnings are issued by the NWS when wind speeds may pose a hazard or may be life threatening. The criterion for each of these varies from state to state. Wind warnings and advisories for New Jersey are as follows:

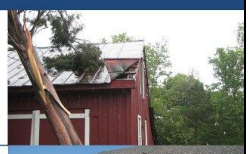
- *High Wind Warnings* are issued when sustained winds of 40 mph or greater are forecast for 1 hour or longer, or wind gusts of 58 mph or greater are forecast for any duration.
- *Wind Advisories* are issued when sustained winds of 30 to 39 mph are forecast for one 1 hour or longer, or wind gusts of 46 to 57 mph are forecast for any duration (NWS 2021).

Tornadoes

The magnitude or severity of a tornado is categorized using the Enhanced Fujita Tornado Intensity Scale (EF Scale). This is the scale now used exclusively for determining tornado ratings by comparing wind speed and

actual damage. Figure 4.3.13-4 illustrates the relationship between EF ratings, wind speed, and expected tornado damage.

Figure 4.3.13-4. Explanation of EF-Scale Ratings

EF Rating	Wind Speeds	Expected Damage		
EF-0	65-85 mph	'Minor' damage: shingles blown off or parts of a roof peeled off, damage to gutters/siding, branches broken off trees, shallow rooted trees toppled.		
EF-1	86-110 mph	'Moderate' damage: more significant roof damage, windows broken, exterior doors damaged or lost, mobile homes overturned or badly damaged.		
EF-2	111-135 mph	'Considerable' damage: roofs torn off well constructed homes, homes shifted off their foundation, mobile homes completely destroyed, large trees snapped or uprooted, cars can be tossed.		
EF-3	136-165 mph	'Severe' damage: entire stories of well constructed homes destroyed, significant damage done to large buildings, homes with weak foundations can be blown away, trees begin to lose their bark.		
EF-4	166-200 mph	'Extreme' damage: Well constructed homes are leveled, cars are thrown significant distances, top story exterior walls of masonry buildings would likely collapse.		
EF-5	> 200 mph	'Massive/incredible' damage: Well constructed homes are swept away, steel-reinforced concrete structures are critically damaged, high-rise buildings sustain severe structural damage, trees are usually completely debarked, stripped of branches and snapped.		

Source: NWS 2021

Thunderstorms

Severe thunderstorm watches and warnings are issued by the local NWS office and SPC. The NWS and SPC will update the watches and warnings and will notify the public when they are no longer in effect. Watches and warnings for thunderstorms in New Jersey are as follows:

Severe Thunderstorm Warnings are issued when there is evidence based on radar or a reliable spotter report that a thunderstorm is producing, or forecast to produce, wind gusts of 58 mph or greater, structural wind damage, and/or hail one-inch in diameter or greater. A warning will include where the storm was located, what municipalities will be impacted, and the primary threat associated with the severe thunderstorm warning. After it has been issued, the NWS office will follow up periodically with Severe Weather Statements which contain

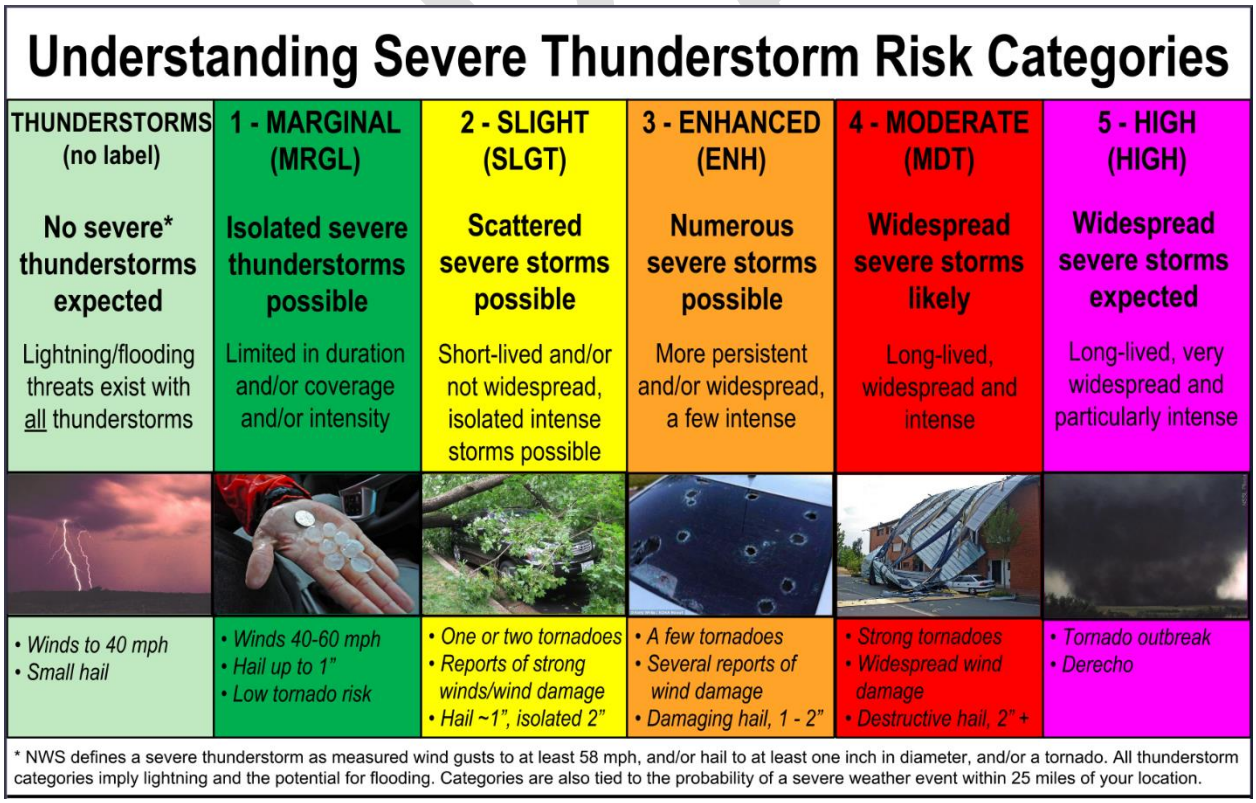
updated information on the severe thunderstorm and will let the public know when the warning is no longer in effect (NWS 2010).

Severe Thunderstorm Watches are issued by the SPC when conditions are favorable for the development of severe thunderstorms over a larger-scale region for a duration of at least three hours. Tornadoes are not expected in such situations, but isolated tornado development may also occur. Watches are normally issued well in advance of the actual occurrence of severe weather. During the watch, the NWS will keep the public informed on what is happening in the watch area and also let the public know when the watch has expired or been cancelled (NWS 2009).

Special Weather State for Near Severe Thunderstorms are issued for strong thunderstorms that are below severe levels, but still may have some adverse impacts. Usually, they are issued for the threat of wind gusts of 40 to 58 mph or small hail less than one-inch in diameter (NWS 2009).

In addition, the SPC issues severe thunderstorm risk maps based on the likelihood of different severities of thunderstorms. Figure 4.3.13-5 shows the SPC's severe thunderstorm risk categories.

Figure 4.3.13-5. Severe Thunderstorm Risk Categories



Source: NOAA 2021

Lightning

Lightning is associated with moderate to severe thunderstorms. Lightning severity is determined by the frequency of lightning strikes during a storm. Multiple devices are available to track and monitor the frequency of lightning.

Derechos

In order for an event to be identified as a derecho, it must have wind gusts of at least 58 mph or greater along most of its length. While derecho winds typically are less than 100 mph, gusts as high as 130 mph have been recorded. Winds associated with derechos are not constant and may vary considerably along the path of the derecho. The winds associated with derechos are not constant and may vary considerably along the derecho path, sometimes being below severe limits (57 mph or less), and sometimes being very strong (from 75 mph to greater than 100 mph) (NOAA 2021).

Hailstorms

Duration, hail size, and geographic extent determine hailstorm severity. Hail can exhibit a variety of sizes, though only the very largest hail stones pose serious risk to people, if exposed (NYSDHSES 2019). The size of hail is estimated by comparing it to a known object. Figure 5.4.8-3 shows the different sizes of hail and the comparison to real-world objects.

Figure 4.3.13-6. Hail Size Chart

Source: NWS 2010

Previous Occurrences and Losses

Numerous sources provided historical information regarding previous occurrences and losses associated with severe weather events affecting Gloucester County. With so many sources reviewed for the purpose of this HMP, loss and impact information for many events may vary. Therefore, the accuracy of monetary figures discussed is based only on the available information identified during research for this HMP.

FEMA Disaster Declarations

Between 1954 and 2020, the State of New Jersey was included in 18 FEMA declared severe weather-related disasters (DR) or emergencies (EM) classified as one or a combination of the following hazards: coastal storms, severe storm, straight-line winds, heavy rains, flooding, hail, tornadoes, and high wind. Generally, these

disasters cover a wide region of the State; therefore, they may have impacted many counties. Of those declarations, Gloucester has been included in five declarations classified as severe storms (FEMA 2021). Table 4.3.13-3 lists FEMA DR and EM declarations for Gloucester County.

Table 4.3.13-3. FEMA DR and EM Declarations for Severe Weather Events in Gloucester County

FEMA Declaration Number	Date(s) of Event	Date of Declaration	Event Type
DR-1588-NJ	April 1-4, 2005	April 20, 2005	Severe Storm(s)
DR-1694-NJ	April 14-27, 2007	April 26, 2007	Severe Storm(s)
DR-1897-NJ	March 12 -April 15, 2010	April 2, 2010	Severe Storm(s)
DR-4033-NJ	August 13-15, 2011	September 15, 2011	Severe Storm(s)
DR-4231-NJ	June 23-24, 2015	July 22, 2015	Severe Storm(s)

Source: FEMA 2021

U.S. Department of Agriculture Disaster Declarations

Between 2015 and 2021, the period for which data was available, Gloucester County was included in four USDA Disaster Declarations with no reported crop loss (USDA 2021), according to Table 4.3.13-4.

Table 4.3.13-4 USDA Disaster Declarations for Gloucester County

Disaster Declaration Number	Dates of Event	Type of Event
S3931	May 28 - July15, 2015	Excessive rain, flash flooding, high winds, and lightning.
S3712	May 22, 2015	Excessive Rain and Related Flooding, High Winds, and Hail.
S3603	May 1 - September 24, 2014	Excessive rain, related flooding, high winds, and hail
S3487	June 28 - November 8, 2012	The combined effects of drought, high winds (Derecho), hail, excessive heat, excessive rain, flash flooding, Hurricane Sandy, snowstorm, and Nor'easter

Source: USDA 2021

Severe Weather Events

For this 2022 Plan Update, known severe weather events, including FEMA disaster declarations, which have impacted Gloucester County between 2015 and 2021 are identified in Table 4.3.13-5. With documentation of severe storms for the State of New Jersey and Gloucester County being extensive, not all sources have been identified or researched. Therefore, the table may not include all events that occurred in the County. For events prior to 2015, refer to Appendix E (Supplementary Data). For detailed information on damages and impacts to each municipality, refer to Section 9 (Jurisdictional Annexes).

Table 4.3.13-5 Severe Weather Events in Gloucester County, 2015 to 2021

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
February 2, 2015	Strong Wind	N/A	N/A	Gloucester County	Strong, gusty northwest winds occurred in the wake of a departing and intensifying low pressure system during the late afternoon into the middle of the evening on the 2nd in New Jersey. Peak wind gusts average around 50 mph and knocked down weak trees, tree limbs and wires. Scattered power outages occurred. This was further exacerbated by snow and ice on tree limbs in the northwest part of the state. A total of $ 2000 of property damage was reported
February 15, 2015	Strong Wind	N/A	N/A	Gloucester County	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 from the late evening of the 14th into the afternoon of the 15th. A total of $ 5000 of property damage was reported
April 22, 2015	Thunderstorm Wind	N/A	N/A	Gloucester County	A severe thunderstorm knocked down a large tree onto a house on West Olive Street in Westville. The tree crashed through the top floor and the home was deemed unsafe to continue to be occupied. No injuries were reported. A wind gust of 71 mph was measured with the same storm at the Philadelphia International Airport. A severe thunderstorm uprooted a large tree in Glassboro. It took down wires and also damaged a sidewalk. The severe thunderstorm also took down another tree that blocked access to a homeowner's driveway. A Skywarn Spotter estimated wind gusts to 60 mph as a severe thunderstorm moved through Pitman. A Skywarn Spotter estimated 60 mph as a severe thunderstorm moved through Williamstown. A total of $55000 of property damage was reported
May 27, 2015	Thunderstorm Wind	N/A	N/A	Gloucester County	A severe thunderstorm knocked down a couple of trees in far northern Gloucester County. Hardest hit was in Westville where a few trees were knocked down along Walnut Street. Gloucester County in sections of Washington Township, Sewell (Mantua Township) and Glassboro. A couple of fallen trees damaged vehicles in Washington Township. Trees and/or power lines were reported knocked down in Glassboro

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
					on Wilmer Street and in Sewell along East Holly Avenue, White Pine Drive, Hemlock Road and Hurffville-Crosskeys Road.
June 23, 2015	Thunderstorm Wind	N/A	N/A	Gloucester County	A Skywarn Spotter estimated a wind gust of 60 mph as a severe thunderstorm moved through Swedesboro Borough. The wind damage from a powerful macroburst started to cause considerable wind damage in eastern parts of Greenwich Township. This then continued farther to the southeast in Gloucester County. There were multiple reports of hundreds of trees and wires down in the Gibbstown area of the township. The roof of Saint Michael's Convent was damaged after it was lifted 10 to 15 feet into the air from the rest of the convent. The roof of a pet store also collapsed. A tree fell through a home on Cucinotta Road. Telephone poles fell across Harmony Road. The wind damage from a powerful macroburst maximized across eastern sections of East Greenwich Township. A survey estimated peak wind gusts of 85 mph. Power poles were snapped in the area of East Chawkin Road and Paul Mills Road along Kings Highway (County Route 551) in the Clarksboro section. Shingle damage occurred to numerous homes and sheds were blown over. Many roads were impassable because of downed trees and wires. Wind damage extended to the Mantua Township border through Windsor Way and Carriage Court where one building's roof was completely destroyed. The township estimated 2,800 trees and 100 poles were knocked down. The macroburst wind damage continued into Mantua Township. There were multiple reports of trees and wires knocked down. In addition, the roof of the township fire department building was badly damaged. Wind damage continued through the Sewell section of the township. The macroburst wind damage continued through Wenonah Borough where numerous and massive trees including oaks were knocked down. The macroburst wind damage clipped western Deptford Township and included the Deptford Mall. A vehicle was flipped by the damaging

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
					winds in the mall parking lot. Mall and store signs along Clements Bridge Road were damaged. A Paulsboro refinery was struck by lightning which caused a loss of power. The refinery then off gassed. No evacuations were needed. A severe thunderstorm knocked over a few trees in Westville Borough. One tree fell onto and damaged a pool. A severe thunderstorm knocked down dozens of trees in Woodbury Heights. Downed trees also caused the closure of the southbound lanes of the New Jersey Turnpike in the Borough. A severe thunderstorm knocked down numerous trees in Pitman Borough. A severe thunderstorm knocked down several trees including one along Greentree Road in Glassboro Borough. A severe thunderstorm knocked down numerous trees in Turnersville as well as other locations within Washington Township. At least one home was damaged by fallen trees. A Kohl's Department store sign was left dangling in a shopping center. A severe thunderstorm knocked down numerous trees in Williamstown within Monroe Township. The squall line of severe thunderstorms caused agricultural damage in Gloucester County. Within Monroe Township, one farmer lost all of his cage free hens. A total of $ 1.7 million of property damage was reported
July 9, 2015	Thunderstorm Wind	N/A	N/A	Gloucester County	A line of strong to severe thunderstorms formed in the warm sector of the Susquehanna Valley and moved through southern New Jersey during the during the evening on the 9th. A severe thunderstorm knocked down large tree limbs and wires in Pitman Borough. A severe thunderstorm knocked down large tree limbs and wires in Washington Township. A total of $ 1000 of property damage was reported.
October 2, 2015	Thunderstorm Wind	N/A	N/A	Gloucester County	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 from the 1st through the 4th.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
February 16, 2016	Thunderstorm Wind	N/A	N/A	Gloucester County	Severe wind gusts associated with a cold front moving through the area brought down trees and traffic lights on Delsea Drive in Deptford Township. A wind gust of 47 mph was measured at Philadelphia International Airport with this cold front at 1238EST just across the Delaware River. Severe wind gusts associated with a cold front moving through the area knocked down numerous trees on Cooper Street in Woodbury.
April 2, 2016	Hail	N/A	N/A	Monroe Township, NJ	Thunderstorms associated with a strong cold front moving across the area during the early morning hours on the 3rd produced three-quarter inch hail in Williamstown.
June 5, 2016	Thunderstorm Wind	N/A	N/A	Gloucester County	Many wind gusts from 60 to over 70 MPH were recorded across the region. The highest gust was in Gloucester Township at 74 mph. Several trees were uprooted due to thunderstorm winds. Several trees were down due to wind. Power out- remove. Large limbs were downed due to winds. Wind gusts estimated over 60 MPH. Trees and powerlines downed due to wind.
June 8, 2016	Thunderstorm Wind	N/A	N/A	Gloucester County	A fast-moving line of thunderstorms produced widespread wind damage and gusts up to 52 mph.
January 23, 2017	Strong Winds	N/A	N/A	Gloucester County	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. A measured 51 mph gust was reported. A total of $ 10 of property damage was reported.
February 13, 2017	High Winds	N/A	N/A	Gloucester County	Wind speeds up to 54 mph were reported, leading to downed power lines and wires.
February 25, 2017	Thunderstorm Wind	N/A	N/A	Gloucester County	Several days of record warmth came to an abrupt end as a strong cold front moved through the state. Moisture and instability were sufficient to develop a line of showers and thunderstorms ahead of the front. These showers and thunderstorms produced damaging winds and hail across western portions of the state. Measured wind gust.
April 6, 2017	Thunderstorm Wind	N/A	N/A	Gloucester County	Moisture and instability was drawn northwest ahead of the front which led to locally heavy showers and thunderstorms. Some of thunderstorms were strong to severe with gusty winds. A couple of trees were taken down due to thunderstorm wind gusts.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
June 19, 2017	Thunderstorm Wind	N/A	N/A	Gloucester County	Wind damage was reported from a complex of thunderstorms that moved into the region. Downed trees and wires on Bridgeton Pike near 4H Fairgrounds.
June 24, 2017	Thunderstorm Wind	N/A	N/A	Gloucester County	A band of gusty convective showers moved through during the morning hours in association with the remnants of Tropical Storm Cindy. Trees and wires were reported down.
July 14, 2017	Lightning	N/A	N/A	Gloucester County	A hot and humid airmass was present ahead of a frontal boundary which slowly moved southeast toward and then through the state. Several rounds of thunderstorms moved through the region ahead of this front over the course of a few days. A transformer was struck by lightning. Trees were taken down from thunderstorm winds near route 322. A total of $ 10 of property damage was reported
July 17, 2017	Hail	N/A	N/A	Gloucester County	Measured hail three quarters of an inch in diameter.
July 23-24, 2017	Heavy Rain; Lightning	N/A	N/A	Gloucester County	Multiple rounds of thunderstorms were reported due to a frontal boundary moving through the area. A total of $ 10 of property damage was reported. A tree was taken down by thunderstorm winds onto Jackson road.
August 2, 2017	Thunderstorm Wind	N/A	N/A	Gloucester County	A hot and humid airmass with weak boundaries led to slow moving strong to severe thunderstorms with damaging winds, hail and flooding. Several trees downed due to thunderstorm winds. Over 2,000 people lost power.
October 24, 2017	Strong Wind	N/A	N/A	Gloucester County	A strong low pressure system over the Great Lakes and a departing high pressure system to our east lead to a tight pressure gradient and a round of strong winds. Over 25,000 homes and businesses lost power. A total of $ 10 of property damage was reported
March 2, 2018	High Wind	N/A	N/A	Gloucester County	Strong winds and flooding causing $100,000 in damage resulted from a stalled cold front from a deep area of low pressure. Recorded wind speeds were up to 71 mph the night of the 2nd. Numerous downed trees were reported throughout the county due to strong winds. A 65 mph wind gust in Washington Township at 1455EST on March 2nd was reported by a trained spotter.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
July 3, 2018	Thunderstorm Winds	N/A	N/A	Gloucester County	Severe thunderstorms caused wind damage across portions of southwestern New Jersey on the evening of July 3. Rainfall amounts of 1 to 3 inches fell along the Interstate 95/New Jersey Turnpike Corridor in a short amount of time. A few locations received 3 to 4 inches of rain.
February 25, 2019	High Winds	N/A	N/A	Gloucester County	A severe weather outbreak impacted much of the East Coast, causing widespread straight line wind damage and a few tornadoes. Based on surrounding reports and observations, winds likely gusted to 50 kts across the county.
April 15, 2019	Thunderstorm Wind	N/A	N/A	Gloucester County	A severe weather outbreak impacted much of the East Coast, causing widespread straight line wind damage and a few tornadoes. Multiple trees were reported down. The time of the event was estimated from radar.
April 26, 2019	Thunderstorm Wind	N/A	N/A	Gloucester County	A strong low pressure system tracked through the eastern Great Lakes on April 26. A warm front moved through the mid-Atlantic that morning with an initial round of locally strong but sub-severe convection. A tree was reported down on US 322 eastbound west of I-295 in Logan Twp. Time estimated from radar.
May 28, 2019	Hail	N/A	N/A	Gloucester County	A frontal boundary that had been stalled over the mid-Atlantic had lifted north of the region by the morning of June 29. The combination of strong frontal forcing and a warm, unstable environment ahead of the front led to widespread severe thunderstorms developing. Quarter size hail was recorded in Gloucester County.
June 2, 2019	Thunderstorm Wind	N/A	N/A	Gloucester County	Several trees and power lines down. Time estimated from radar.
June 13, 2019	Tornado	N/A	N/A	Gloucester County	A tornado formed in the development near Saddle Court in Mullica Hill. This caused damage to fencing at one residence, and ripped a gutter off another residence. Backyard furniture was lifted approximately 50 yards. From there, the tornado moved in a northeasterly direction and caused a narrow path of tree damage before lifting southwest of Highway 322. The same storm which earlier produced a tornado in Mullica Hill, NJ later produced a second, slightly stronger tornado. This tornado took a

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
					non-continuous path from Deptford Township in Gloucester County|into the Blackwood section of Gloucester Township in Camden County. There were |several locations of tree damage, including snapped and uprooted |hardwood trees. There was damage to three residences in Deptford |Township when portions of trees fell on these residences. In |Blackwood, an uprooted tree caused damage to an apartment building.
June 29, 2019	Thunderstorm Wind/ Hail	N/A	N/A	Gloucester County	Severe thunderstorms generating 51 mph formed from a stalled frontal boundary that over the mid-Atlantic that left the region during the day and then returned. Quarter size hail. Two trees were blown down. An mPing report was received of trees and power lines down at this location.
July 6, 2019	Thunderstorm Wind	N/A	N/A	Elk Township, NJ	A camping trailer was blown over at Oldmans Creek Campground in Elk Township. Time estimated from radar.
July 17., 2019	Thunderstorm Wind	N/A	N/A	Gloucester County	The remnants of Hurricane Barry moved near and west of the mid-Atlantic on July 17, in tandem with a frontal system which was absorbing the former tropical cyclone. A downed tree closed one or two lanes of US-130 northbound at NJ-44. Time estimated from radar. An mPing report of 3 inch tree limbs or power poles broken. A downed tree closed one or two lanes of US-130 northbound at NJ-44. Time estimated from radar. An mPing report of 3 inch tree limbs or power poles broken. A tree was downed on the NJ-42 southbound exit ramp to College Dr. The ramp was closed due to the obstruction. Time estimated from radar.
July 22, 2019	Thunderstorm Wind	N/A	N/A	Gloucester County	A stalled frontal boundary generated and upper level trough spurred severe weather with wind speeds of 51mph recorded in the County. A tree was downed on the I-295 northbound ramp from Exit 10.
February 7, 2020	Thunderstorm Wind	N/A	N/A	Gloucester County	A line of low topped but intense convection developed, and despite producing little thunder and lightning it produced a long swath of wind damage over the mid-Atlantic, along with a few tornadoes between Virginia and Maryland. A tree was downed on the New Jersey Turnpike southbound north of interchange 2 Time estimated from radar.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
March 3, 2020	Thunderstorm Winds	N/A	N/A	Gloucester County	A warm front moved north through parts of the mid-Atlantic during the late morning and afternoon of March 3. A cold front followed closely behind it in association with strengthening low pressure moving through the eastern Great Lakes. An mPing report of tree or shingle damage.
April 9, 2020	Thunderstorm/ Hail	N/A	N/A	Gloucester County	A warm front moved through the mid-Atlantic on the morning of April 9. Estimated wind gusts of 60 mph.
April 13, 2020	Thunderstorm Wind; High Wind	N/A	N/A	Gloucester County	A warm front moved through the mid-Atlantic, mixing with a low level jet with strong wind gusts, particularly near the coast. Later in the day, a strong cold front entered the region, bringing extreme wind shear. Heating produced strong to severe thunderstorms and 70 mph winds. .
April 21, 2020	Thunderstorm Wind; Hail	N/A	N/A	Gloucester County	An unseasonable strong cold front brought a squall line through the region. Destabilized air masses brought 60 mph winds and a tornado off the coast. A pole struck by lightning caught fire and downed wires and power lines were reported in Gloucester. Power lines were reported down in the area.
April 30, 2020	High Wind	N/A		Deptford Township, NJ	Slow moving low pressure tracked through the Great Lakes region on April 30. As it did so, an associated cold front began to approach the coastal mid-Atlantic. A few reports of tree and utility damage including a social media report of multiple large trees damaged in Deptford.
June 3-4, 2020	Thunderstorm	N/A	N/A	Gloucester County	Strong winds and rain caused numerous areas to report power outage and downed trees across the county, causing subsequent flooding and road closure. Downed tree on Interstate 295 south of Exit 15 in Gibbstown. Downed tree on State Highway 47 near Broadway Avenue in Cherry Hill. Downed tree on New Jersey Turnpike southbound south of Exit 3 near Runnemeade. Time estimated from radar. Downed tree on Interstate 295 at Exit 15. Multiple large trees down near and along Fish Pond Road east of Rowan University. Downed tree limbs and damage to shed and fence near Pitman. A tree fell onto two mobile home trailers. Time estimated from radar.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
					Downed tree and wires on US Rt. 322 in both directions west of Harvard Road. All lanes closed. Time estimated from radar.
July 30, 2020	Thunderstorm Wind	N/A	N/A	Gloucester County	A stalled frontal boundary was draped in the area of southern New Jersey and Delmarva on July 30. Meanwhile, another cold front was approaching the region from the northwest. Several reports were received of downed power lines in the Fairview and Jericho area. Wires were downed near Pennsylvania Ave in Glassboro. Time estimated from radar. . Time estimated from radar.
August 3, 2020				Washington Township, NJ	A diffuse, slow moving frontal boundary was present over the mid-Atlantic on August 3 as an upper level trough also approached from the west. Power lines were downed near Mantua Blvd in Sewell. Time estimated from radar.
August 7, 2020	Thunderstorm Wind	N/A	N/A	Deptford Township, NJ	An impulse riding along a west to east boundary stalled near the Mason-Dixon line produced severe thunderstorms and heavy rain across sections of South Jersey from late afternoon through the evening hours on August 7th. Strong winds knocked down trees, and torrential downpours on ground already saturated from the remnants of Hurricane Isaias produced flash flooding on many roadways and small streams in the area. Downed tree, pole, and wires on NJ 41, both directions, north of Good Intent Road in Deptford Township. All lanes closed. Time estimated from radar.
August 12, 2020	Thunderstorm Wind	N/A	N/A	Deptford Township, NJ	Tree limbs and wires were downed near Girard St in Woodbury. Time estimated from radar. Several reports of downed tree limbs and wires in West Deptford and Woodbury. Time estimated from radar. Tree limbs and wires were downed near the intersection of Lake Ave and Park Ave in Woodbury Heights. Time estimated from radar. A large tree was downed on New St. Time estimated from radar.
November 15, 2020	Thunderstorm Wind	N/A	N/A	Gloucester County	Strong low pressure moved through the Great Lakes on November 15, 2020. As it did so, it pushed a warm front through the mid-Atlantic during the late morning and early afternoon hours, causing unseasonably warm conditions to develop. An mPing report of trees and power lines down. Time estimated from radar.

Dates of Event	Event Type	FEMA Declaration Number (if applicable)	County Designated?	Location	Event Details*
December 24-25, 2020	High Wind	N/A	N/A	Pittman Township, NJ	Strong low pressure tracked through the Great Lakes region early on December 24. Later on the 24th, a secondary area of low pressure began to develop over the Southeast along the trailing cold front from the primary low. A trained spotter in Pitman reported a measured wind gust of 58 mph. Several reports of tree and utility damage were also received.
September 1, 2021	Tornado	Pending	Yes	South Harrison Township, Harrison Township, Deptford Township, NJ	The remnants of Hurricane Ida passed over the region. Combined with a warm-front, resulting in severe weather. A tornado touched down in Harrisonville and ran through Mullica Hill and Deptford along a 12.6 miles long path with a width up to 400 yards. 2 injuries occurred and many homes were heavily damaged or destroyed. Peak strength was at a rating of EF-3 with winds of 150 mph making it one of the most powerful tornados on record in the state.

Source(s): FEMA 2021; NOAA-NCEI 2021; NJ OEM 2019
** Unless explicitly stated, no property or crop damage was reported.*
FEMA Federal Emergency Management Agency
HMP Hazard Mitigation Plan
NCDC National Climatic Data Center
NOAA National Oceanic and Atmospheric Administration
NWS National Weather Service

Probability of Future Occurrences

Predicting future severe weather events in a constantly changing climate has proven to be a difficult task. Predicting extremes in New Jersey and Gloucester County is particularly difficult because of their geographic location. Both are positioned roughly halfway between the equator and the North Pole and are exposed to both cold and dry airstreams from the south. The interaction between these opposing air masses often leads to turbulent weather across the region (UCAR 2021).

Table 4.3.13-6 summarizes data regarding the probability of occurrences of severe weather events in Gloucester County based on the historic record. The information used to calculate the probability of occurrences is based solely on NOAA-NCEI storm events database results and FEMA disaster declarations.

Table 4.3.13-6. Probability of Future Occurrences of Severe Weather Events

Hazard Type	Number of Occurrences Between 1950 and 2020	% Chance of Occurring in Any Given Year
Funnel Cloud	2	3%
Hail	32	45%
High Wind	34	48%
Lightning	22	31%
Strong Wind	95	100%
Thunderstorm Wind	242	100%
Tornado	11	16%
Total	**438**	**100%**

Source: NOAA-NCEI 2021
Note: Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected storm events since 1968. Due to limitations in data, not all severe storm events occurring between 1954 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.

It is estimated that Gloucester County will continue to experience direct and indirect impacts of severe weather events annually that may induce secondary hazards such as flooding, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents and inconveniences. It is estimated that the County will continue to experience these events annually.

In Section 4.4, the identified hazards of concern for Gloucester County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for severe weather events in the County is considered 'frequent' (100 percent chance of event occurring; occurs multiple times a year).

Climate Change Impacts

Providing projections of future climate change for a specific region is challenging. Shorter term projections are more closely tied to existing trends making longer term projections even more challenging. The further out a prediction reaches the more subject to changing dynamics it becomes.

Climate change includes major changes in temperature, precipitation, or wind patterns, which occur over several decades or longer. Due to the increase in greenhouse gas concentrations since the end of the 1890s, New Jersey has experienced a 3.5° F (1.9° C) increase in the State's average temperature (ONJSC 2021) which is faster than the rest of the Northeast region (2° F [1.1° C]) (Melillo 2014) and the world (1.5° F [0.8° C]) (Meyer 2014). This warming trend is expected to continue. By 2050, temperatures in New Jersey are expected to increase by 4.1 to 5.7° F (2.3° C to 3.2° C) (Horton 2015). Thus, New Jersey can expect to experience an average annual temperature that is warmer than any to date (low emissions scenario) and future temperatures could be as much as 10° F (5.6° C) warmer (high emissions scenario) (Runkle 2017). New Jersey can also expect that by the middle of the 21st century, 70 percent of summers will be hotter than the warmest summer experienced to date. The increase in temperatures is expected to be felt more during the winter months (December, January, and February), resulting in less intense cold waves, fewer sub-freezing days, and less snow accumulation.

As temperatures increase, Earth's atmosphere can hold more water vapor which leads to a greater potential for precipitation. Currently, New Jersey receives an average of 46 inches of precipitation each year (ONJSC 2021). Since the end of the twentieth century, New Jersey has experienced slight increases in the amount of precipitation it receives each year, and over the last 10 years there has been a 7.9 percent increase. By 2050, annual precipitation in New Jersey could increase by 4 percent to 11 percent (Horton et al. 2015). By the end of this century, heavy precipitation events are projected to occur two to five times more often (Walsh 2014) and with more intensity (Huang 2017) than in the last century. New Jersey will experience more intense rain events, less snow, and more rainfalls (Fan 2014). Also, small decreases in the amount of precipitation may occur in the summer months, resulting in greater potential for more frequent and prolonged droughts (Trenberth 2011). New Jersey could also experience an increase in the number of flood events (Broccoli 2020).

A warmer atmosphere means storms have the potential to be more intense (Guilbert 2015) and occur more often (Broccoli 2020). In New Jersey, extreme storms typically include coastal nor'easters, snowstorms, spring and summer thunderstorms, tropical storms, and on rare occasions hurricanes. Most of these events occur in the warmer months between April and October, with nor'easters occurring between September and April. Over the last 50 years, in New Jersey, storms that resulted in extreme rain increased by 71 percent (Walsh 2014) which is a faster rate than anywhere else in the United States (Huang et al. 2017).

4.3.13.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed and vulnerable. For the severe weather hazard, the entire County is exposed. The following section discusses Gloucester County's vulnerability, in a qualitative nature, to the summer weather hazard.

Impact on Life, Health, Safety

The impact of a severe weather on life, health and safety is dependent upon several factors including the severity of the event and whether adequate warning time was provided to residents. The entire population of

Gloucester County (291,165) is exposed to this hazard (2015-2019) American Community Survey 5-Year Population Estimate).

Lightning can be responsible for deaths, injuries, and property damage. Lightning-based deaths and injuries typically involve heart damage, inflated lungs, or brain damage, as well as loss of consciousness, amnesia, paralysis, and burns, depending on the severity of the strike. Additionally, most people struck by lightning survive, although they may have severe burns and internal damage. People located outdoors (i.e., recreational activities and farming) are considered most vulnerable to hailstorms, thunderstorms, and tornadoes because there is little to no warning, and shelter might not be available. Moving to a lower risk location will decrease a person's vulnerability.

Downed trees, damaged buildings, and debris carried by high winds from hurricanes, tropical storms, or tornadoes can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on several factors, including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

Impact on General Building Stock

All buildings are exposed to summer weather hazards such as hailstorms and lightning strikes. Refer to Section 3 (County Profile), which summarizes the building inventory in Gloucester County. While hailstorms are not frequently known to cause major injuries or damage in New Jersey, an extreme event can carry hail stones traveling at speeds greater than 100 miles per hour (NOAA 2021). This could cause structural damage for the general building stock in the County. Severe summer weather that causes lightning could be a threat to the County's general building stock if the lightning starts a fire. Over 22,000 fires caused by lightning occurred annually throughout the U.S. between 2007 and 2011, which was valued at approximately $450 million of damages per year (National Fire Protection Association 2013).

Impact on Critical Facilities and Lifelines

Critical facilities are at risk of being impacted by high winds associated with structural damage, or falling tree limbs/flying debris, which can result in the loss of power. Power loss can greatly impact households, business operations, public utilities, and emergency personnel. Emergency personnel such as police, fire, and EMS will not be able to effectively respond in a power loss event to maintain the safety of its citizens unless backup power and fuel sources are available. Loss of power can impact other public utilities, including potable water, wastewater treatment, and communications. In addition to public water services, property owners with private wells might not have access to potable water until power is restored.

All critical facilities in the County are exposed to the extreme temperature hazard with similar risks as discussed for the general building stock. It is essential that critical facilities remain operational during natural hazard events. Extreme heat events can sometimes cause short periods of utility failures, commonly referred to as "brown-outs", 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 as well. Backup power is recommended for critical facilities and infrastructure. Where backup power is needed for critical facilities that provide essential services, municipalities identified mitigation actions in Section 9 (Jurisdictional Annexes).

Impact on Economy

Severe weather events can have short- and long-lasting impacts on the economy. When a business is closed during storm recovery, there is lost economic activity in the form of day-to-day business and wages to employees. Overall, economic impacts include the loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss and rental loss due to the repair/replacement of buildings. 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.

According to the State of New Jersey 2019 HMP, hail alone causes $2 billion worth of crop and property damage on an annual basis in the United States (State of NJ 2019). Even though New Jersey is estimated to experience an average of two hailstorm events per year, the outcome of these events could be detrimental depending on the cost it would take for the community to recover from the damages. Likewise, these costs can add up for other severe weather events such as tornados destroying key infrastructure and level local businesses, or extreme rain events flooding out shopping centers or transportation hubs.

Impact on the Environment

The impact of severe weather events on the environment varies, but researchers are finding that the long-term impacts of more severe weather can be destructive to the natural and local environment. National organizations such as USGS and NOAA have been studying and monitoring the impacts of extreme weather phenomena as it impacts long term climate change, streamflow, river levels, reservoir elevations, rainfall, floods, landslides, erosion, etc. (USGS 2017). For example, severe weather that creates longer periods of rainfall can erode natural banks along waterways and degrade soil stability for terrestrial species. Tornadoes can tear apart habitats causing fragmentation across ecosystems. Researchers also believe that a greater number of diseases will spread across ecosystems because of impacts that severe weather and climate change will have on water supplies (NOAA 2013c). Overall, as the physical environment becomes more altered, species will begin to contract or migrate in response, which may cause additional stressors to the entire ecosystem within Gloucester County. Refer to Sections 4.4.3 (Disease Outbreak) for more information about these stressors.

Future Changes that May Impact Vulnerability

Understanding future changes that effect vulnerability in the County can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures.

Gloucester County considered the following factors to examine potential conditions that may affect hazard vulnerability:

- Potential or projected development.
- Projected changes in population.
- Other identified conditions as relevant and appropriate, including the impacts of climate change.

Projected Development

The ability of new development to withstand extreme summer weather hazard impacts lies in sound land use practices, building design considerations (e.g., Leadership in Energy and Environmental Design [LEED]), and consistent enforcement of codes and regulations for new construction. New development will change the landscape where buildings, roads, and other infrastructure potentially replace open land and vegetation. Surfaces that were once permeable and moist are now impermeable and dry, potentially making them more susceptible to fires caused by lightning.

The Pinelands Commission has identified Pinelands Management Area Boundaries, including regional growth areas and rural development areas that may also provide insight to where development and growth may occur in the County. In addition, each community was requested to provide recent and anticipated new development and infrastructure projects; summarized in Section 9 (Jurisdictional Annexes).

Specific areas of recent and new development are indicated in tabular form and/or on the hazard maps included in the jurisdictional annexes in Volume II, Section 9 (Jurisdictional Annexes) of this plan.

Projected Changes in Population

Gloucester County has experienced population increase since 2010. According to the U.S. Census Bureau, the County's population has increased 1.0-percent between 2010 and 2019 (U.S. Census Bureau 2021). Any changes in the density of population can impact the number of persons exposed to the severe weather hazard.

Climate Change

As discussed above, most studies project that the State of New Jersey will see an increase in average annual temperatures. As the climate warms, the intensity of summer weather may change, with the potential to create more frequent events with lightning and/or hail.

Change of Vulnerability Since the 2016 HMP

Overall, the County's vulnerability has not changed, and the entire County will continue to be exposed and vulnerable to severe weather events. As existing development and infrastructure continue to age, they can be at increased risk to failed utility and transportation systems if they are not properly maintained and do not adapt to the changing environment.