5.4.7 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 Morris County.

2015 Plan Update Changes

- For the 2015 Plan Update, the severe weather hazard groups together hail, high wind, tornadoes, lightning and thunderstorms, which differs from the 2010 HMP when each were profiled individually. The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, probability of future occurrence, and potential change in climate and its impacts on the severe weather hazard is discussed. The severe weather hazard is now located in Section 5 of the plan update.
- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 2010 and 2014.
- A vulnerability assessment was conducted for the severe weather hazard and it now directly follows the hazard profile.

5.4.7.1 Profile

Hazard Description

For the purpose of this HMP Update and as deemed appropriated by the Morris County Planning Committee, the severe weather hazard includes high winds, tornadoes, thunderstorms, hurricanes/tropical storms, storm surge, and hail, which are defined 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). 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 (Ilicak 2005). High winds have the potential to down trees, tree limbs and power lines which lead to widespread power outages and damaging residential and commercial structures throughout Morris County. High winds are often associated by other severe weather events such as thunderstorms, tornadoes, hurricanes and tropical storms (all discussed further in this section).

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 U.S., though, on occasion, can persist into the mid-Atlantic and northeast U.S. (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 occur in the State of New Jersey including Morris County; however, they are generally weak and short lived. Tornado season in the State begins around March and goes through August, but tornadoes can occur any time of the year.

Tornado watches and warning are 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. Occasionally, tornadoes develop so rapidly, that little, if any, advance warning is possible (NOAA 2013; FEMA 2013; Robinson 2013).

Thunderstorms

A thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS 2009d). 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. 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).

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. It ranks as one of the top weather killers in the United States and kills approximately 50 people and injures hundreds each year. Lightning can occur anywhere there is a thunderstorm.

Thunderstorms can lead to 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 utility losses, such as water, phone and electricity. Lightning can damage homes and injure people. In the U.S., 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 U.S., with approximately 10% of them classified as severe. During the warm season, thunderstorms are responsible for most of the rainfall.

Hurricanes/Tropical Storms

A hurricane is a tropical storm that attains hurricane status when its wind speed reaches 74 or more miles an hour. Tropical systems may develop in the Atlantic between the Lesser Antilles and the African coast, or may develop in the warm tropical waters of the Caribbean and Gulf of Mexico. These storms may move up the Atlantic coast of the United States and impact the eastern seaboard, or move into the United States through the states along the Gulf Coast, bringing wind and rain as far north as New England before moving offshore and heading east.

A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds and heavy rain (winds are at a lower speed than hurricane-force winds, thus gaining its status as tropical storm versus hurricane). Tropical storms strengthen when water evaporated from the ocean is released as the saturated air rises, resulting in condensation of water vapor contained in the moist air. They are fueled by a different heat mechanism than other cyclonic windstorms such as Nor'Easters and polar lows. The characteristic that separates tropical cyclones from other cyclonic systems is that at any height in the atmosphere, the center of a tropical cyclone will be warmer than its surroundings; a phenomenon called "warm core" storm systems (NOAA 1999).

The National Weather Service (NWS) issues hurricane and tropical storm watches and warnings. These watches and warnings are issued or will remain in effect after a tropical cyclone becomes post-tropical, when such a storm poses a significant threat to life and property. The NWS allows the National Hurricane Center (NHC) to issue advisories during the post-tropical stage. The following are the definitions of the watches and warnings:

- *Hurricane/Typhoon Warning* is issued when sustained winds of 74 mph or higher are expected somewhere within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the warning is issued 36 hours in advance of the anticipated onset of tropical storm force winds (24 hours in the western north Pacific). The warning can remain in effect when dangerously high water or combination of dangerously high water and waves continue, even though winds may be less than hurricane force.
- *Hurricane Watch* is issued when sustained winds of 74 mph or higher are possible within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the hurricane watch is issued 48 hours prior to the anticipated onset of tropical storm force winds.
- *Tropical Storm Warning* is issued when sustained winds of 39 to 73 mph are expected somewhere within the specified area within 36 hours (24 hours for the western north Pacific) in association with a tropical, subtropical, or post-tropical storm.
- *Tropical Storm Watch* is issued when sustained winds of 39 to 73 mph are possible within the specified area within 48 hours in association with a tropical, sub-tropical, or post-tropical storm (NWS 2013).

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).

Location

High Winds

All of Morris County is subject to high winds from thunderstorms, hurricanes/tropical storms, tornadoes, and other severe weather events. According to the FEMA Winds Zones of the United States map, Morris County is located in Wind Zone II, where wind speeds can reach up to 160 mph. The County is also located in the Hurricane Susceptible Region, which extends along the entire east coast from Maine to Florida, the Gulf Coast, and Hawaii. This figure 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.

Tornadoes

Tornadoes have been documented in every state in the United States, and on every continent with the exception of Antarctica. Approximately 1,200 tornadoes occur in the United States each year, with the central portion of the country experiencing the most. Tornadoes can occur at any time of the year, with peak seasons at different times for different states (NSSL 2014). 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. New Jersey experienced an average of two tornadoes annually between 1991 and 2010 (NCDC 2013). For Morris County, between 1950 and 2013, the County experienced seven tornadoes, which averages approximately 0.1 tornadoes each year (SPC 2014).

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. 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. The most thunderstorms are seen in the southeast United States, with Florida having the highest incidences (80 to over 100 thunderstorm days each year). Morris County can experience an average of 20 to 30 thunderstorm days each year (NWS 2009d; NWS 2010).

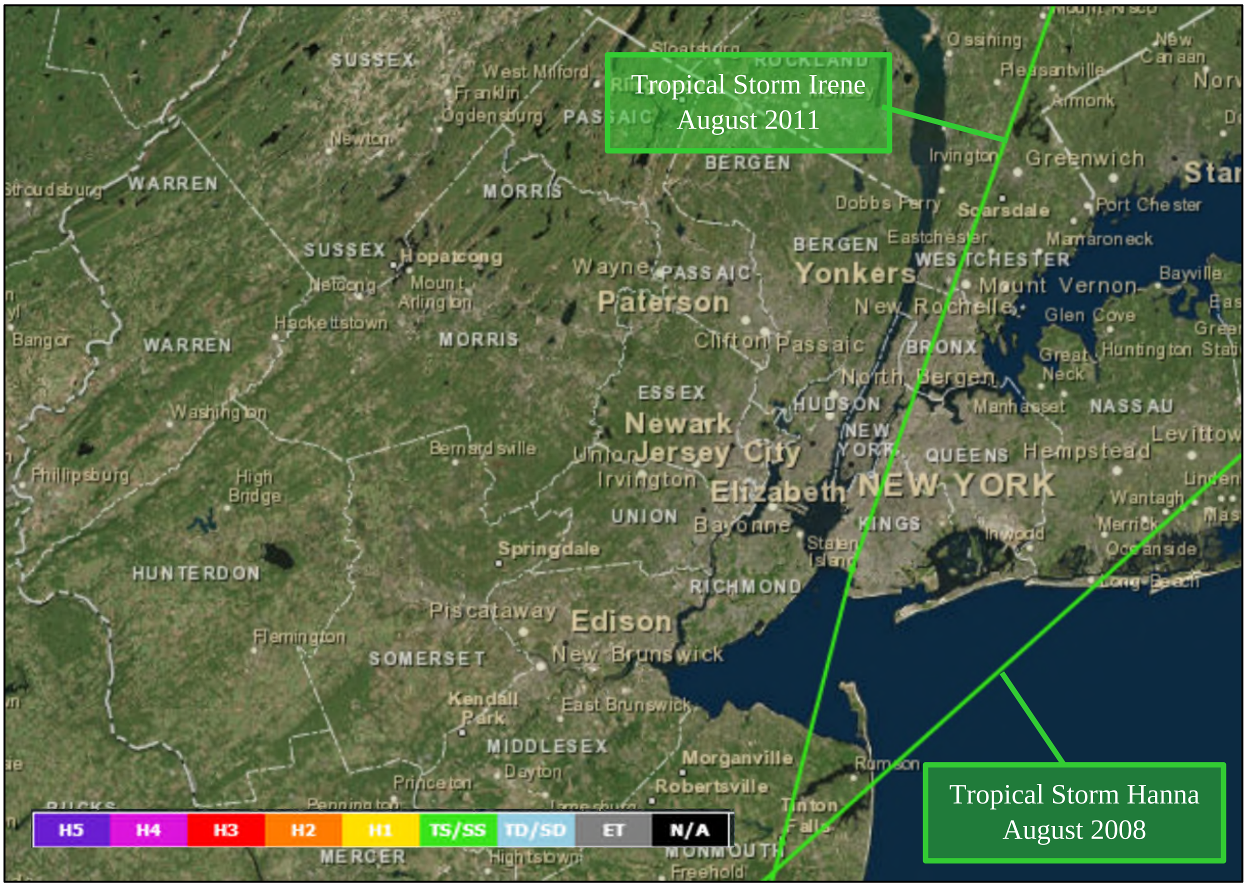
Thunderstorms spawned in Pennsylvania and New York State often move into northern New Jersey (which includes Morris County), where they usually reach maximum development during the evening hours. This region of the State has about twice as many thunderstorms as the coastal zone. The conditions most favorable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

Hurricanes/Tropical Storms

The entire Morris County Planning Area is vulnerable to hurricanes and tropical storms. It all depends on the storm's track. Inland areas, such as Morris County, are at risk for flooding due to the heavy rain and winds produced by hurricanes and tropical storms. The majority of damage from these events often results from residual wind damage and inland flooding, most recently experienced during Hurricane Irene in August 2011.

NOAA's Historical Hurricane Tracks tool is a public interactive mapping application that displays Atlantic Basin and East-Central Pacific Basin tropical cyclone data. This interactive tool catalogs tropical cyclones that have occurred from 1842 to 2012 (latest date available from data source). Between 1842 and 2013, 27 tropical cyclones tracked within 65 nautical miles of Morris County. Figure 5.4.7-1 displays tropical cyclone tracks for Morris County that tracked with 65 nautical miles between 2008 and 2012. Please note that the figure does not show Hurricane Sandy passing within 65 nautical miles of the County. Even though this storm did not pass near the County, the impacts from Sandy in the County were devastating, which included extensive power outages, downed trees and power lines, and closed roadways due to wind damage. For details regarding Hurricane Sandy in Morris County, refer to Appendix G.

Figure 5.4.7-1. Historical Tropical Storm and Hurricane Tracks 2008 to 2012



Source: NOAA NHC 2014

Hailstorms

Hailstorms are most frequent in the southern and central plains states in the United States, where warm moist air off of the Gulf of Mexico and cold dry air from Canada collide, and thereby spawning violent thunderstorms. This area of the United States is known as hail alley and lies within the states of Texas, Oklahoma, Colorado, Kansas, Nebraska, and Wyoming. While this area has the greatest frequency of hailstorms, they have been observed nearly everywhere thunderstorms occur, including New Jersey and Morris County.

Extent

High Winds

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

Table 5.4.7-1. 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

Descriptive Term	Sustained Wind Speed (mph)
None	5-15 or 10-20
Light or light and variable wind	0-5

Source: NWS 2010
mph miles per hour

The NWS issues advisories and warnings for winds. 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 is 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 one hour or longer, or wind gusts of 58 mph or greater for any duration
- Wind Advisories are issues when sustained winds of 30 to 39 mph are forecast for one hour or longer, or wind gusts of 46 to 57 mph for any duration (NWS, 2010).

Tornadoes

The magnitude or severity of a tornado was originally categorized using the Fujita Scale (F-Scale) or Pearson Fujita Scale introduced in 1971. This used to be the standard measurement for rating the strength of a tornado. The F-Scale categorized tornadoes by intensity and area and was divided into six categories, F0 (gale) to F5 (incredible). Table 5.4.7-2 explains each of the six F-Scale categories.

Table 5.4.7-2. Fujita Damage Scale

Scale	Wind Estimate (mph)	Typical Damage
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) Date Unknown
mph miles per hour

On February 1, 2007, the Enhanced Fujita Scale (EF-Scale) became operational. The EF-Scale is now the standard used to measure the strength of a tornado. 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 5.4.7-3 displays the EF-Scale and each of its six categories.

Table 5.4.7-3. Enhanced Fujita Damage Scale

EF-Scale Number	Intensity Phrase	Wind Speed (mph)	Type of Damage Done
EF0	Light tornado	65–85	**Light damage**. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over.
EF1	Moderate tornado	86-110	**Moderate damage**. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	Significant tornado	111-135	**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	Severe tornado	136-165	**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	Devastating tornado	166-200	**Devastating damage**. Well-constructed houses and whole frame houses completely leveled; cars thrown and small missiles generated.
EF5	Incredible tornado	>200	**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); high-rise buildings have significant structural deformation; incredible phenomena occur.

Source: SPC Date Unknown
EF-Scale Enhanced Fujita Scale
mph miles per hour

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 tornadoes 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 2009; 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; NWS 2010).
- 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 2010).

Hurricanes/Tropical Storms

The extent of a hurricane is categorized in accordance with the Saffir-Simpson Hurricane Scale. The Saffir-Simpson Hurricane Wind Scale is a 1-to-5 rating based on a hurricane's sustained wind speed. This scale estimates potential property damage. Hurricanes reaching Category 3 and higher are considered major hurricanes because of their potential for significant loss of life and damage. Category 1 and 2 storms are still dangerous and require preventative measures (NOAA 2013b). Table 5.4.7-4 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

Table 5.4.7-4. The Saffir-Simpson Scale

Category	Wind Speed (mph)	Expected Damage
1	74-95 mph	Very dangerous winds will produce some damage: Homes with well-constructed frames could have damage to roof, shingles, vinyl siding, and gutters. Large branches of trees will snap and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph	Extremely dangerous winds will cause extensive damage: Homes with well-constructed frames could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (major)	111-129 mph	Devastating damage will occur: Homes with well-built frames may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (major)	130-156 mph	Catastrophic damage will occur: Homes with well-built frames can sustain severe damage with loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (major)	>157 mph	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

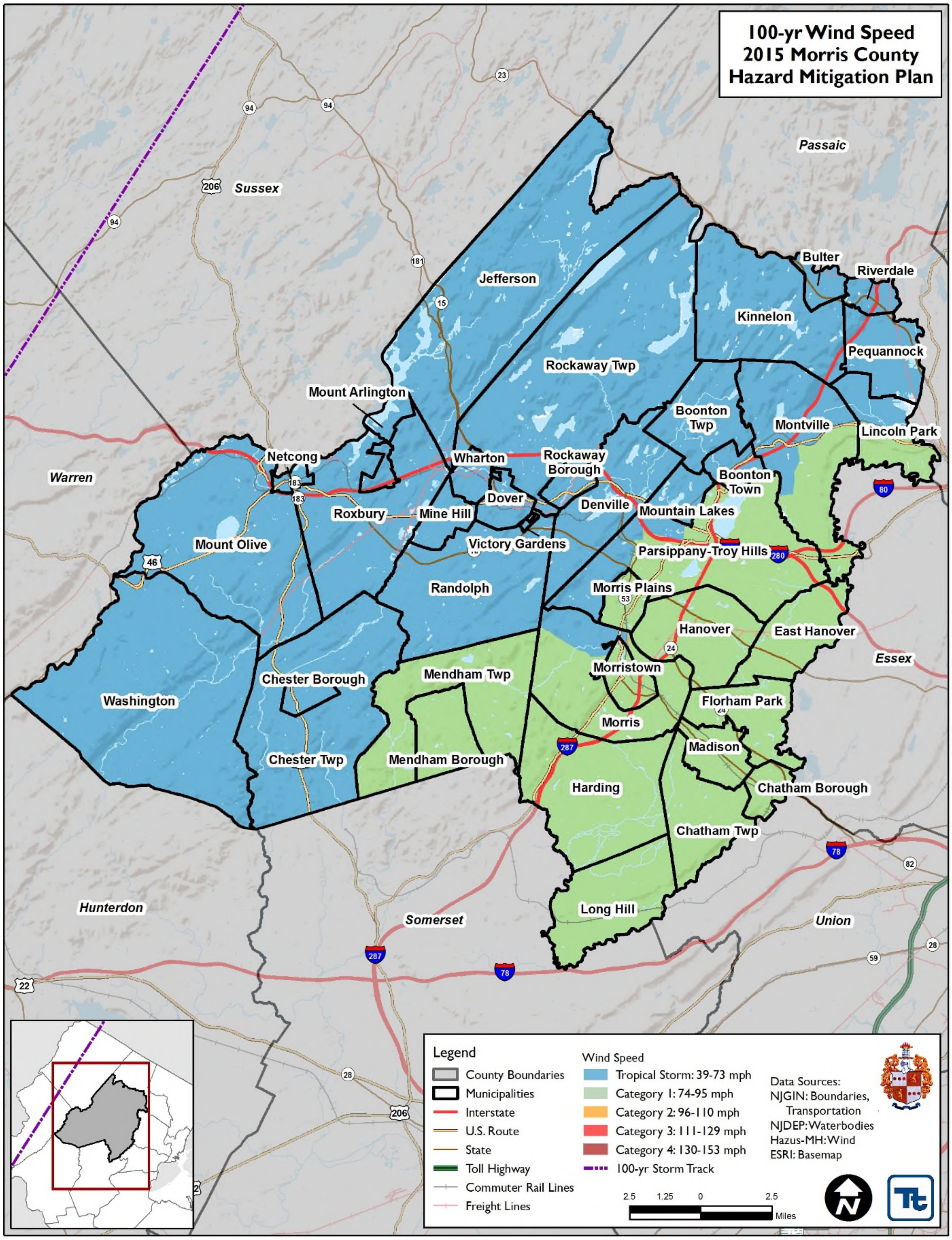
Source: NOAA 2013b
Notes: mph = Miles per hour
> = Greater than

Mean Return Period

In evaluating the potential for hazard events of a given magnitude, a mean return period (MRP) is often used. The MRP provides an estimate of the magnitude of an event that may occur within any given year based on past recorded events. MRP is the average period of time, in years, between occurrences of a particular hazard event, equal to the inverse of the annual frequency of exceedance (Dinicola 2009).

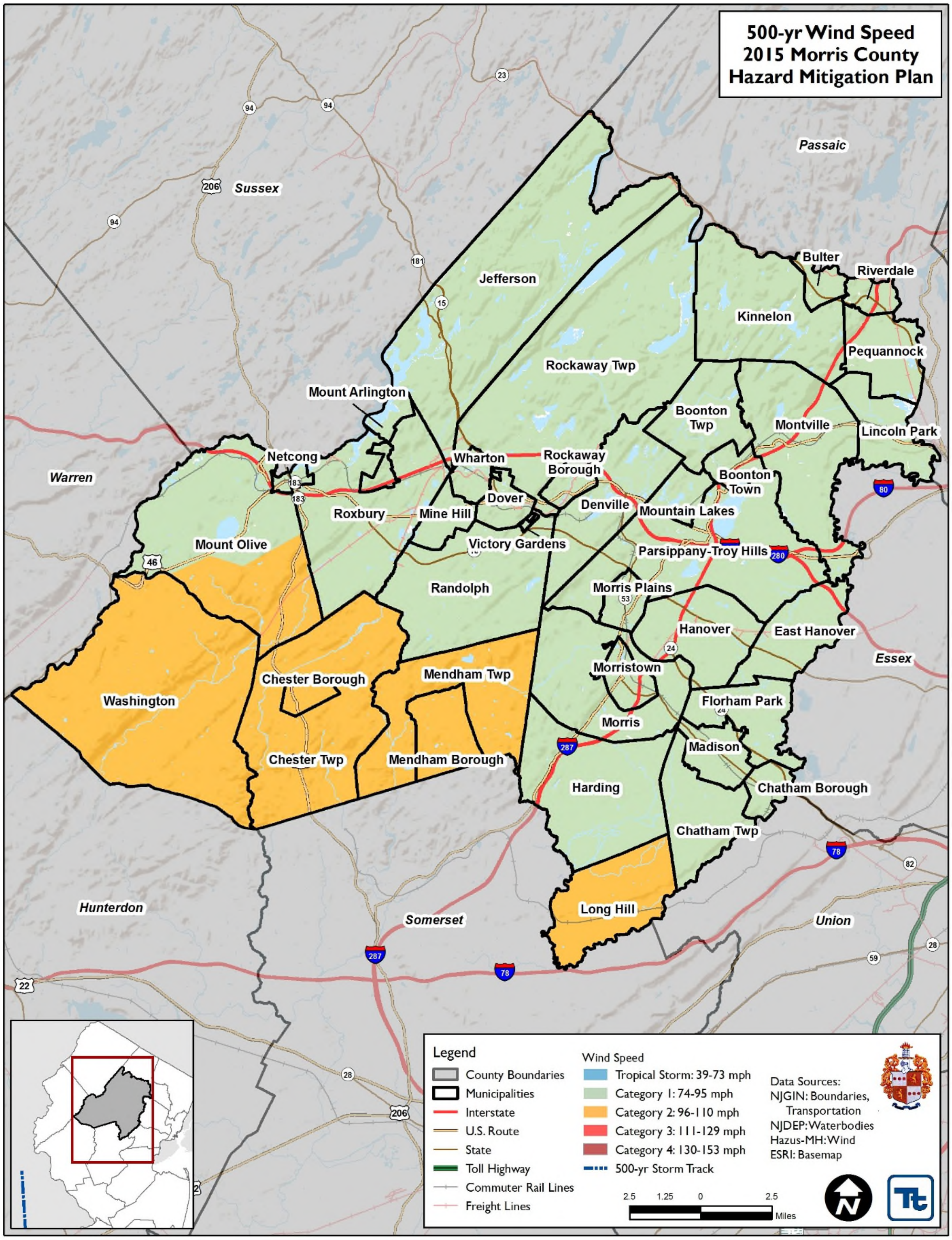
Figure 5.4.7-2 and Figure 5.4.7-3 show the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP events. These peak wind speed projections were generated using Hazards U.S. Multi-Hazard (HAZUS-MH) model runs. The estimated hurricane track used for the 100- and 500-year event is also shown. The maximum 3-second gust wind speeds for Morris County range from 68 to 75 mph for the 100-year MRP event. The maximum 3-second gust wind speeds for Morris County range from 83 to 98 for the 500-year MRP event. The associated impacts and losses from these 100-year and 500-year MRP hurricane event model runs are reported in the Vulnerability Assessment.

Figure 5.4.7-2. Wind Speeds for the 100-Year Mean Return Period Event



Source: Hazus-MH

Figure 5.4.7-3. Wind Speeds for the 500-Year Mean Return Period Event



Source: Hazus-MH

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.

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 5.4.7-5 shows the different sizes of hail and the comparison to real-world objects.

Table 5.4.7-5. 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

Previous Occurrences and Losses

In 2012, the U.S. Natural Hazards Statistics provided 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*. According to this 2013 data, New Jersey had eight injuries, and over $7.9 million in property and crop damages. This data includes statistics on cold, flood, heat, lightning, tornado, tropical cyclone, wind, and winter storm events. In relation to severe weather, New Jersey did not have any lightning-, wind-, tornado-, or tropical cyclone-related fatalities (National Oceanic and Atmospheric Administration [NOAA] 2014).

Many sources provided historical information regarding previous occurrences and losses associated with severe weather events throughout Morris County. 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.

Between 1954 and 2014, the State of New Jersey was included in 14 FEMA declared severe weather-related disasters (DR) or emergencies (EM) classified as one or a combination of the following hazards: severe weather, flooding, mudslides, 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, Morris County has been included in 13 declarations (FEMA 2014).

For this 2015 Plan Update, known severe weather events, including FEMA disaster declarations, which have impacted Morris County between 2008 and 2014 are identified in Appendix G. For detailed information on damages and impacts to each municipal, refer to Section 9 (jurisdictional annexes). Please note that not all events that have occurred in Morris County are included due to the extent of documentation and the fact that not all sources may have been identified or researched. Loss and impact information 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 Update.

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 Morris 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 (Keim1997).

It is estimated that Morris 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.

For hurricanes and tropical storms, the hurricane return periods are the frequency at which a certain intensity of hurricane can be expected within a given distance of a given location. For example, a return period of 20 years for a major hurricane means that on average during the previous 100 years, a Category 3 or greater hurricane passed within 58 miles of a specific location approximately five times. According to the NHC, the return period of hurricanes for Morris County was not calculated. However, the return period for surrounding counties is 18 to 19 years for a hurricane (greater than 64 mph winds) and 74 to 76 years for a major hurricane (greater than 110 mph winds) (NHC 2014).

In Section 5.3, the identified hazards of concern for Morris 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 weathers in the County is considered ‘frequent’ (likely to occur within 25 years, as presented in Table 5.3-3).

Climate Change Impacts

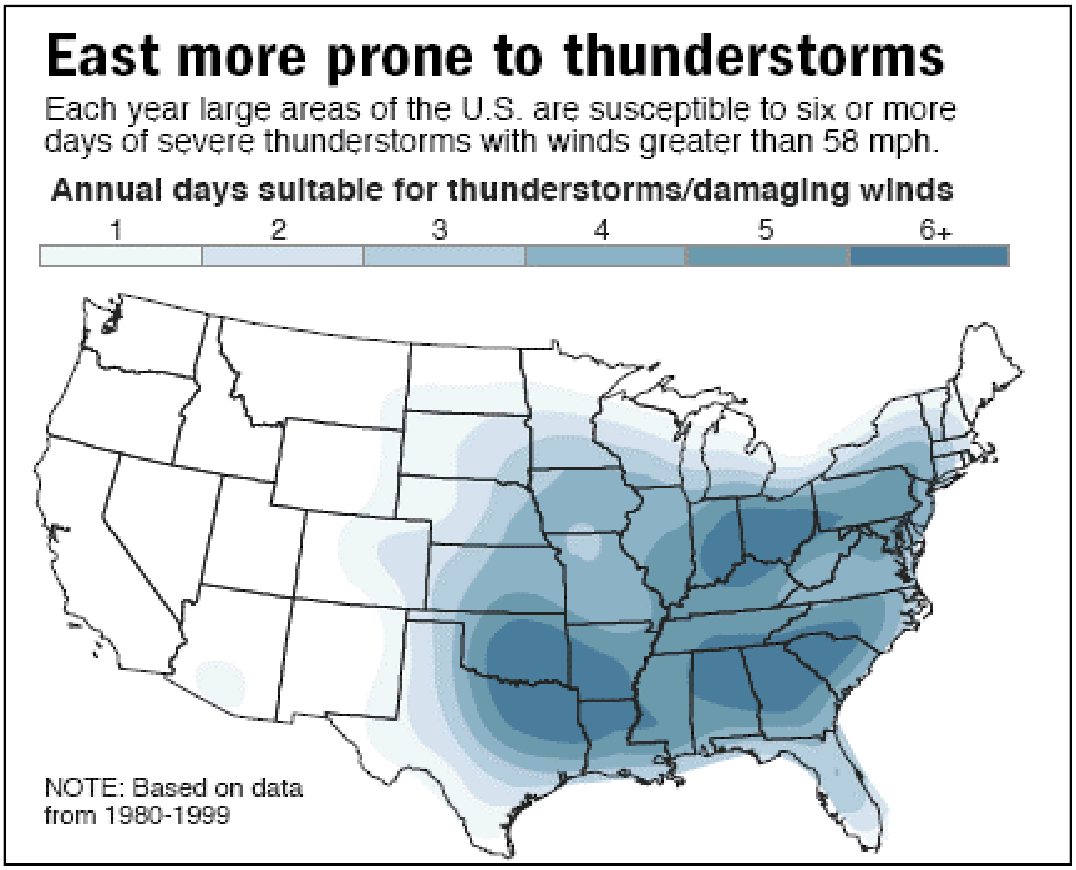
Providing projections of future climate change for a specific region is challenging. Shorter term projections are more closely tied to existing trends making longer term projections even more challenging. The further out a prediction reaches the more subject to changing dynamics it becomes. As the climate changes, temperatures and the amount of moisture in the air will both increase, thus leading to an increase in the severity of thunderstorms which can lead to derechos and tornadoes. Studies have shown that an increase in greenhouse gases in the atmosphere would significantly increase the number of days that severe thunderstorms occur in the southern and eastern United States (NASA 2013). Additionally, climate change may lead to stronger, more intense severe weather events.

Climate Change in New Jersey: Trends and Projections describes changes in temperature, precipitation, and Temperatures in the Northeast United States have increased 1.5 degrees Fahrenheit (°F) on average since 1900. Most of this warming has occurred since 1970. The State of New Jersey, for example, has observed an increase in average annual temperatures of 1.2°F between the period of 1971-2000 and the most recent decade of 2001-2010 (ONJSC, 2011). Winter temperatures across the Northeast have seen an increase in average temperature of 4°F since 1970 (Northeast Climate Impacts Assessment [NECIA] 2007). By the 2020s, the average annual temperature in New Jersey is projected to increase by 1.5°F to 3°F above the statewide baseline (1971 to 2000), which was 52.7°F. By 2050, the temperature is projected to increase 3°F to 5°F (Sustainable Jersey Climate Change Adaptation Task Force 2013).

Both northern and southern New Jersey have become wetter over the past century. Northern New Jersey's 1971-2000 precipitation average was over five inches (12%) greater than the average from 1895-1970. Southern New Jersey became two inches (5%) wetter late in the 20th century (Office of New Jersey State Climatologist). Average annual precipitation is projected to increase in the region by five-percent by the 2020s and up to 10% by the 2050s. Most of the additional precipitation is expected to come during the winter months (New York City Panel on Climate Change [NPCC] 2009).

National Aeronautics and Space Administration (NASA) scientists suggest that the U.S. 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. As prepared by the NWS, Figure 5.4.7-7 identifies those areas, particularly within the eastern U.S., that are more prone to thunderstorms, including New Jersey (NWS 2010).

Figure 5.4.7-7. Annual Days Suitable for Thunderstorms/Damaging Winds



Source: Borenstein, 2007
mph miles per hour

5.4.7.2 Vulnerability Assessment

To understand risk, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the severe weather hazard, all of Morris County is exposed and vulnerable. Therefore, all assets in the County (population, structures, critical facilities and lifelines), as described in Section 4 (County Profile), are exposed and potentially vulnerable. The following text evaluates and estimates the potential impact of severe weathers on the County including:

- Overview of vulnerability
- Data and methodology used for the evaluation
- Impact on: (1) life, health and safety of residents, (2) general building stock, (3) critical facilities, (4) economy, and (5) future growth and development
- Effect of climate change on vulnerability
- Change of vulnerability as compared to that presented in the 2010 Morris County Hazard Mitigation Plan
- Further data collections that will assist understanding this hazard over time

Overview of Vulnerability

People and property in virtually the entire United States are exposed to damage, injury, and loss of life from severe storm events (thunderstorms, lightning, wind, hail, tornadoes). Everywhere they occur; thunderstorms are responsible for significant structural damage to buildings, forest and wildfires, downed power lines and trees, and loss of life.

To protect life and property from wind events, all counties in New Jersey, including Morris County, are required to comply with the design wind loads developed by the International Building Code (IBC) and the International Residential Code (IRC). The building code administered within the incorporated areas of Morris County require all new construction to be designed and constructed to 90 or 100 mph wind loads (NJDCA 2013).

The high winds and air speeds of a hurricane often result in power outages, disruptions to transportation corridors and equipment, loss of workplace access, significant property damage, injuries and loss of life, and the need to shelter and care for individuals impacted by the events. A large amount of damage can be inflicted by trees, branches, and other objects that fall onto power lines, buildings, roads, vehicles, and, in some cases, people. Additionally, hurricanes can cause storm surge related damages along the coast or riverine reaches subject to tidal flooding.

The entire inventory of the County is at risk of being damaged or lost due to impacts of severe storms, especially hurricanes. Certain areas, infrastructure, and types of buildings are at greater risk than others due to proximity to flood waters, falling hazards, and their manner of construction. Potential losses associated with high winds were calculated for Morris County for the 100-year and 500-year MRP wind events.

Data and Methodology

After reviewing historic data, the HAZUS-MH methodology and model were used to analyze the wind hazard for Morris County. Data used to assess this hazard include data available in the HAZUS-MH 2.1 wind model, professional knowledge, information provided by the Planning Committee.

A probabilistic scenario was run for the County for annualized losses and the 100- and 500-year MRPs were examined for the wind hazard. These results are shown in Figures 5.4.7-2 and 5.4.7-3, earlier in this section, which show the HAZUS-MH maximum peak gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP events. The estimated hurricane storm track for the 100- and 500-year events is also shown.

HAZUS-MH contains data on historic hurricane events and wind speeds. It also includes surface roughness and vegetation (tree coverage) maps for the area. Surface roughness and vegetation data support the modeling of wind force across various types of land surfaces. Hurricane and inventory data available in HAZUS-MH were used to evaluate potential losses from the 100- and 500-year MRP events (severe wind impacts).

Impacts to life, health, and safety and structures are discussed below using the methodology described above.

Impact on Life, Health and Safety

For the purposes of this HMP, the entire population of Morris County (492,276 people) is exposed to severe weather events (U.S. Census, 2010). Residents may be displaced or require temporary to long-term sheltering. 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. HAZUS-MH estimates there will be zero displaced households and no people will require temporary shelter due to a 100-year MRP event. For a 500-year MRP event, HAZUS-MH estimates 1 households will be displaced, while no people will require short-term sheltering. Refer to Table 5.4.7-6 which summarizes the sheltering estimates for the 100- and 500-year MRP events by municipality. Please note these estimates are based on wind speed only and do not account for sheltering needs associated with flooding that may accompany severe storm events.

Table 5.4.7-6. Sheltering Needs for the 100- and 500-year MRP Hurricane Event

Municipality	500-Year MRP Displaced Households	500-Year MRP People Requiring Short-Term Shelter
Township of Mount Olive	1	0
Morris County (Total)	**1**	**0**

Source: HAZUS-MH v 2.1 (U.S. Census 2000)
Note: Sheltering estimates are based on the default 2000 U.S. Census data in HAZUS-MH. Therefore, these are conservative estimates given the increase in population as indicated by the 2010 U.S. Census data.

Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions based on the major economic impact to their family and may not have funds to evacuate. The population over the age of 65 is also more vulnerable and, physically, they may have more difficulty evacuating. The elderly are considered most vulnerable because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention which may not be available due to isolation during a storm event. Please refer to Section 4 for the statistics of these populations.

People located outdoors (i.e., recreational activities and farming) are considered most vulnerable to hailstorms, thunderstorms and tornadoes. This is because there is little to no warning and shelter may not be available. Moving to a lower risk location will decrease a person's vulnerability.

Impact on General Building Stock

After considering the population exposed to the hurricane hazard, the value of general building stock exposed to and damaged by 100- and 500-year MRP hurricane wind events was considered. Potential damage is the modeled loss that could occur to the exposed inventory, including damage to structural and content value based on the wind-only impacts associated with a hurricane, followed by a consideration of wind and storm surge impacts (using the methodology described earlier).

The entire study area is considered at risk to the hurricane wind hazard. Please refer to Section 4 (County Profile) which presents the total exposure value for general building stock by occupancy class for Morris County.

Expected building damage was evaluated by HAZUS across the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 5.4.7-7 summarizes the definition of the damage categories.

Table 5.4.7-7. Description of Damage Categories

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
No Damage or Very Minor Damage Little or no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very Limited water penetration.	≤2%	No	No	No	No	No
Minor Damage Maximum of one broken window, door or garage door. Moderate roof cover loss that can be covered to prevent additional water entering the building. Marks or dents on walls requiring painting or patching for repair.	>2% and ≤15%	One window, door, or garage door failure	No	<5 impacts	No	No
Moderate Damage Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water.	>15% and ≤50%	> one and ≤ the larger of 20% & 3	1 to 3 panels	Typically 5 to 10 impacts	No	No
Severe Damage Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	>50%	> the larger of 20% & 3 and ≤50%	>3 and ≤25%	Typically 10 to 20 impacts	No	No
Destruction Complete roof failure and/or, failure of wall frame. Loss of more than 50% of roof sheathing.	Typically >50%	>50%	>25%	Typically >20 impacts	Yes	Yes

Source: HAZUS-MH Hurricane Technical Manual

Table 5.4.7-8 summarizes the building value (structure only) damage estimated for the 100- and 500-year MRP hurricane wind-only events. Damage estimates are reported for the County's probabilistic HAZUS-MH model scenarios. The data shown indicates total losses associated with wind damage to building structure.

Table 5.4.7-8. Estimated Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Hurricane-Related Winds

Municipality	Estimated Total Damages*			Percent of Total Building Replacement Cost Value			Estimated Residential Damage		Estimated Commercial Damage	
	Annualized Loss	100-Year	500-Year	Annualized Loss	100-Year	500-Year	100-Year	500-Year	100-Year	500-Year
Town of Boonton	$93,301	$1,319,258	$5,390,852	<1%	<1%	<1%	$1,284,366	$5,175,349	$13,234	$85,123
Township of Boonton	$70,485	$1,074,459	$4,807,778	<1%	<1%	<1%	$1,059,342	$4,711,680	$1,652	$8,972
Borough of Butler	$90,115	$1,352,276	$4,086,183	<1%	<1%	<1%	$1,329,688	$4,003,331	$10,698	$43,096
Chatham Borough	$138,125	$2,088,826	$9,504,609	<1%	<1%	<1%	$2,064,566	$9,234,528	$13,820	$160,188
Chatham Township	$211,350	$3,587,065	$17,681,938	<1%	<1%	<1%	$3,569,922	$17,503,754	$4,363	$44,510
Chester Borough	$15,004	$258,553	$2,668,818	<1%	<1%	<1%	$238,584	$2,224,536	$13,917	$302,385
Chester Township	$132,069	$2,465,196	$24,563,004	<1%	<1%	1.0%	$2,432,935	$23,492,429	$7,060	$137,914
Denville Township	$246,309	$4,128,525	$21,999,780	<1%	<1%	<1%	$4,059,243	$21,453,615	$29,053	$248,431
Town of Dover	$92,897	$1,594,397	$9,894,548	<1%	<1%	<1%	$1,535,644	$9,268,280	$19,534	$222,883
Township of East Hanover	$299,946	$4,503,365	$17,867,113	<1%	<1%	<1%	$4,390,276	$16,867,988	$63,982	$585,195
Borough of Florham Park	$232,661	$3,769,458	$15,894,125	<1%	<1%	<1%	$3,687,231	$15,113,555	$43,693	$463,139
Township of Hanover	$286,062	$4,038,535	$22,372,631	<1%	<1%	<1%	$3,883,719	$20,817,295	$79,320	$888,005
Township of Harding	$138,620	$2,446,416	$14,077,856	<1%	<1%	<1%	$2,428,193	$13,569,461	$4,500	$80,390
Township of Jefferson	$167,175	$2,560,589	$14,902,883	<1%	<1%	<1%	$2,520,451	$14,688,417	$21,477	$122,659
Borough of Kinnelon	$181,760	$2,899,630	$10,142,312	<1%	<1%	<1%	$2,883,353	$10,086,206	$5,907	$22,116
Borough of Lincoln Park	$168,173	$2,550,498	$7,761,113	<1%	<1%	<1%	$2,518,192	$7,631,995	$6,982	$31,159
Township of Long Hill	$155,106	$2,948,676	$16,569,685	<1%	<1%	1.0%	$2,918,445	$16,114,061	$13,891	$202,316
Borough of Madison	$226,609	$3,508,561	$17,306,382	<1%	<1%	<1%	$3,458,885	$16,778,733	$22,489	$279,714
Borough of Mendham	$74,180	$1,401,465	$10,380,306	<1%	<1%	<1%	$1,381,885	$9,878,510	$6,648	$123,521
Township of Mendham	$110,616	$2,073,274	$14,091,428	<1%	<1%	<1%	$2,057,743	$13,714,413	$550	$8,327
Township of Mine Hill	$28,266	$415,487	$3,901,278	<1%	<1%	<1%	$406,386	$3,806,194	$2,899	$31,747
Township of Montville	$403,192	$6,112,983	$21,864,013	<1%	<1%	<1%	$6,006,432	$21,330,046	$23,430	$134,372
Borough of Morris Plains	$90,271	$1,416,558	$8,003,040	<1%	<1%	<1%	$1,368,920	$7,521,481	$19,339	$231,760
Township of Morris	$377,308	$6,069,058	$35,960,754	<1%	<1%	<1%	$5,971,461	$34,807,657	$40,128	$520,687
Town of Morristown	$148,707	$2,044,270	$13,614,670	<1%	<1%	<1%	$1,941,121	$12,121,316	$76,596	$1,166,362
Borough of Mount Arlington	$56,192	$666,211	$8,630,479	<1%	<1%	<1%	$656,925	$8,525,687	$5,159	$63,094

Municipality	Estimated Total Damages*			Percent of Total Building Replacement Cost Value			Estimated Residential Damage		Estimated Commercial Damage	
	Annualized Loss	100-Year	500-Year	Annualized Loss	100-Year	500-Year	100-Year	500-Year	100-Year	500-Year
Township of Mount Olive	$183,137	$2,634,832	$32,671,275	<1%	<1%	<1%	$2,503,972	$30,283,275	$36,082	$627,306
Borough of Mountain Lakes	$64,562	$1,027,938	$4,481,180	<1%	<1%	<1%	$1,012,022	$4,370,288	$7,339	$55,597
Netcong Borough	$33,174	$471,352	$5,565,562	<1%	<1%	1.0%	$457,373	$5,345,162	$5,545	$82,805
Township of Parsippany-Troy Hills	$591,129	$9,184,123	$40,089,614	<1%	<1%	<1%	$8,872,562	$37,637,149	$189,991	$1,608,143
Township of Pequannock	$293,376	$4,289,718	$12,468,298	<1%	<1%	<1%	$4,218,803	$12,156,832	$20,034	$80,501
Township of Randolph	$270,220	$4,714,650	$32,396,931	<1%	<1%	<1%	$4,620,838	$31,304,188	$30,835	$334,824
Borough of Riverdale	$55,002	$805,891	$2,174,150	<1%	<1%	<1%	$777,478	$2,087,584	$18,668	$57,099
Borough of Rockaway	$53,085	$813,935	$4,687,196	<1%	<1%	<1%	$779,488	$4,394,983	$18,435	$155,209
Township of Rockaway	$214,804	$3,548,830	$19,023,380	<1%	<1%	<1%	$3,399,678	$18,106,762	$42,412	$366,192
Township of Roxbury	$211,190	$3,722,591	$30,589,358	<1%	<1%	<1%	$3,624,418	$29,247,177	$60,132	$816,057
Borough of Victory Gardens	$3,289	$42,646	$352,953	<1%	<1%	<1%	$40,390	$325,762	$1,572	$19,438
Township of Washington	$194,282	$3,003,560	$39,836,835	<1%	<1%	1.0%	$2,957,013	$37,198,441	$10,252	$250,525
Borough of Wharton	$45,848	$689,569	$5,393,124	<1%	<1%	<1%	$653,995	$5,023,604	$8,921	$87,986
Morris County (Total)	**$6,447,600**	**$102,243,221**	**$583,667,434**	**<1%**	**<1%**	**<1%**	**$99,971,936**	**$557,921,722**	**$1,000,536**	**$10,749,743**

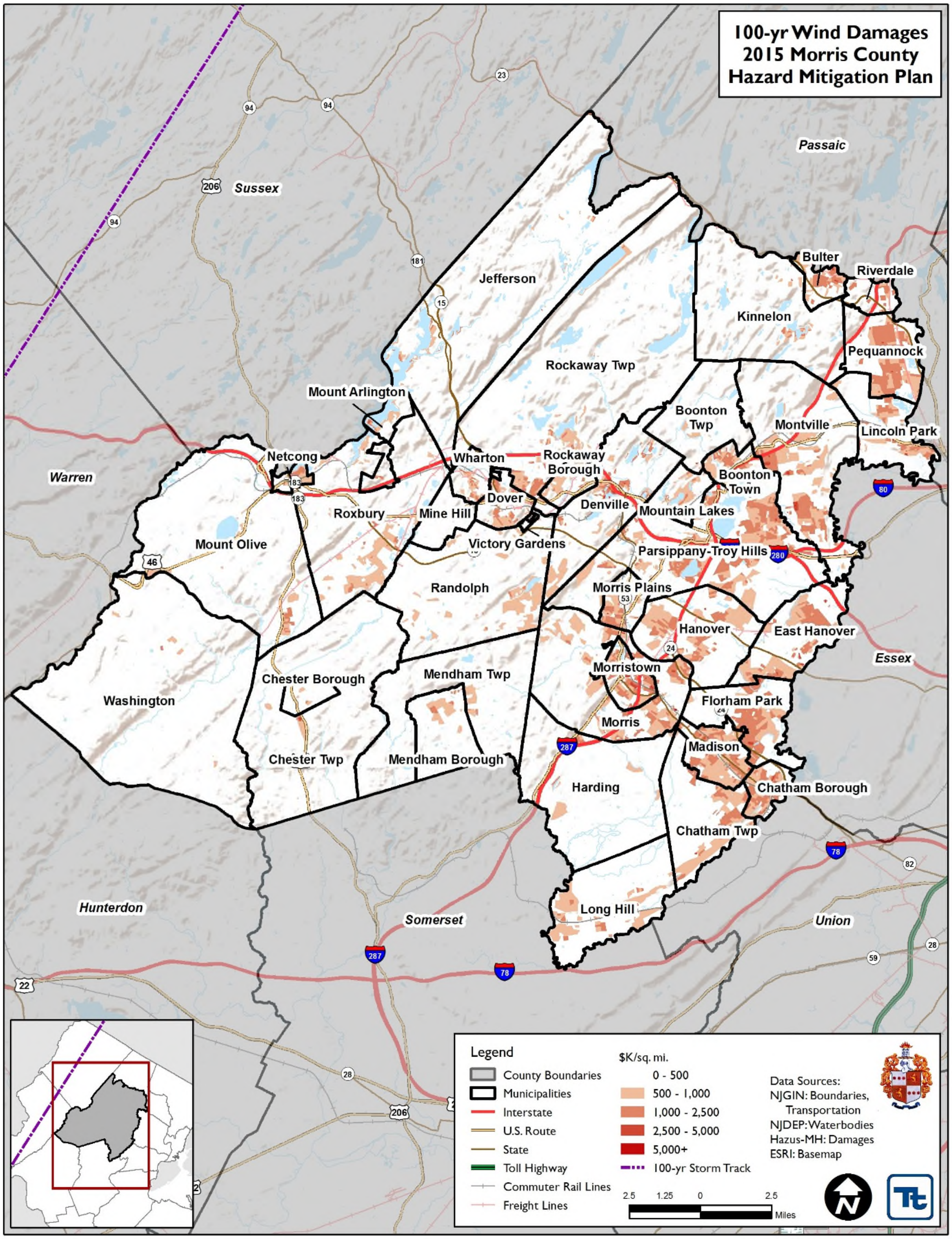
Source: HAZUS-MH 2.1;

**The Total Damages column represents the sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious and government) based on estimated replacement cost value.*

The total damage to buildings (structure only) for all occupancy types across the County is estimated to be $102 million for the 100-year MRP wind-only event, and approximately $584 million for the 500-year MRP wind-only event. The majority of these losses are to the residential building category.

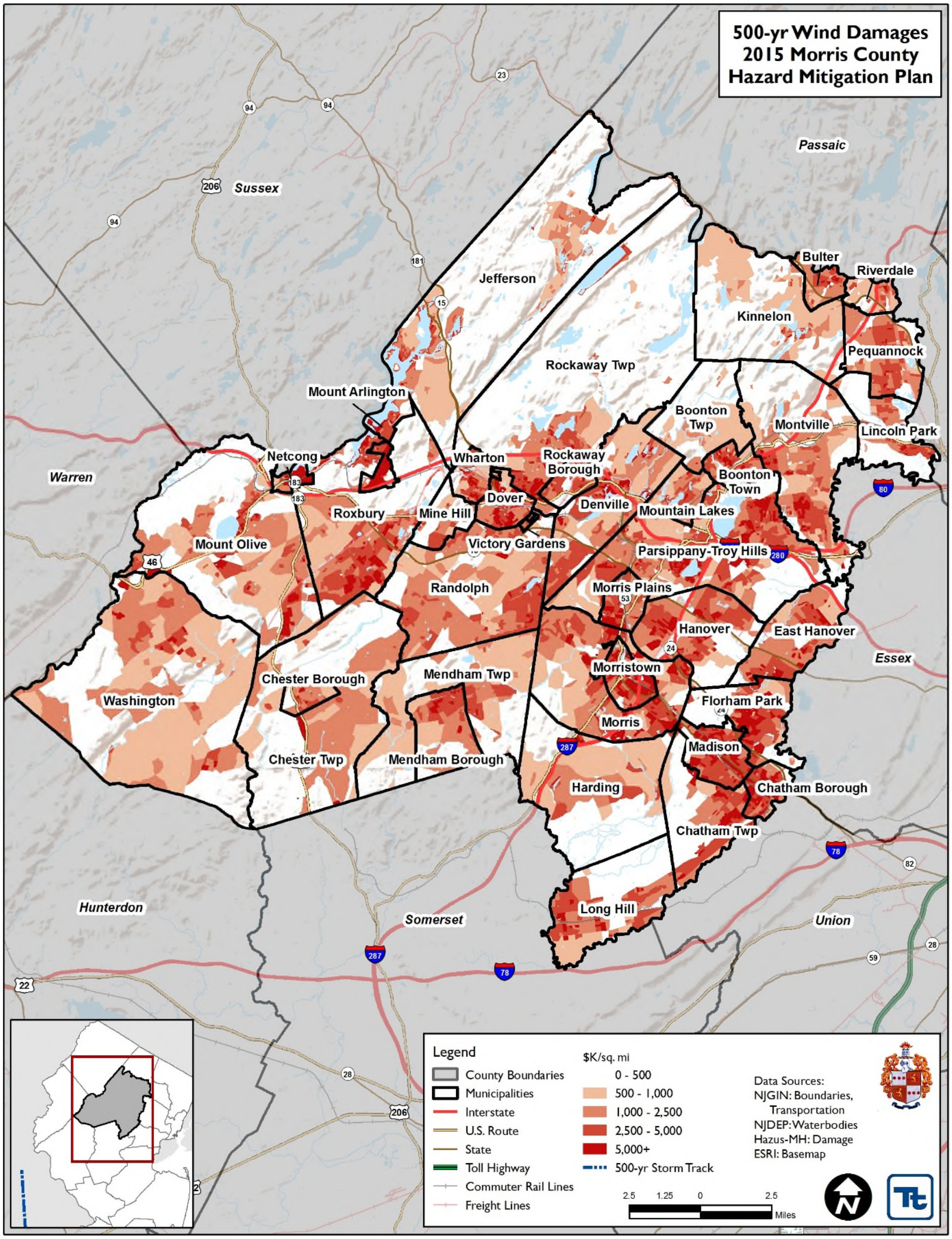
Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. The damage counts include buildings damaged at all severity levels from minor damage to total destruction. Total dollar damage reflects the overall impact to buildings at an aggregate level.

Figure 5.4.7-4. Density of Losses for Structures (All Occupancies) for the County 100-Year MRP Hurricane (Wind-Only) Event



Source: HAZUS-MH 2.1

Figure 5.4.7-5. Density of Losses for Structures (All Occupancies) for the County 500-Year MRP Hurricane (Wind-Only) Event



Source: HAZUS-MH 2.1

Impact on Critical Facilities

Overall, all critical facilities are exposed to the wind hazard associated with severe storms. HAZUS-MH estimates the probability that critical facilities (i.e., medical facilities, fire/EMS, police, EOC, schools, and user-defined facilities such as shelters and municipal buildings) may sustain damage as a result of 100-year and 500-year MRP wind-only events. Additionally, HAZUS-MH estimates the loss of use for each facility in number of days. Due to the sensitive nature of the critical facility dataset, individual facility estimated loss is not provided.

Table 5.4.7-9 and Table 5.4.7-10 summarize the potential damages to the critical facilities in Morris County as a result of the 100- and 500-year MRP wind events.

Table 5.4.7-9. Estimated Impacts to Critical Facilities for the 100- Year Mean Return Period Hurricane-Related Winds

	100-Year Event					
		Percent-Probability of Sustaining Damage				
Facility Type	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	0-1	0	0	0
Medical	0	0-2	0-28	0-53	0
Police	0	0-1	0	0	0
Fire	0	0	0	0	0
Schools	0	0-2	0	0	0

Source: HAZUS-MH 2.1

Table 5.4.7-10. Estimated Impacts to Critical Facilities for the 500-Year Mean Return Period Hurricane-Related Winds

	500-Year Event				
		Percent-Probability of Sustaining Damage			
Facility Type	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	1-8	0-1	0	0
Medical	0-1	0-7	5-14	2-89	0-3
Police	0	1-8	0-1	0	0
Fire	0	1-5	0-1	0	0
Schools	0-65	1-12	0-26	0-7	0

Source: HAZUS-MH 2.1

Impact on Economy

Hurricanes and tropical storms also impact the economy, including: 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. HAZUS-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are the estimated costs to repair or replace the damage caused to the building. This is reported in the "Impact on General Building Stock" subsection discussed earlier. Business interruption losses are the losses associated with the inability to operate a business because of the wind damage sustained during the storm or the temporary living expenses for those displaced from their home because of the event.

For the 100-year MRP wind event, HAZUS-MH estimates approximately $47,000 in business interruption costs (income loss, relocation costs, rental costs and lost wages). For the 500-year MRP wind only event, HAZUS-

MH estimates approximately $13.7 million in business interruption losses for the County which includes loss of income, relocation costs, rental costs and lost wages.

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.

HAZUS-MH 2.1 also estimates the amount of debris that may be produced a result of the 100- and 500-year MRP wind events. Table 5.4.7-12 estimates the debris produced. Because the estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur.

According to the HAZUS-MH Hurricane User Manual: '*The Eligible Tree Debris columns provide estimates of the weight and volume of downed trees that would likely be collected and disposed at public expense. As discussed in Chapter 12 of the HAZUS-MH Hurricane Model Technical Manual, the eligible tree debris estimates produced by the Hurricane Model tend to underestimate reported volumes of debris brought to landfills for a number of events that have occurred over the past several years. This indicates that that there may be other sources of vegetative and non-vegetative debris that are not currently being modeled in HAZUS. For landfill estimation purposes, it is recommended that the HAZUS debris volume estimate be treated as an approximate lower bound. Based on actual reported debris volumes, it is recommended that the HAZUS results be multiplied by three to obtain an approximate upper bound estimate. It is also important to note that the Hurricane Model assumes a bulking factor of 10 cubic yards per ton of tree debris. If the debris is chipped prior to transport or disposal, a bulking factor of 4 is recommended. Thus, for chipped debris, the eligible tree debris volume should be multiplied by 0.4*'.

Table 5.4.7-11. Debris Production for 100- and 500-Year Mean Return Period Hurricane-Related Winds

Municipality	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year
Town of Boonton	29	308	0	0	36	761	31	619
Township of Boonton	35	228	0	0	459	4,292	114	1,149
Borough of Butler	30	163	0	0	92	539	85	485
Chatham Borough	42	502	0	0	175	1,231	129	997
Chatham Township	73	805	0	0	789	5,960	238	2,023
Chester Borough	5	230	0	0	23	792	4	402
Chester Township	77	1,495	0	1	1,106	16,562	142	2,364
Denville Township	98	1,060	0	0	963	6,365	428	3,060
Town of Dover	29	667	0	0	86	1,123	65	948
Township of East Hanover	126	872	0	0	881	3,844	488	2,091
Borough of Florham Park	94	800	0	0	668	3,687	341	1,727
Township of Hanover	141	1,260	0	0	857	5,021	425	2,406
Township of Harding	55	743	0	0	1,341	12,278	152	1,410
Township of Jefferson	29	807	0	0	1,506	21,838	243	3,835
Borough of Kinnelon	72	363	0	0	1,142	9,301	307	2,521
Borough of Lincoln Park	57	294	0	0	842	3,119	318	1,173

Table 5.4.7-11. Debris Production for 100- and 500-Year Mean Return Period Hurricane-Related Winds

Municipality	Brick and Wood (tons)		Concrete and Steel (tons)		Tree (tons)		Eligible Tree Volume (cubic yards)	
	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year	100 Year	500 Year
Township of Long Hill	59	877	0	0	1,175	8,341	347	2,683
Borough of Madison	80	919	0	0	262	2,051	182	1,633
Borough of Mendham	46	687	0	0	78	2,656	30	1,071
Township of Mendham	60	843	0	0	559	10,349	108	1,816
Township of Mine Hill	9	253	0	0	2	1,381	2	614
Township of Montville	185	1,046	0	0	1,038	8,227	431	3,383
Borough of Morris Plains	48	473	0	0	84	1,104	77	859
Township of Morris	179	1,958	0	0	759	8,243	366	4,352
Town of Morristown	100	1,047	0	0	164	1,351	150	1,209
Borough of Mount Arlington	20	528	0	1	17	1,025	10	692
Township of Mount Olive	73	2,459	0	0	605	16,615	171	3,789
Borough of Mountain Lakes	16	230	0	0	152	1,351	82	902
Netcong Borough	10	300	0	0	52	455	43	355
Township of Parsippany-Troy Hills	289	2,483	0	0	1,843	10,715	825	5,035
Township of Pequannock	96	504	0	0	636	2,387	412	1,395
Township of Randolph	153	2,041	0	0	802	11,008	289	4,950
Borough of Riverdale	22	89	0	0	159	569	75	275
Borough of Rockaway	30	349	0	0	43	718	27	551
Township of Rockaway	99	1,205	0	0	441	21,214	132	3,669
Township of Roxbury	49	1,918	0	0	826	12,065	339	4,341
Borough of Victory Gardens	5	56	0	0	2	55	2	55
Township of Washington	56	2,739	0	4	780	24,095	136	4,684
Borough of Wharton	20	379	0	0	35	872	25	550
Morris County (Total)	**2,696**	**33,980**	**0**	**6**	**21,480**	**243,560**	**7,769**	**76,074**

Source: HAZUS-MH 2.1

Effect of Climate Change on Vulnerability

Climate is defined not simply as average temperature and precipitation but also by the type, frequency and intensity of weather events. Both globally and at the local scale, climate change has the potential to alter the prevalence and severity of events like hurricanes. While predicting changes to the prevalence or intensity of hurricanes and the events affects under a changing climate is difficult, understanding vulnerabilities to potential changes is a critical part of estimating future climate change impacts on human health, society and the environment (U.S. Environmental Protection Agency [EPA], 2006).

Change of Vulnerability

Morris County and its municipalities continue to be vulnerable to the severe weather hazard. However, there are several differences between the exposure and potential loss estimates between the 2015 HMP update and the results in the original 2010 HMP. Their differences are due to changes in the HAZUS model and the new and updated population (U.S. Census 2010) and building inventories available and used for this update.

Differences in exposure and potential losses estimated from the 2010 HMP can be attributed to the difference in building stock inventory and methodology used for the risk assessment. For this plan update, an updated building stock was generated using structure-specific data with estimated replacement cost value.

For this plan update, the HAZUS-MH hurricane model was run for the entire County and reported at the municipal level. The HAZUS-MH version 2.1 was utilized for this plan update and the hurricane model has been enhanced since the 2010 HMP. The FEMA Wind Hurricane BCA module was not used for this plan update.

Overall, this vulnerability assessment using a more accurate and updated building inventory which provides more accurate estimated exposure and potential losses for Morris County.

Future Growth and Development

As discussed and illustrated in Section 4, areas targeted for future growth and development have been identified across the County. Any areas of growth could be potentially impacted by the hurricane and tropical storm hazard because the entire Planning Area is exposed and vulnerable to the wind and storm surge hazards associated with these events. 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. Areas targeted for potential future growth and development in the next five (5) years have been identified across the County at the jurisdiction level. Refer to the jurisdictional annexes in Volume II of this HMP.

Additional Data and Next Steps

Over time, the County will obtain additional data to support the analysis of this hazard. Data that will support the analysis would include additional detail on past hazard events and impacts, building footprints and specific building information such as details on protective features (for example, hurricane straps).