4.3.8 HURRICANE AND TROPICAL STORM

2021 HMP update Changes

- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 2016 and 2021.
- A vulnerability assessment was conducted for the hurricane and tropical storm hazard using a more accurate and updated building inventory and Hazus version 4.2.

Profile

Hazard Description

A tropical cyclone is a rotating, organized system of clouds and thunderstorms that originates over tropical or sub-tropical waters and has a closed low-level circulation. Tropical depressions, tropical storms, and hurricanes are all considered tropical cyclones. These storms rotate counterclockwise around the center in the northern hemisphere and are accompanied by heavy rain and strong winds (NWS 2013a). Almost all tropical storms and hurricanes in the Atlantic basin (which includes the Gulf of Mexico and Caribbean Sea) form between June 1 and November 30 (hurricane season). August and September are peak months for hurricane development (NWS 2013a).

Over a two-year period, the U.S. coastline is struck by an average of three hurricanes, one of which is classified as a major hurricane. Hurricanes, tropical storms, and tropical depressions pose a threat to life and property. These storms bring heavy rain, storm surge, and flooding (NOAA 2013b). The cooler waters off the coast of New Jersey can diminish the energy of storms that have traveled up the eastern seaboard. However, historical data show that a number of hurricanes/tropical storms have impacted New Jersey, often as the remnants of a larger storm hitting the Gulf or Atlantic Coast hundreds of miles south of New Jersey. These storms maintain sufficient wind and precipitation to cause substantial damage to the state.

Tropical cyclones most frequently affect New Jersey during the month of September, though the state has experienced tropical cyclones throughout the hurricane season, excluding November. Because of peak warm water temperatures in September, storms usually affect New Jersey during this time.

For the purpose of this HMP update, this hazard profile will include hurricanes and tropical storms. Detailed information regarding these hazards in Mercer County are discussed further in this section.

Hurricanes and Tropical Storm

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, therefore categorized as a tropical storm instead of a 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 2011).

A hurricane is a tropical storm that attains hurricane status when its wind speed reaches 74 or more miles per hour (mph). 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.

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. 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 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).

Storm Surge

Storm surges inundate coastal floodplains through dune overwash, tidal elevation rise in inland bays and harbors, and backwater flooding through coastal river mouths. Strong winds can increase tide levels and water-surface elevations. Storm systems generate large waves that run up and flood coastal beaches. The combined effects create storm surges that affect the beach, dunes, and adjacent low-lying floodplains. Shallow, offshore depths can cause storm-driven waves and tides to pile up against the shoreline and inside bays.

Based on an area's topography, a storm surge can inundate only a small area (along sections of the northeast or southeast coasts) or coastal lands for a mile or more inland from the shoreline.

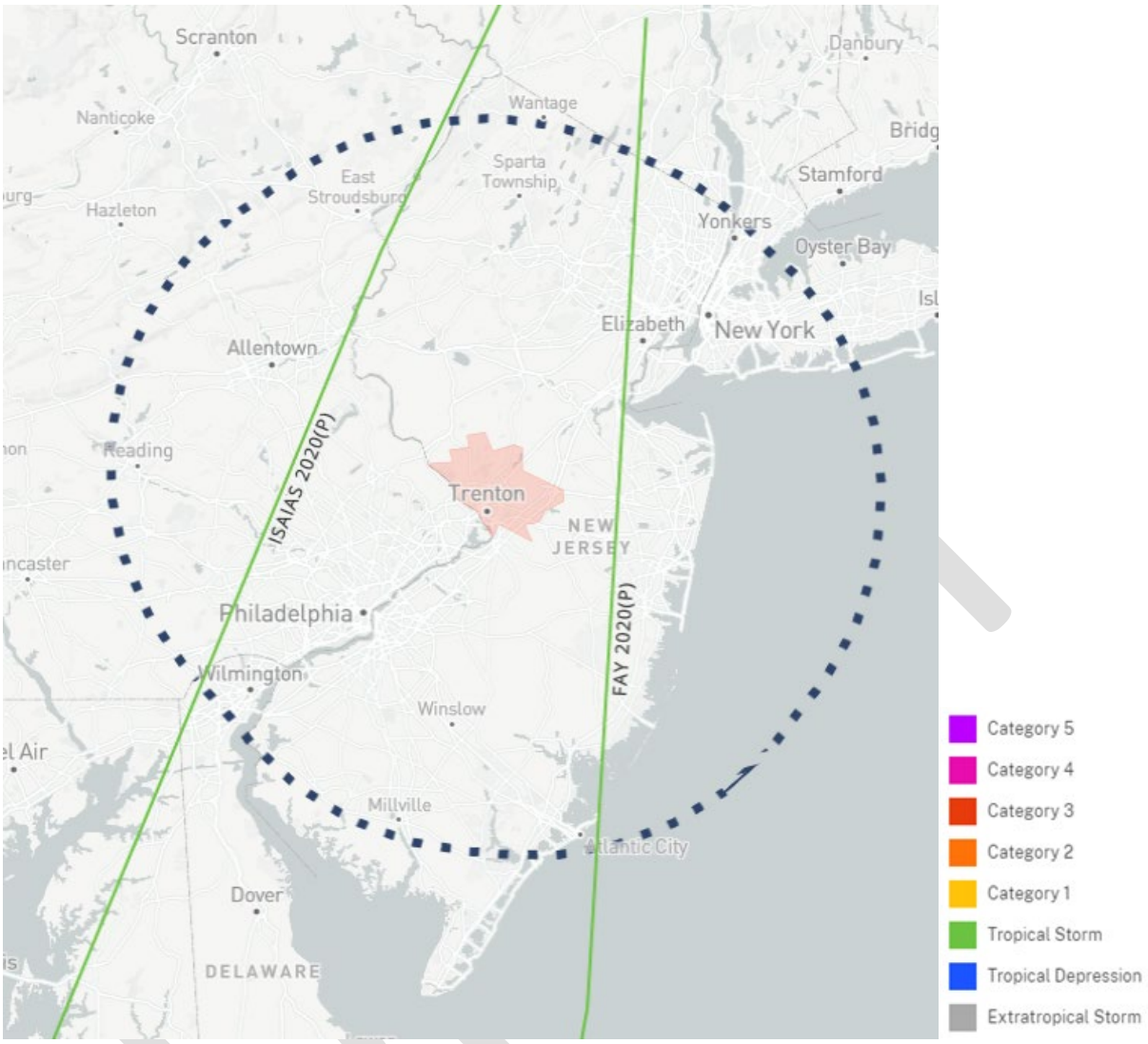
Location

All of Mercer County is vulnerable and at risk to flooding due to heavy rains and winds produced by hurricanes and tropical storms. A small area of the County along the Delaware River in southern Trenton and Hamilton Township could be impacted by storm surge during the most extreme of storm surge scenarios.

Tropical Storm and Hurricane Tracks

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 1856 to 2021 (latest date available from data source). Between 1856 and 2021, 39 events classified as either a hurricane, tropical storm, or tropical depression tracked within 65 nautical miles of Mercer County. Figure 4.3.6- 1 displays tropical cyclone tracks for Mercer County that tracked with 65 nautical miles between 2015 and 2021 (only two events – Tropical Storm Fay and Tropical Storm Isaias in 2020, identified as tropical storms when passing by the County). Refer to the "Previous Occurrences and Losses" section for further information regarding hurricane and tropical storm events that impacted Mercer County.

Figure 4.3.8-1. Historical Tropical Storm and Hurricane Tracks 2015 to 2021

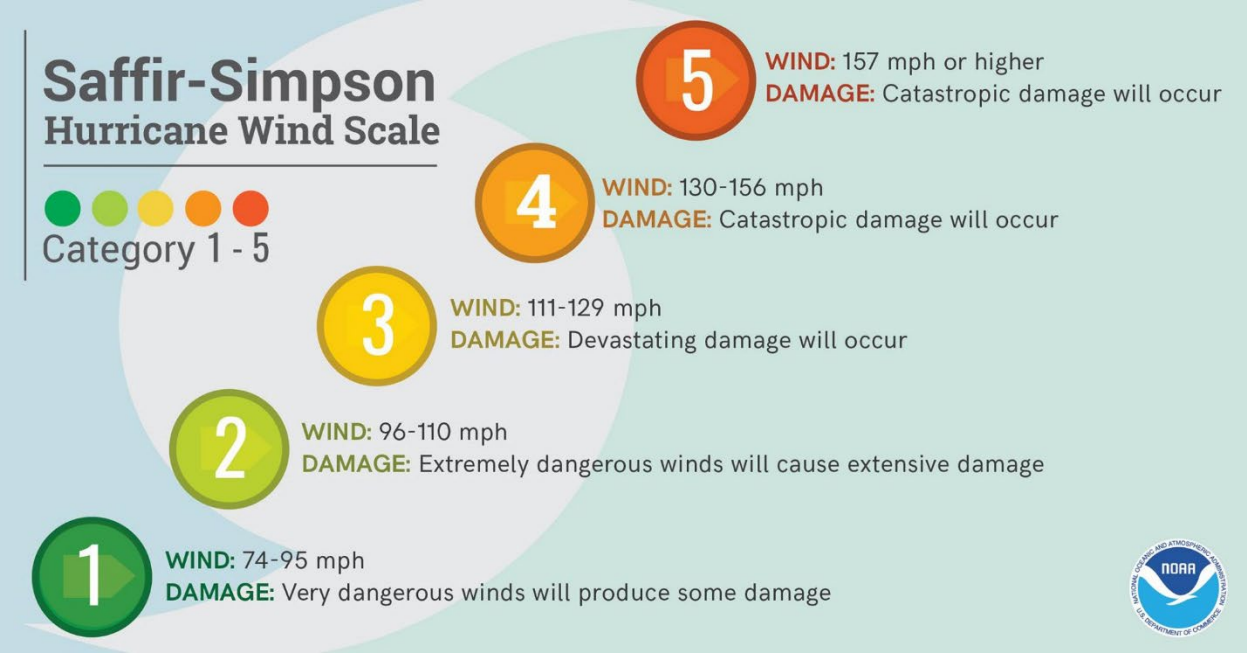


Source: NOAA 2021a

Extent

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). Figure 4.3.6-2 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

Figure 4.3.8-2. Saffir-Simpson Scale



Source: NWS 2013b

Mean Return Period

In evaluating the potential for hazard events of a given magnitude, a 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 4.3.6-3 and Figure 4.3.6-4 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 Hazus' probabilistic wind model. The maximum 3-second gust wind speeds for Mercer County are 59-64 mph (Tropical Storm), for the 100-year MRP event (tropical storm). The maximum 3-second gust wind speeds for Mercer County are 74-95 mph (Category 1 hurricane) for the 500-year MRP event. The associated impacts and losses from these 100-year and 500-year MRP hurricane event model runs are discussed in the Vulnerability Assessment subsection.

Figure 4.3.8-3. Wind Speeds for the 100-Year Mean Return Period Event

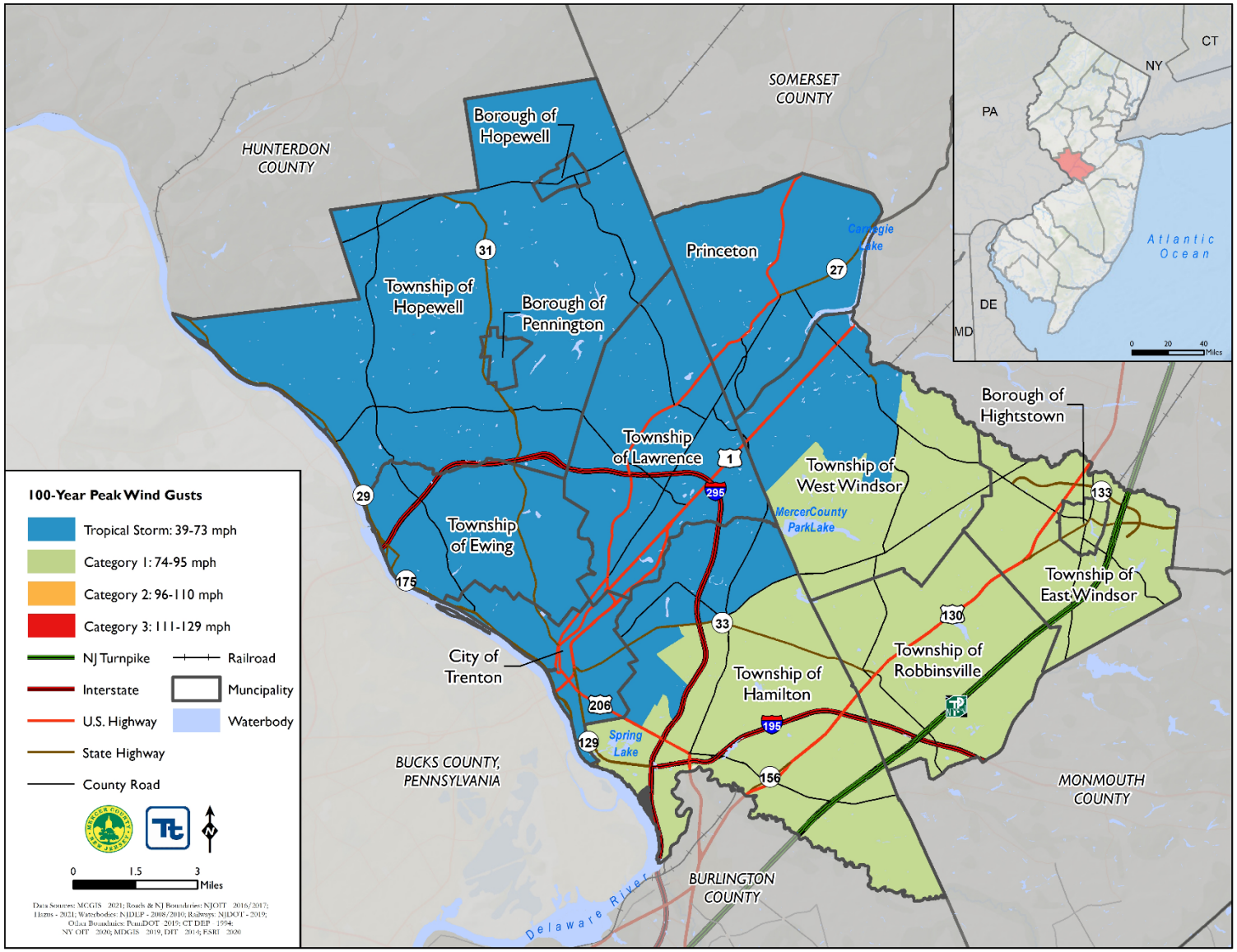
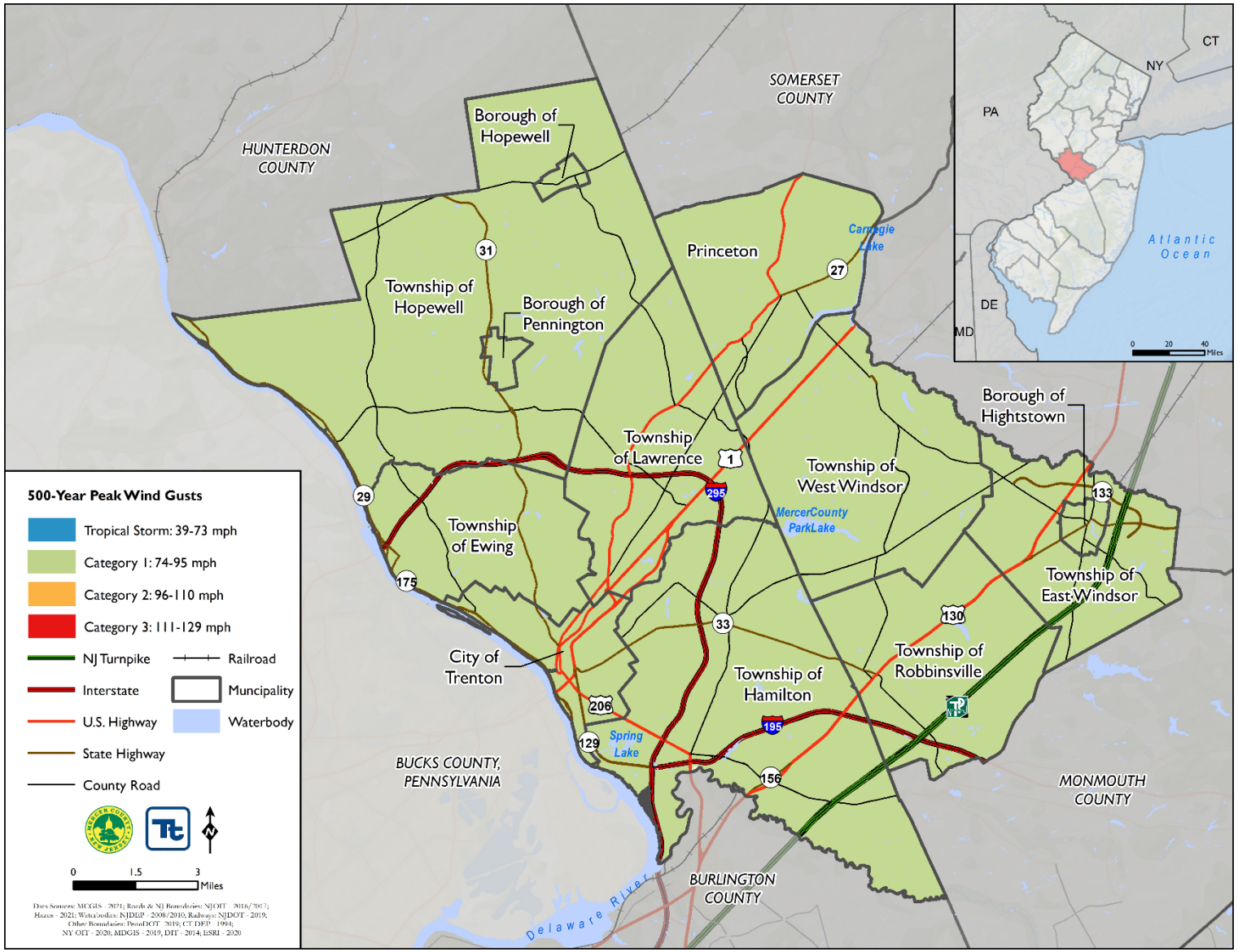


Figure 4.3.8-4. Wind Speeds for the 500-Year Mean Return Period Event



Storm Surge

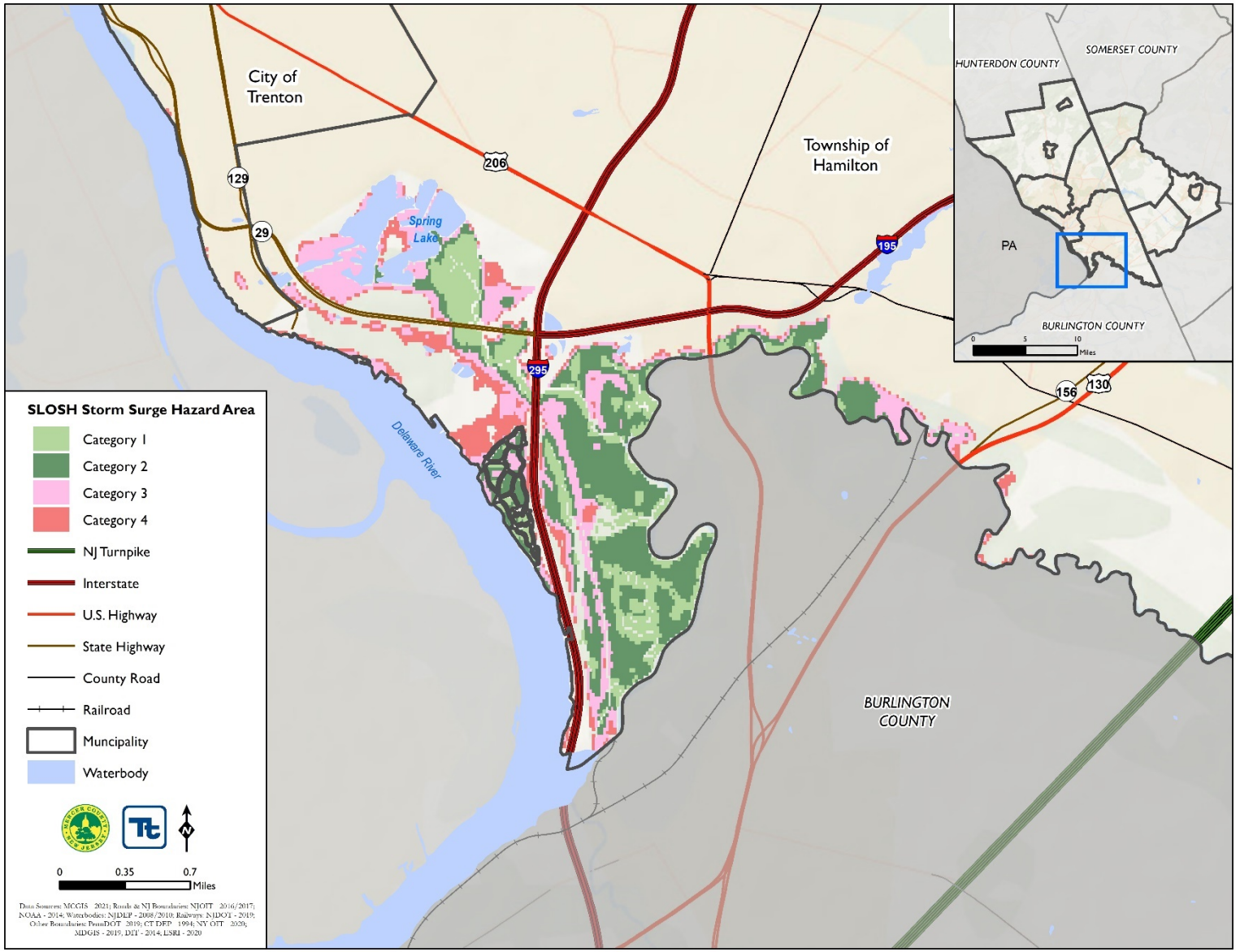
Typically, storm surge is estimated by subtracting the regular/astrological tide level from the observed storm tide. Typical storm surge heights range from several feet to more than 25 feet. The exact height of the storm surge and which coastal areas will be flooded depends on many factors, including strength, intensity, and speed of the hurricane or storm; the direction the storm is moving relative to the shoreline; how rapidly the sea floor is sloping along the shore; the shape of the shoreline; and the astronomical tide. Storm surge is the most damaging when it occurs along a shallow sloped shoreline, during high tide, in a highly populated and developed area with little or no natural buffers (for example, barrier islands, coral reefs, and coastal vegetation).

The most common reference to a return period for storm surges has been the elevation of the coastal flood having a one-percent chance of being equaled or exceeded in any given year, also known as the 100-year flood. Detailed hydraulic analyses include establishing the relationship of tide levels with wave heights and wave run-up. The storm surge inundation limits for the one-percent annual chance coastal flood event are a function of the combined influence of the water surface elevation rise and accompanying wave heights and wave run-up along the coastline.

The U.S. Army Corps of Engineers (USACE), in cooperation with FEMA, initially prepared Sea, Lake and Overland Surge from Hurricanes (SLOSH) inundation maps. SLOSH maps represent potential flooding from worst-case combinations of hurricane direction, forward speed, landfall point, and high astronomical tide. It does not include riverine flooding caused by hurricane surge or inland freshwater flooding. The mapping was developed for the coastal communities in New Jersey using the computer model to forecast surges that occur from wind and pressure forces of hurricanes coastline topography. In New Jersey, hurricane category is the predominant factor in worst-case hurricane surges. The resulting inundation areas are grouped into Category 1 and 2 (dangerous), Category 3 (devastating), and Category 4 (catastrophic) classifications. The hurricane category refers to the Saffir-Simpson Hurricane Intensity Scale.

FEMA Region IV Risk Analysis Team developed storm surge inundation grids for the State in a spatial format from the maximum of maximums outputs from the SLOSH model. These represent the worst-case storm surge scenarios for hurricane categories 1 through 4. The SLOSH boundaries do not account for any inland flash flooding.

Figure 4.3.8-5. NOAA National Hurricane Center SLOSH Model (Categories 1 through 4)



Previous Occurrences and Losses

FEMA Major Disasters and Emergency Declarations

Between 1954 and 2021, Mercer County was included in six declarations for hurricane and tropical storm-related events. Table 4.3.8-1 lists these events.

Table 4.3.8-1. Hurricane-Related Disaster (DR) and Emergency (EM) Declarations 1954-2021

Declaration	Event Date	Declaration Date	Event Description
EM-3148	September 16-18, 1999	September 17, 1999	Hurricane Floyd Emergency Declarations
DR-1295	September 16-18, 1999	September 17, 1999	Hurricane Floyd Major Disaster Declarations
EM-3332	August 26 – September 5, 2011	August 27, 2011	Hurricane Irene
DR-4021	August 26 – September 5, 2011	August 31, 2011	Hurricane Irene
EM-3354	October 26 – November 8, 2012	October 28, 2012	Hurricane Sandy
DR-4086	October 26 – November 8, 2012	October 30, 2012	Hurricane Sandy

Source: FEMA 2021

USDA Declarations

The Secretary of Agriculture from the USDA is authorized to designate counties as disaster areas to make emergency loans to producers suffering losses in those counties and in counties that are contiguous to a designated county. Between 2015 and 2021, Mercer County was not included in any USDA agricultural disasters relating to hurricanes or tropical storms (USDA 2021).

Hurricane and Tropical Storm Events

Hurricane and tropical storm events that have impacted Mercer County between 2015 and 2021 are identified in Table 4.3.8-2. Please see Section 9 (Jurisdictional Annexes) for detailed information regarding impacts and losses to each municipality and Appendix E (Risk Assessment Supplement) for events prior to 2015 as summarized in the 2016 HMP.

Table 4.3.8-2. Hurricane and Tropical Storm Events in Mercer County, 2015 to 2021

Date(s) of Event	Event Type	FEMA Declaration Number (if applicable)	Mercer County Designated?	Location	Description
July 10, 2020	Tropical Storm	N/A	TBD, pending	Mercer County	Tropical Storm Fay moved northward along the coasts of Delaware and New Jersey on the afternoon and evening of July 10. The storm produced rainfall totals up to 3 to 6 inches in New Jersey, with the highest totals occurring in the southern part of the state. Some areas also experienced a period of tropical storm force winds, especially near the coast. Overall impacts from wind were limited.
August 4, 2020	Tropical Storm	N/A	N/A	Mercer County	Tropical Storm Isaias brought high winds, heavy rain, several tornadoes, and coastal flooding to the mid-Atlantic region, becoming the most impactful tropical cyclone to impact most of the region since Sandy in 2012. Multiple observations of sustained 40 to 50 mph winds with higher gusts were made, including at Trenton Mercer Airport (KTTN). Numerous reports of downed trees and power lines were received.

Source: FEMA 2021; NOAA-NCEI 2021; NWS 2021; SPC 2021; NJOEM 2019
Note: Not all events that have occurred in Mercer County are included due to the extent of documentation and the fact that not all sources have been identified or researched.
K: Thousand
DR Disaster Declaration (FEMA)
FEMA Federal Emergency Management Agency
Mph miles per hour
N/A Not Applicable

Probability of Future Occurrences

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 5 times. The return period of hurricanes for Mercer 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) (NOAA 2013).

In order to determine the recurrence interval and the average annual number of events, data from 1856 to 2021 was looked at using NOAA's Historical Hurricane Tracks tool. A 65 nautical mile radius was used to identify any hurricane and tropical storm events that were likely to have impacted Mercer County. Based on this data, 39 hurricanes, tropical storms, tropical depressions or extra-tropical storms passed within 100 nautical miles of Mercer County. The table below shows these statistics, as well as the annual average number of events and the estimated percent change of an event occurring in a given year (NHC 2021).

Table 4.3.8-3. Probability of Future Hurricane and Tropical Storm Events

Hazard Type	Number of Occurrences Between 1856 and 2021	Rate of Occurrence or Annual Number of Events (average)	Recurrence Interval (in years) (# Years/Number of Events)	Probability of Event in any given year	Percent chance of occurrence in any given year
Tropical Depression	4	0.02	41.50	0.02	2.4
Tropical Storm	27	0.16	6.15	0.16	16.3
Hurricanes (all categories)	10	0.06	16.60	0.06	6.0
Total	39	0.24	4.26	0.23	23.5

Source: *NHC 2021a*
Note: *The total number of events is not the sum of all categories as some storms transitioned between categories within the planning area.*

Prior to the 2021 hurricane season, NOAA updated updating the set of statistics used to determine when hurricane seasons are above-, near-, or below-average relative to the climate record. This update process occurs once every decade. The average number of hurricanes now uses 1991-2020 as the 30-year period of record. The updated averages for the Atlantic hurricane season have increased with 14 named storms and 7 hurricanes. The previous Atlantic storm averages, based on the period from 1981 to 2010, were 12 named storms, 6 hurricanes, and 3 major hurricanes (NOAA 2021b). The average for major hurricanes (Category 3, 4 or 5) remains unchanged at 3. This data indicates an increase in hurricane activity from the previous 30-year period.

It is estimated that Mercer County will continue to experience direct and indirect impacts of hurricane and tropical storms annually that may induce secondary hazards such as flooding, extreme wind, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents, and inconveniences.

In Section 4.4, the identified hazards of concern for Mercer 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 hurricane and tropical storms in the County is considered 'frequent'. The ranking of the hurricane and tropical storm hazard for individual municipalities is presented in the jurisdictional annexes.

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 (Office of the New Jersey State Climatologist 2020), which is faster than the rest of the Northeast region (2° F [1.1° C]) (Melillo et al. 2014) and the world (1.5° F [0.8° C]) (IPCC 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 et al. 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 et al. 2017). New Jersey can also expect that by the middle of the 21st century, 70% of summers will be hotter than the warmest summer experienced to date (Runkle et al. 2017).

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 (Office of the New Jersey State Climatologist 2020). 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% increase. By 2050, annual precipitation in New Jersey could increase by 4% to 11% (Horton et al. 2015). By the end of this century, heavy precipitation events are projected to occur two to five times more often (Walsh et al. 2014) and with more intensity (Huang et al. 2017) than in the last century. New Jersey will experience more intense rain events, less snow, and more rainfalls (Fan et al. 2014, Demaria et al. 2016, Runkle et al. 2017). 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 et al. 2020).

A warmer atmosphere means storms have the potential to be more intense (Guilbert et al. 2015) and occur more often (Coumou and Rahmstorf 2012, Marquardt Collow et al. 2016, Broccoli et al. 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% (Walsh et al. 2014) which is a faster rate than anywhere else in the United States (Huang et al. 2017).

Climate change may result in changes to the frequency of coastal storms. A warmer atmosphere means storms have the potential to be more intense (Guilbert et al. 2015) and occur more often (Coumou and Rahmstorf 2012, Marquardt Collow et al. 2016, Broccoli et al. 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% (Walsh et al. 2014) which is a faster rate than anywhere else in the United States (Huang et al. 2017). As temperatures increase so will the energy in a storm system, increasing the potential for more intense tropical storms (Huang et al. 2017), especially those of Category 4 and 5 (Melillo et al. 2014).

As oceans warm, the length of hurricane season may expand. The past six hurricane seasons have featured a tropical system occurring before the official start of the season. In 2016, a very rare winter hurricane named Alex developed in the middle of January (BBC 2019). According to NOAA's database, 39 storms formed in the

Atlantic Basin before June 1 from 1851 through 2020, a long-term average of one such early storm every four to five years. The 2010s had the most such storms, and there has been a steady increase since the 1990s. However, the 1950s had six such storms, the 1930s had four and there was another four preseason storm streak from 1887 through 1890. It is possible there were other such storms in the era before satellites – before the mid-1960s – that were missed by ship observations or reports from areas impacted. It remains to be seen if expansion of the traditional hurricane season is a long-term trend or a common occurrence (Weather.com 2020). The National Hurricane Center is currently considering expanding the official hurricane season to begin in May, rather than June, as a result of the frequency of pre-season events (Highlands News-Sun 2021).

Temperatures are predicted to increase in Mercer County and ocean temperatures are forecast to continue to increase, which may lead to an increase in intensity and frequency of hurricanes. It remains to be seen if other factors such as steering currents, atmospheric sheer, and the presence of Saharan dust will be impacted in ways which increase or decrease the risk of hurricanes in Mercer County.

4.3.9 VULNERABILITY ASSESSMENT

All assets in Mercer County are at risk to hurricane and tropical storm events. Potential losses associated with high-wind events were calculated for two probabilistic hurricane events: the 100-year and 500-year MRPs. The estimated impacts on population, existing structures, critical facilities and the economy are presented below.

Impact on Life, Health and Safety

The impact of a hurricane wind event on life, health, and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time was provided to residents. The entire population of Mercer County (367,922 people) is exposed to hurricanes and tropical storm events and associated wind and rain (ACS 5-year Population Estimates 2019).

To estimate the number of persons at risk to flooding caused by storm surge, NOAA's SLOSH Category 1 through Category 4 storm surge data was referenced. Hamilton Township has population residing Categories 2, 3, and 4 storm surge hazard areas.

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. 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 might lack funds to evacuate. The population over the age of 65 is also more vulnerable and might physically have more difficulty evacuating. The elderly is considered most vulnerable because they require extra time or outside assistance during evacuations and are more likely to seek or need medical attention that might not be available due to isolation during a storm event. The 2019 ACS population estimates indicate there were 54,941 persons over 65 years old and 40,980 living below the poverty level in Mercer County. Refer to Section 3 (County Profile) for a more detailed summary of these population statistics.

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. Hazus estimates 43 households will be displaced and temporary shelter will be required by 26 persons as a result of the 100 or 500-year MRP event.

Impact on General Building Stock

Damage to buildings is dependent upon several factors, including wind speed, storm duration, and path of the storm track. Building construction plays a major role in the extent of damage resulting from a severe storm event. Due to differences in construction, residential structures are generally more susceptible to wind damage

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

To better understand these risks, Hazus was used to estimate the expected wind-related building damages. Specific types of wind damages are summarized in Hazus at the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Table 4.3.8-4 summarizes the definition of the damage categories. Table 4.3.8-5 summarizes the number and type of buildings and their estimated severity of expected damage.

Table .4.3.8-4 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 cover, 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 4.3.8-5. Expected Damages from 100 and 500-Year MRP Hurricane Wind Events

Occupancy Class	Total Number of Buildings in Occupancy	Severity of Expected Damage	100-Year Mean Return Period Hurricane		500-Year Mean Return Period Hurricane	
			Building Count	Percent of Buildings in Occupancy Class	Building Count	Percent of Buildings in Occupancy Class
Residential Exposure (Single and	89,786	None	89,439	99.6%	83,421	92.9%
		Minor	342	0.4%	5,993	6.7%
		Moderate	5	0.0%	360	0.4%
		Severe	0	0.0%	3	0.0%

Occupancy Class	Total Number of Buildings in Occupancy	Severity of Expected Damage	100-Year Mean Return Period Hurricane		500-Year Mean Return Period Hurricane	
			Building Count	Percent of Buildings in Occupancy Class	Building Count	Percent of Buildings in Occupancy Class
Multi-Family Dwellings)		Complete Destruction	0	0.0%	8	0.0%
Commercial Buildings	7,298	None	7,272	99.6%	6,975	95.6%
		Minor	25	0.3%	302	4.1%
		Moderate	0	0.0%	19	<0.1%
		Severe	0	0.0%	2	0.0%
		Complete Destruction	0	0.0%	0	0.0%
Industrial Buildings	707	None	701	99.2%	673	95.2%
		Minor	6	0.8%	31	4.4%
		Moderate	0	0.0%	3	0.4%
		Severe	0	0.0%	0	0.0%
		Complete Destruction	0	0.0%	0	0.0%
Government, Religion, Agricultural, and Education Buildings	5,788	None	5,768	99.7%	5,570	96.2%
		Minor	20	0.3%	209	3.6%
		Moderate	0	0.0%	9	<0.1%
		Severe	0	0.0%	0	0.0%
		Complete Destruction	0	0.0%	0	0.0%

Source: Hazus v4.2

Table 4.3.8-6 and Table 4.3.8-7 summarize the replacement cost value damage estimated for the 100- and 500-year MRP wind-only events. The data shown indicates total losses associated with wind damage to building structure and content.

The total damage to buildings for all occupancy types across Mercer County is estimated to be approximately $62.0 and $310 million for the 100- and 500-year MRP wind-only events, respectively. Most of these losses are to the residential building category. Due to 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 destruction. Total dollar damage reflects the overall impact to buildings at an aggregate level. The Township of Hamilton would experience the greatest damage, losing approximately $13 million in a 100-year MRP event and $83 million in a 500-year MRP event.

Table 4.3.8-6. Estimated Building Damages by the 100 and 500-Year MRP Hurricane-Related Winds

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Total Damages		Percent of Total Building and Contents Replacement Cost Value	
		100-Year	500-Year	100-Year	500-Year
East Windsor (Twp)	$4,536,454,703	$2,651,426	$35,857,594	0.1%	0.8%
Ewing (Twp)	$10,203,494,268	$7,106,102	$19,414,506	0.1%	0.2%
Hamilton (Twp)	$17,546,798,111	$13,244,220	$82,947,750	0.1%	0.5%
Hightstown (B)	$1,018,152,318	$388,935	$5,563,871	0.0%	0.5%

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Total Damages		Percent of Total Building and Contents Replacement Cost Value	
		100-Year	500-Year	100-Year	500-Year
Hopewell (B)	$487,586,569	$529,837	$924,677	0.1%	0.2%
Hopewell (Twp)	$7,010,959,532	$8,495,146	$15,248,947	0.1%	0.2%
Lawrence (Twp)	$7,978,669,288	$6,559,254	$23,422,347	0.1%	0.3%
Pennington (B)	$600,460,682	$800,071	$1,544,015	0.1%	0.3%
Princeton	$7,326,718,155	$4,922,108	$20,987,462	0.1%	0.3%
Robbinsville (Twp)	$3,676,588,802	$1,774,116	$19,886,336	0.0%	0.5%
Trenton (C)	$19,841,364,451	$10,143,074	$44,080,820	0.1%	0.2%
West Windsor (Twp)	$7,829,923,922	$5,578,203	$40,036,600	0.1%	0.5%
Mercer County (Total)	**$88,057,170,800**	**$62,192,492**	**$309,914,925**	**0.1%**	**0.4%**

Source: Hazus 4.2; Mercer County GIS 2020; RS Means 2020
Notes: B – Borough; C – City: Twp. – Township; % - Percent
**The Total Damages column represents the sum of damages for all occupancy classes (residential, commercial, industrial, agricultural, educational, religious, and government) based on replacement cost value.*

Table 4.3.8-7. Estimated Residential and Commercial Building Damage by the 100-Year and 500-Year MRP Hurricane-Related Winds

Jurisdiction	Building Replacement Cost Value	Residential		Commercial	
		Estimated Building Losses Caused by the 100-Year Mean Return Period Winds	Estimated Building Losses Caused by the 500-Year Mean Return Period Winds	Estimated Building Losses Caused by the 100-Year Mean Return Period Winds	Estimated Building Losses Caused by the 500-Year Mean Return Period Winds
East Windsor (Twp)	$4,536,454,703	$2,528,092	$31,825,704	$77,113	$2,677,771
Ewing (Twp)	$10,203,494,268	$6,269,675	$16,377,207	$513,017	$2,295,631
Hamilton (Twp)	$17,546,798,111	$12,370,125	$70,932,398	$487,065	$9,049,349
Hightstown (B)	$1,018,152,318	$325,740	$3,847,302	$28,441	$1,059,484
Hopewell (B)	$487,586,569	$486,657	$859,394	$21,175	$39,343
Hopewell (Twp)	$7,010,959,532	$8,268,725	$14,681,519	$127,741	$338,030
Lawrence (Twp)	$7,978,669,288	$6,003,870	$20,067,301	$358,055	$2,529,768
Pennington (B)	$600,460,682	$762,893	$1,458,556	$21,496	$51,713
Princeton	$7,326,718,155	$4,745,358	$18,994,569	$56,100	$1,295,791
Robbinsville (Twp)	$3,676,588,802	$1,596,648	$14,753,724	$45,980	$1,636,737
Trenton (C)	$19,841,364,451	$7,727,727	$29,024,320	$1,817,868	$12,899,940
West Windsor (Twp)	$7,829,923,922	$5,496,680	$36,447,615	$32,750	$2,891,594
Mercer County (Total)	**$88,057,170,800**	**$56,582,190**	**$259,269,609**	**$3,586,802**	**$36,765,151**

Source: Hazus 4.2; Mercer County GIS 2020; RS Means 2021
Notes: B – Borough; C – City; Twp. – Township; % - Percent

In addition to evaluating potential building wind impacts, the SLOSH model was also used to determine the number of buildings located in storm surge inundation areas. In summary, Hamilton Township has one structure located in the Category 2 storm surge inundation area; six buildings in Category 3; and 25 buildings in Category 4. The City of Trenton has one building located in the Category 4 storm surge inundation area as well.

Impact on Critical Facilities and Lifelines

Critical facilities may experience structural damage directly from high winds or falling tree limbs/flying debris, which can also result in the loss of power. Power loss can greatly impact households, business operations, public utilities, and emergency personnel. The elderly population may be more vulnerable if power loss results in interruption of heating and cooling services, stagnated hospital operations, and potable water supplies. Emergency personnel such as police, fire, and EMS may not be able to effectively respond and maintain the safety of its residents.

Hazus 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) could sustain damage as a result of 100-year and 500-year MRP wind events. Additionally, Hazus 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.

No critical facilities would experience damage as the result of the 100-year MRP event. Table 4.3.8-8 summarizes the percent probability that each facility type may experience damage as a result of the 500-year MRP event and also shows no expected impact from such an event.

Table 4.3.8-8. Estimated Impacts to Critical Facilities for the 500-Year Mean Return Period Hurricane-Related Winds

	500-Year Mean Return Period Hurricane				
		Percent-Probability of Sustaining Damage			
Facility Type	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	2.4%	<0.1%	0.0%	0.0%
Medical	0	0.6% - 7.3%	<0.1% - 2.6%	0.0%	0.0%
Police	0	1.3% - 8.2%	<0.1% - 1.4%	<0.1% - 0.2%	0.0%
Fire	0	0.6% - 4.8%	<0.1% - 1.0%	<0.1% - 0.2%	0.0%
Schools	0	1.0% - 8.6%	<0.1% - 5.8%	<0.1%	0.0%

Source: Hazus-MH v4.2; Mercer County GIS 2020

In terms of critical facilities exposed to storm surge, Hamilton Township has three critical assets located in the Category 4 storm surge inundation area (hazardous materials facility; oil facility; and potable water well).

Impact on Economy

Damage to structures from flooding and wind occur immediately; however, this damage can have 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.

Hazus 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. Refer to Table 4.3.8-9 for a summary of Hazus estimated economic losses for Mercer County caused by the 100-year and the 500-year MRP hurricane wind events.

Table 4.3.8-9. Estimated Economic Losses for the 100-Year and 500-Year Mean Return Period Hurricane Wind Events

Mean Return Period (MRP)	Inventory Loss	Relocation Loss	Building and Content Losses	Wages Losses	Rental Losses	Income Losses
100-Year MRP	$0	$25,230	$71,713,720	$0	$10,170	$0
500-Year MRP	$80,560	$11,751,010	$358,101,100	$3,548,200	$5,233,130	$5,689,090

Source: Hazus v4.2; Mercer County GIS 2020; RS Means 2021

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 heating or cooling provisions to the population.

Debris management can be costly. Hazus estimates the amount of debris that might be produced as result of the 100- and 500-year MRP wind events. Table 4.3.8-10 summarizes the estimated debris by municipality, which should be considered a lower-bound analysis. Because the estimated debris production does not include debris generated by flooding, this is likely a conservative estimate and could be higher if multiple impacts occur.

Table 4.3.8-10. Debris Production for 100- and 500-Year Mean Return Period Hurricane-Related Winds

Jurisdiction	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
East Windsor (Twp)	186	3,759	0	0	1,000	7,645	3,472	26,140
Ewing (Twp)	585	1,945	0	0	1,271	3,026	6,473	16,466
Hamilton (Twp)	842	8,472	0	0	3,087	15,501	14,893	71,809
Hightstown (B)	34	651	0	0	87	619	679	4,768
Hopewell (B)	36	70	0	0	81	130	566	939
Hopewell (Twp)	446	966	0	0	2,665	5,160	3,553	7,495
Lawrence (Twp)	442	2,179	0	0	2,115	5,877	7,851	22,313
Pennington (B)	45	103	0	0	93	187	726	1,452
Princeton	195	1,618	0	0	609	4,042	2,545	16,085
Robbinsville (Twp)	132	2,322	0	0	1,311	9,806	2,668	19,020
Trenton (C)	1,255	6,207	0	0	530	1,556	3,900	11,404
West Windsor (Twp)	212	3,266	0	0	1,680	9,175	5,283	29,073

Source: Hazus 4.2; Mercer County GIS 2020
Notes: B – Borough; C - City; Twp. – Township; % - Percent

Impact on the Environment

The impacts of hurricane related windstorms on the environment typically take place over a large area. Where these events occur, widespread, severe damage to plant species is likely. This includes uprooting or destruction

of trees and an increased threat of wildfire in areas where dead trees are not removed. Section 4.3.5 (Flood) provides additional environmental impacts due to flooding from heavy rainfalls.

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. The 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 and Changes in Population

Understanding future changes that impact vulnerability in the Mercer County can assist in planning for future development and ensuring that appropriate mitigation, planning, and preparedness measures are in place. It is anticipated that any new development and new residents will be exposed to the hurricane and tropical storm hazard. However, due to increased standards and codes, new development might be less vulnerable to wind-related hazards compared to the aging building stock. The tables and hazard maps included in the jurisdictional annexes contain additional information regarding the specific areas of development that would increase County vulnerability to a wind event.

Effect of Climate Change on Vulnerability

As discussed above, most studies project that the State of New Jersey will see an increase in average annual temperatures and precipitation. An increase in temperatures may also lead to an increase in the frequency and intensity of coastal storms. More frequent and severe storms will increase the County's vulnerability to both wind-related and storm surge impacts.

The northeast region of the United States has experienced a greater increase in extreme precipitation than any other region in the U.S. between 1958 and 2010, the Northeast experienced more than 70% increase in the amount of precipitation falling in rain events (Global Change 2014). Refer to Section 4.3.5 (Flood) for a discussion related to the impact of climate change due to increases in rainfall. With an increased likelihood of more frequent storm events and associated strong winds and tornado events, the County's asset continue to be at risk.

Change of Vulnerability Since the 2016 HMP

Mercer County remains vulnerable to hurricanes and tropical storms. The 2021 HMP update utilized more current datasets to evaluate each municipality's vulnerability to this hazard. The Hazus wind analysis was performed in Hazus v4.2 and was based on the most current and best available hurricane model and inventory data (building and critical facility inventories).