5.4.1 Coastal Hazards

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 coastal hazards in Dutchess County.

5.4.1.1 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 2013). 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 (NOAA 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).

For the purpose of this HMP and as deemed appropriated by the Dutchess County Steering and Planning Committees, coastal hazards in the County include hurricanes/tropical storms, storm surge, coastal erosion, and Nor'Easters, which are defined below.

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. 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).

Storm Surge

Storm surges inundate coastal floodplains by 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 may inundate only a small area (along sections of the northeast or southeast coasts) or storm surge may inundate coastal lands for a mile or more inland from the shoreline.

Coastal Erosion

Erosion and flooding are the primary coastal hazards that lead to the loss of lives or damage to property and infrastructure in developed coastal areas. Coastal storms are an intricate combination of events that impact a coastal area. A coastal storm can occur any time of the year and at varying levels of severity. One of the greatest threats from a coastal storm is coastal flooding caused by storm surge. Coastal flooding is the inundation of land areas along the oceanic coast and estuarine shoreline by seawaters over and above normal tidal action.

Many natural factors affect erosion of the shoreline, including shore and nearshore morphology, shoreline orientation, and the response of these factors to storm frequency and sea level rise. Coastal shorelines change constantly in response to wind, waves, tides, sea-level fluctuation, seasonal and climatic variations, human alteration, and other factors that influence the movement of sand and material within a shoreline system.

Unsafe tidal conditions, as a result of high winds, heavy surf, erosion, and fog are ordinary coastal hazard phenomena. Some or all of these processes can occur during a coastal storm, resulting in an often detrimental impact on the surrounding coastline. Factors including: (1) storms such as Nor'Easters and hurricanes, (2) decreased sediment supplies, and (3) sea-level rise contribute to these coastal hazards.

Coastal erosion can result in significant economic loss through the destruction of buildings, roads, infrastructure, natural resources, and wildlife habitats. Damage often results from an episodic event with the combination of severe storm waves and dune or bluff erosion.

Nor'Easters

A Nor'Easter is a cyclonic storm that moves along the East Coast of North America. It is called a Nor'Easter because the damaging winds over coastal areas blow from a northeasterly direction. Nor'Easters can occur any time of the year, but are most frequent and strongest between September and April. These storms usually develop between Georgia and New Jersey within 100 miles of the coastline and typically move from southwest to northeast along the Atlantic Coast of the United States (NOAA 2013b).

In order to be called a Nor'Easter, a storm must have the following conditions, as per the Northeast Regional Climate Center (NRCC):

- Must persist for at least a 12-hour period
- Have a closed circulation
- Be located within the quadrilateral bounded at 45°N by 65° and 70°W and at 30°N by 85°W and 75°W
- Show general movement from the south-southwest to the north-northeast
- Contain wind speeds greater than 23 miles per hour (mph)

A Nor'Easter event can cause storm surges, waves, heavy rain, heavy snow, wind, and coastal flooding. Nor'Easters have diameters that can span 1,200 miles, impacting large areas of coastline. The forward speed of a Nor'Easter is usually much slower than a hurricane, so with the slower speed, a Nor'Easter can linger for days and cause tremendous damage to those areas impacted. Approximately 20 to 40 Nor'Easters occur in the northeastern United States every year, with at least two considered severe (Storm Solution, 2014). The intensity of a Nor'Easter can rival that of a tropical cyclone in that, on occasion, it may flow or stall off the mid-Atlantic coast resulting in prolonged episodes of precipitation, coastal flooding, and high winds.

Location

The entire planning area of Dutchess County is vulnerable hurricanes/tropical storms and Nor'Easters; however, only some areas of the County are vulnerable to storm surge and coastal erosion. Impacts from coastal storms, such as hurricanes, tropical storms, and Nor'Easters, depends on the track of the storm.

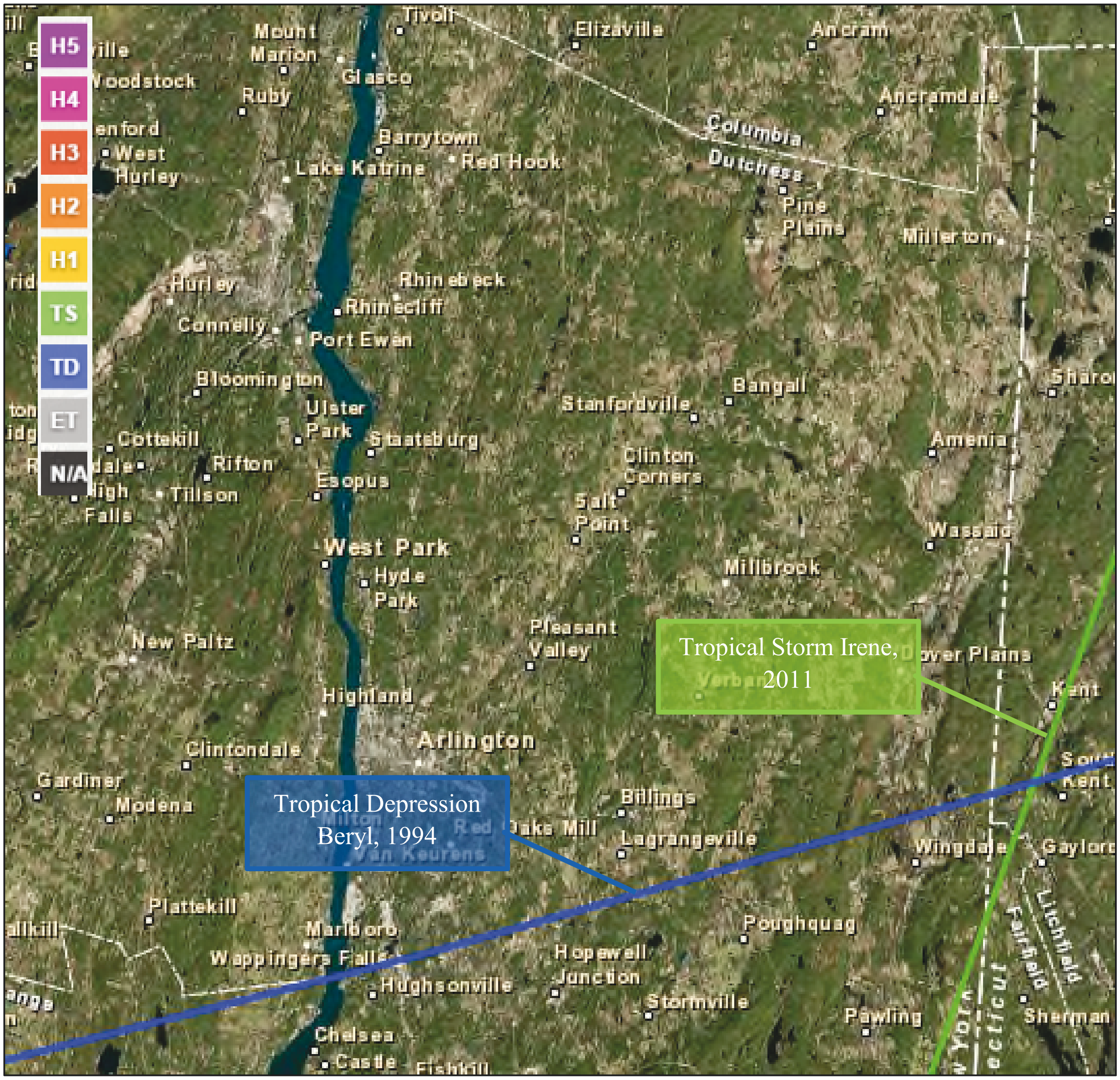
Hurricanes/Tropical Storms

Hurricanes and tropical storms can impact New York State from June to November, the official eastern U.S. hurricane season. However, late July to early October is the period hurricanes and tropical storms are most likely to impact New York State, due to the coolness of the North Atlantic Ocean waters (NYS DHSES, 2014).

The entire Dutchess County Planning Area is vulnerable to hurricanes and tropical storms. It all depends on the storm's track. Inland areas, like those within Dutchess 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 2013 (latest date available from data source). Between 1990 and 2013, three tropical cyclones tracked within 65 nautical miles of Dutchess County. Figure 5.4.1-1 displays tropical cyclone tracks for Dutchess County that tracked with 65 nautical miles between 1990 and 2013. 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.

Figure 5.4.1-1. Historical Tropical Storm and Hurricane Tracks 1990 to 2013



Source: NOAA NHC 2015

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: strength, intensity, and speed of the hurricane or storm; the direction it 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 1% 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 1% 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 New York State Office of Emergency Management (NYS DHSES) utilizes a computer-based model that hypothetically generates the effects of storm surge, as well as assists with planning efforts for coastal storms known as SLOSH (Sea, Lake, and Overland Surges from Hurricanes). This model computes storm surges based on storm movement in different directions and strengths. SLOSH models analyze storms moving northeast, northwest, and changing in strength from Category 1 to Category 4 (NYS DHSES 2014). Even though Dutchess County has been impacted by storm surge, the County is not located within hurricane storm surge zones.

Coastal Erosion

Coastal erosion impacts areas located along the coast in bays, estuaries, and shallow waters. In New York State, certain sections of the State's coastlines are more vulnerable to coastal erosion through natural actions and through human activities. Coastal areas in New York State include: Lake Erie and the Niagara River, Lake Ontario and the St. Lawrence River, the Atlantic Ocean and Long Island Sound, the Hudson River south of the federal dam in Troy, the East River, the Harlem River, the Kill van Kull and Arthur Kill, and all connecting water bodies, bays, harbors, shallows and wetlands. According to the NYSDEC, the coastlines along Lake Erie and Lake Ontario, Long Island Sound, and the Atlantic Ocean coastline of NYC and Long Island are at risk to coastal erosion from natural and human activities and are regulated.

Nor'Easters

Nor'Easters threaten the entire east coast of the United States, where the coastal ears are the most susceptible because these areas are directly exposed; however, the impacts of these storms are often felt far inland as well. According to the New York State Hazard Mitigation Plan, the coastal region of New York State, which includes parts of Dutchess County, is extremely vulnerable to Nor'Easters.

Extent

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 5.4.1-1 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

Table 5.4.1-1. 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.

Table 5.4.1-1. The Saffir-Simpson Scale

Category	Wind Speed (mph)	Expected Damage
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.

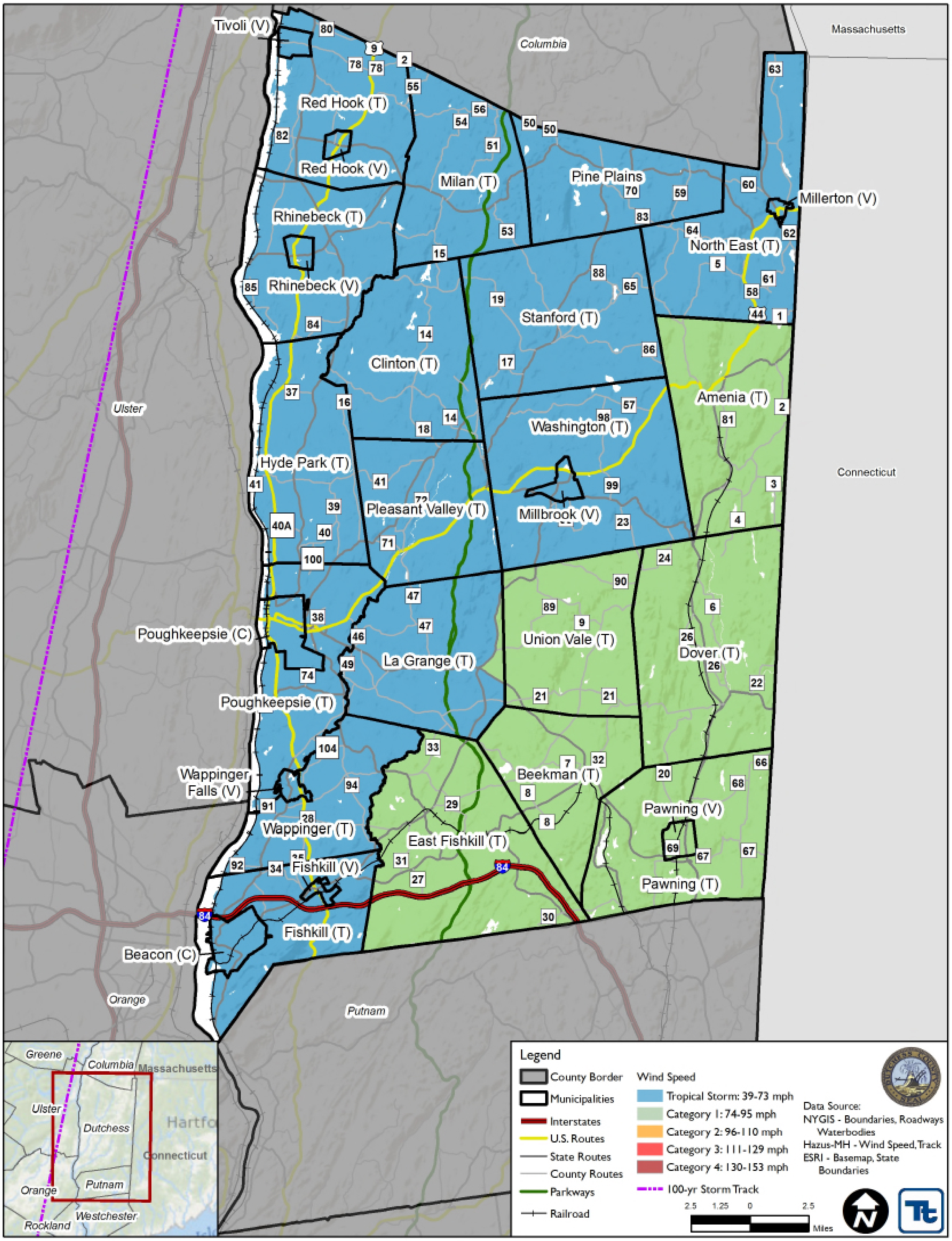
Source: NOAA 2013b
Notes: mph = Miles per hour
> = Greater than

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).

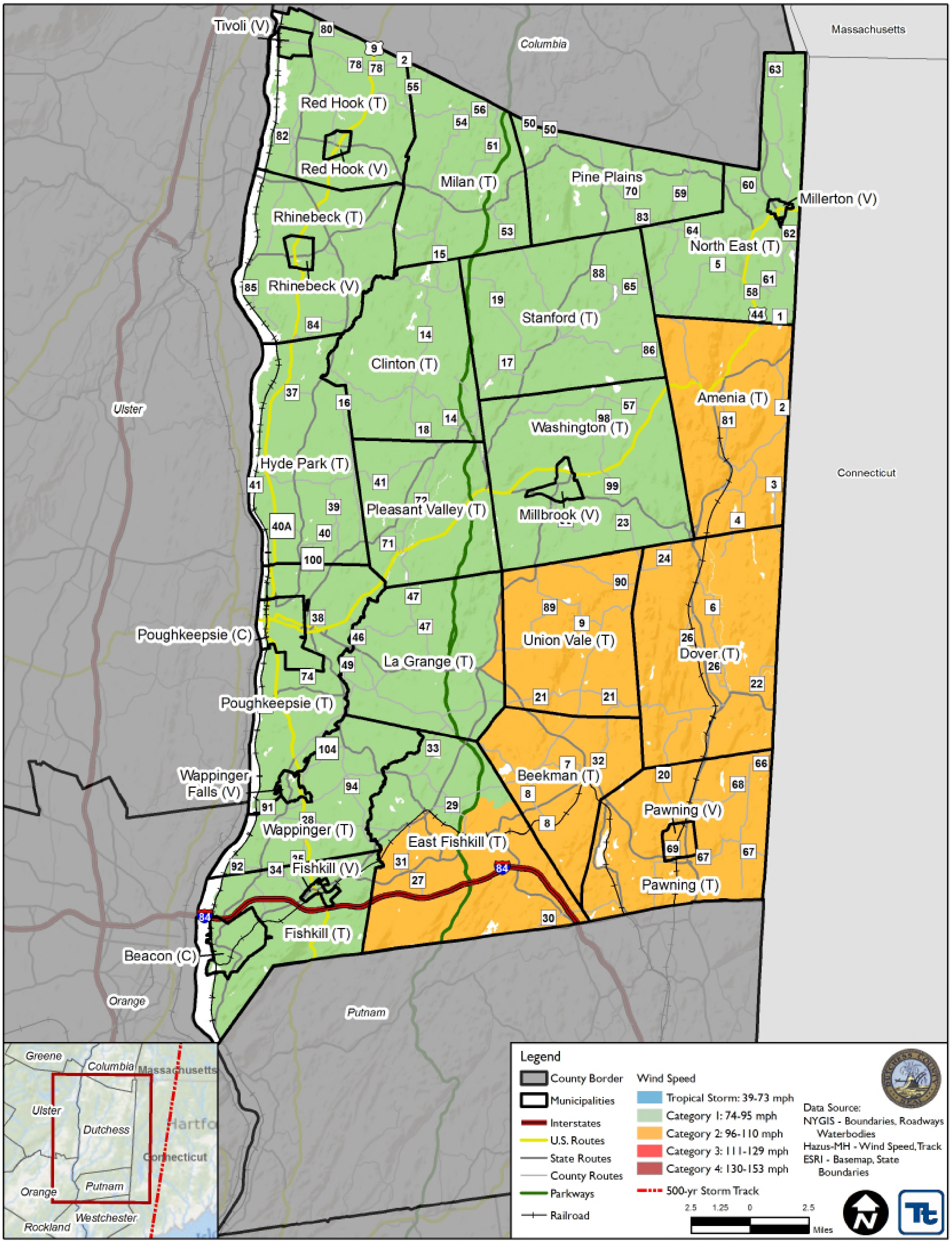
Figure 5.4.1-2 and Figure 5.4.1-3 show the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100- and 500-year MRP events. These peak wind speed projections were generated using Hazards U.S. Multi-Hazard (HAZUS-MH) model runs. The estimated hurricane track used for the 100- and 500-year event is also shown. The maximum 3-second gust wind speeds for Dutchess County range from 69 to 75 mph for the 100-year MRP event. The maximum 3-second gust wind speeds for Dutchess County range from 85 to 101 mph 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 5.4.1-2. Wind Speeds for the 100-Year Mean Return Period Event



Source: *HAZUS-MH*

Figure 5.4.1-3. Wind Speeds for the 500-Year Mean Return Period Event



Source: HAZUS-MH

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: strength, intensity, and speed of the hurricane or storm; the direction it 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, and in a highly populated and developed area with little or no natural buffers (for example, barrier islands, coral reefs, and coastal vegetation). For details regarding storm surge, see previous section.

Coastal Erosion

Coastal erosion is measured as the rate of change in the position or horizontal displacement of a shoreline over a period of time (FEMA 1996). A number of factors determine whether a community exhibits greater long-term erosion or accretion:

- Exposure to high-energy storm waves
- Sediment size and composition of eroding coastal landforms feeding adjacent beaches
- Near-shore bathymetric variations which direct wave approach
- Alongshore variations in wave energy and sediment transport rates
- Relative sea level rise
- Frequency and severity of storm events
- Human interference with sediment supply (e.g., revetments, seawalls, jetties) (Woods Hole Sea Grant 2003)

Such erosion may be intensified by activities such as boat wakes, shoreline hardening, or dredging. Natural recovery after erosive episodes can take months or years. If a dune or beach does not recover quickly enough via natural processes, coastal and upland property may be exposed to further damage in subsequent events. Coastal erosion can cause the destruction of buildings and infrastructure (FEMA 1996).

Nor'Easter

The extent of a Nor'Easter can be classified by meteorological measurements and by evaluating its societal impacts. NOAA's NCDC is currently producing the Regional Snowfall Index (RSI) for significant snowstorms that impact the eastern two-thirds of the U.S. The RSI ranks snowstorm impacts on a scale from 1 to 5. It is based on the spatial extent of the storm, the amount of snowfall, and the interaction of the extent and snowfall totals with population (based on the 2000 U.S. Census). The NCDC has analyzed and assigned RSI values to over 500 storms since 1900 (NOAA-NCDC 2011). Table 5.4.1-3 lists the five categories.

Table 5.4.1-2. RSI Ranking Categories

Category	Description	RSI Value
1	Notable	1-3
2	Significant	3-6
3	Major	6-10
4	Crippling	10-18
5	Extreme	18+

Source: NOAA-NCDC 2011

RSI *Regional Snowfall Index*

Nor'Easters have the potential to impact society to a greater extent than hurricanes and tornadoes. These storms often have a diameter three to four times larger than a hurricane and therefore, impact much larger areas. More homes and properties become susceptible to damage as the size and strength of a Nor'Easter intensifies (Storm Solution 2013). The severity of a Nor'Easter depends on several factors including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, time of occurrence during the day (e.g., weekday versus weekend), and season.

Coastal Storm Frequency Caveats

Similar to flood and hurricanes, storms are often categorized by return frequencies (e.g., this was a 100-year storm). However, there are several shortcomings related to trying to categorize storms by return frequencies. First, the historical record of storms is relatively short to accurately assess the true long-term frequency of long period events. Most records only go back about 100 years. It is a little like sampling 20 ocean waves and making a conclusion of the full range of wave amplitudes in that part of the ocean. Second, when it comes to coastal flood impacts, it is not a level playing field. Sea-level rise changes the vulnerability such that storms previously calculated at an average 100-year frequency will occur considerably more often. Determining how well that can be quantified is dependent on the accuracy of sea-level rise predictions. Third, coastal flood impacts can vary significantly from one locality to another depending upon such factors as onshore wind component and incidence of wave activity to the coastline. Fourth, a storm may have been a 100-year storm for coastal flooding but a 10-year storm for wind, snowfall, or rainfall. Also, the impact of a storm can be compounded if it has multiple severe dimensions (e.g., major coastal flooding in addition to very heavy snow and extreme winds) or if it impacts such a large area that mutual aid cannot be exercised. Fifth, development along the coastline or in other vulnerable areas can significantly increase the impact of a storm. Thus, the same storm in 1950 might not have generated the same amount of damage as now with increased coastal development.

In addition, there is a great deal of misunderstanding surrounding the reference to a "100-year storm" or a return frequency of 100 years. Similar to the flood events, a 100-year storm event does not mean that one should expect such a storm (or a storm of greater intensity) once every 100 years. Instead, a 100-year storm, to use that frequency as an example, is best described as a 1% chance that a storm of that magnitude will occur in any given year. There might be two or three such storms in a 100-year period and then no more for the next 200 or 300 years.

Previous Occurrences and Losses

Many sources provided historical information regarding previous occurrences and losses associated with severe weather events throughout Dutchess 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 2015, New York State was included in 16 FEMA declared coastal hazard-related disasters (DR) or emergencies (EM) classified as one or a combination of the following hazards: hurricanes, floods, tropical storm, coastal storms, high tides, heavy rain, and tropical depression. Generally, these disasters cover a wide region of the State; therefore, they may have impacted many counties. Of those declarations, Dutchess County has been included in four declarations (FEMA 2014).

For this 2015 Plan Update, known coastal hazard events, including FEMA disaster declarations, which have impacted Dutchess County between 1990 and 2015 are identified in Table 5.4.1-3. 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 Dutchess 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.

Table 5.4.1-3. Coastal Hazard Events between 1990 and 2015

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
March 12-15, 1993	Blizzard / Nor'Easter	EM-3107	Yes	This event brought between three and six inches of snow to much of eastern New York State. There were numerous accidents reported across the area. Travel was extremely difficult in the State and a state of emergency was declared across most of eastern and central New York State. Dutchess County had approximately $50,000 in damages from this event.
January 7-9, 1996	Nor'Easter / Heavy Snow	DR-1083	Yes	Heavy snow fell across southeast New York State causing many power outages across the region and several roofs to collapse. Snowfall totals ranged from 15.5 inches in Ulster County to 36 inches in Dutchess County. Dutchess County had approximately $80,000 in property damage.
September 16-17, 1999	Remnants of Hurricane Floyd	DR-1296	Yes	The remnants of Hurricane Floyd moved up the east coast of the United States; it brought high winds and heavy rain to eastern New York State. Rainfall totals ranged from three to six inches. Some areas received up to a foot of rain. The rain produced widespread flooding across the region, leading to severe damage and one fatality (in Dutchess County). Significant flooding was noted on many smaller tributaries including the Esopus, Catskill and Schoharie Creeks. Wind gusts from Floyd ranged from 49 mph to over 60 mph. The rain and strong winds produced massive power outages. Damages to Dutchess County were approximately $1 million.
November 17, 2002	Winter Storm / Nor'Easter	N/A	N/A	A strong Nor'Easter developed off of Cape Hatteras and slowly moved north along the Atlantic coast. Across eastern New York State, the storm produced a heavy winter mix of precipitation and totals ranged from one to six inches. The storm also brought strong winds and ice which caused power outages throughout the area. Dutchess County had approximately $25,000 in property damage from this event.
December 25-26, 2002	Nor'Easter / Snowstorm	N/A	N/A	Snow began early on Christmas morning in eastern New York State and western New England. The storm picked up intensity as the day went on and it event was characterized by a band of very heavy snow which produced snowfall rates of up to four and five inches an hour. Snowfall totals in Dutchess County ranged from 8.8 inches in Boston Corners (Town of Northeast) to 14 inches in the Village of Tivoli.
January 3-4, 2003	Nor'Easter / Snowstorm	N/A	N/A	A heavy mix of freezing rain, sleet and snow fell over eastern New York State. Following this event, a coastal storm developed with periods of heavy snow. The weight of the snow combined with the ice, brought down trees and power lines that resulted in power outages to 15,000 customers. Snowfall totals in Dutchess County ranged from 10.5 inches in Stormville (Town of East Fishkill) to 15.8 inches in Poughkeepsie.
April 16-18, 2007	Severe Storms and Inland and Coastal Flooding	DR-1692	Yes	An intense coastal storm brought heavy precipitation across the lower Hudson Valley of New York State. At first, the precipitation fell as wet snow, sleet and rain and then changed to all rain. Precipitation totals ranged from three to eight inches and led to widespread flooding across the lower and mid-Hudson Valley region. In Dutchess County, small streams and creeks flooded throughout the County. Record flooding occurred on the Wappingers Creek at Wappingers Falls which crested at 7.06 feet above its flood stage of eight feet. Moderate flooding was recorded along Tenmile River at Webatuck which

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
				crested at 11.23 feet. The flooding led to numerous road closures which included large stretches of the Taconic State Parkway in both directions. Additionally, numerous home foundations collapsed near Stormville (Town of East Fishkill). The County had approximately $5.7 million in damages.
December 26-27, 2010	Severe Winter Storm and Snowstorm (Nor'Easter)	DR-1957	Yes	A major Nor'Easter brought significant snow and blizzard conditions to much of the northeast United States. Bands of heavy snow with snowfall rates of one to three inches an hour occurred across the region. Strong, gusty winds were also associated with this storm. Wind gusts across the region ranged from 35 to 45 mph with gusts of 50 to 70 mph reported across southeastern New York State, Connecticut and eastern Massachusetts. Snowfall totals in Dutchess County ranged from nine inches in Salt Point (Town of Poughkeepsie) to 25 inches in the Town of Pine Plains.
August 26 – September 5, 2011	Hurricane Irene	DR-4020	Yes	As Hurricane Irene moved north along the Atlantic coast, it weakened and made its second landfall as a Tropical Storm near Little Egg Inlet along the southeast New Jersey coast. The storm made its third landfall in New York City on August 28th. This storm brought sustained winds, heavy rain, destructive storm surge and two confirmed tornadoes. Heavy rainfall resulted in widespread moderate flooding across the area. Seven deaths resulted from Irene. At least 600,000 people were ordered to evacuate their homes from storm surge and inland flooding. Widespread power outages of up to one week followed the storm. The strong winds from Irene pushed a three to five foot storm surge of water along western Long Island South, New York Harbor, the southern and eastern bays of Long Island, and southern bays of New York City. This resulted in moderate to major coastal flooding, wave damage and erosion along the coast, with heavy damage to public beaches and other public and private facilities. In Dutchess County, flash flooding was reported in several locations. Numerous roads and bridges were closed or damaged due to flooding and downed trees. There were mandatory evacuations in the County as well. Record flooding was recorded on the Hudson River at Poughkeepsie and major flooding occurred on the Hoosic River at Eagle Bridge, Hudson River at Troy and on Wappingers Creek at Wappingers Falls. Moderate flooding was reported on Tenmile River at Webatuck (Town of Amenia) and minor flooding on the Hudson River at Waterford. Flooding occurred in the Town of Rhinebeck along Route 9G. Power outages in Dutchess County impacted 25,000 customers.
October 29-30, 2011	Nor'Easter / Snowstorm	N/A	N/A	An early season Nor'Easter brought heavy, wet snow to the south and east of the Capital District. Snowfall rates were as high as two to four inches per hour. Power outages occurred due to downed trees and wires. In Dutchess County, snowfall totals ranged from 4.8 inches in Salt Point (Town of Poughkeepsie) to 21.6 inches in the Village of Millbrook. More than 115,000 homes and businesses were without power in Dutchess and Ulster Counties.
October 27 – November 8, 2012	Hurricane Sandy	DR-4085 / EM-3351	No / Yes	Hurricane Sandy moved up the east coast of the United States during the last week of October 2012. As the storm made landfall in southern New Jersey, bands of rain moved across eastern New York State. Rainfall totals in this part of the State were minimal and

Dates of Event	Event Type	FEMA Declaration Number	County Designated?	Losses / Impacts
				did not cause any flooding. The storm did bring strong and gusty winds to the area, bringing down trees and power lines across the region. Wind gusts ranged from 40 to 60 mph. In Dutchess County, wind speeds reached 47 mph. Flooding in Dutchess County occurred along the Hudson River throughout the County. Roads were closed throughout the region. There were numerous debris lines along the Poughkeepsie Waterfront on the Hudson River due to tidal flooding. Record flooding occurred on the Hudson River at Poughkeepsie as the River reached 9.54 feet. The surge of water moved all the way to the City of Albany. Water reached the deck of the Icehouse Restaurant (City of Poughkeepsie). Two to four feet of water reached inside the restaurant, based on water marks.
November 7-8, 2012	Nor'Easter	N/A	N/A	An early season Nor'Easter impacted the region a week after Hurricane Sandy struck. Most of the precipitation from the storm fell as snow across the mid-Hudson Valley region. Approximately three to six inches of snow fell in Dutchess County. In addition to the snow, strong and gusty winds of up to 35 mph impacted the County.
November 26-27, 2014	Nor'Easter / Snowstorm	DR-4204	No	An early season winter storm impacted eastern New York State during Thanksgiving. The storm began the morning of the 26th and once the snow began, it increased in intensity, falling at rates at or greater than one inch per hour. Temperatures dropped to or below freezing across the entire region. There were heavy bands of snow occurring in some locations, especially across the Taconics, Mohawk Valley and southeastern Adirondacks. Snowfall totals ranged from six to 12 inches, with up to 15 inches in the southeastern Adirondacks. The weight of the snow caused power outages in the area, especially across the mid-Hudson Valley. There were up to 32,000 customers without power in Dutchess and Ulster Counties. Snowfall totals in Dutchess County ranged from five inches in the Town of Hyde Park to 12 inches in the Town of Pine Plains.

Sources: NYSDEC 2015; FEMA 2015; NYS HMP 2014; NOAA-NCDC 2015; SPC 2015

FEMA Federal Emergency Management Agency
HMP Hazard Mitigation Plan
NCDC National Climatic Data Center
NOAA National Oceanic and Atmospheric Administration
NYS New York State
NYSDEC New York State Department of Environmental Conservation
SPC Storm Prediction Center

Probability of Future Occurrences

Predicting future severe storm events in a constantly changing climate has proven to be a difficult task. Predicting extremes in New York State is particularly difficult because of the region's geographic location. It is positioned roughly halfway between the equator and the North Pole and is 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 (Keim, 1997).

It is estimated that Dutchess County will continue to experience direct and indirect impacts of coastal hazards annually that may induce secondary hazards such as flooding, extreme wind, coastal erosion, storm surge in coastal areas, infrastructure deterioration or failure, utility failures, power outages, water quality and supply concerns, and transportation delays, accidents, and inconveniences.

In Section 5.3, the identified hazards of concern for Dutchess 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 coastal hazards in the county is considered "frequent" (likely to occur within 25 years, as presented in Table 5.3-3).

The following provides probability of each type of coastal storm discussed in this section.

Hurricane and Tropical Storm

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. According to the NHC, the return period of hurricanes for Dutchess County was not calculated. However, the return period for surrounding counties is 17 to 24 years for a hurricane (greater than 74 mph winds) and 53 to 120 years for a major hurricane (greater than 110 mph winds) (NHC 2014).

Nor'Easter

As with any weather phenomenon, it is nearly impossible to assign probabilities to Nor'Easters, except over the long-term. High activity seasons are when storm activity exceeds the historical 75th percentile. This means that seasons with this number of storms are expected to occur during one out of four years. Lower activity seasons are defined as when storm activity falls below the historical 75th percentile; meaning this number of storms are expected to occur during three out of four years (East Coast Winter Storms 2013).

Coastal Erosion

Long-term coastal erosion is a continuous and dynamic process, impacting the coastal counties along the Atlantic Ocean and those with shorelines along the Great Lakes. It is anticipated that coastal erosion will continue due to the predicted increase in sea level rise and storm frequency and intensity. In New York State, coastal erosion will continue to be an on-going problem along many areas of coastline. It is difficult to assign a probability to the near constant small, on-going erosion that may occur over a continuous period of time. However, a probability can be assigned to larger storm events such as Nor'Easters and coastal storms, which can result in significant, rapid coastal erosion. The period of time suggest the probability of coastal erosion will be about the same in the future, with year-to-year variations.

For Dutchess County, impacts will vary from place to place along the surge-impacted areas of the county, especially to those municipalities located along the Hudson River. As temperatures increase (see climate change impacts), the probability for future events will likely increase as well. It is estimated that the County will continue to experience direct and indirect impacts of coastal erosion on occasion.

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 is beginning to affect both people and resources in New York State, and these impacts are projected to continue growing. Impacts related to increasing temperatures and sea level rise are already being felt in the State. ClimAID: the Integrated Assessment for Effective Climate Change in New York State (ClimAID) was undertaken to provide decision-makers with information on the State's vulnerability to climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge (New York State Energy Research and Development Authority [NYSERDA], 2011).

Each region in New York State, as defined by ClimAID, has attributes that will be affected by climate change. Dutchess County is part of Region 5, East Hudson and Mohawk River Valleys. Some of the issues in this region, affected by climate change, include: more frequent heat waves and above 90°F days, more heat-related deaths, increased frequency of heavy precipitation and flooding, decline in air quality, etc. (NYSERDA, 2011).

Temperatures in New York State are warming, with an average rate of warming over the past century of 0.25° F per decade. Average annual temperatures are projected to increase across New York State by 2° F to 3.4° F by the 2020s, 4.1° F to 6.8° F by the 2050s, and 5.3° F to 10.1° F by the 2080s. By the end of the century, the greatest warming is projected to be in the northern section of the State (NYSERDA, 2014).

Regional precipitation across New York State is projected to increase by approximately one to eight-percent by the 2020s, three to 12-percent by the 2050s, and four to 15-percent by the 2080s. By the end of the century, the greatest increases in precipitation are projected to be in the northern areas of the State (NYSERDA, 2014).

Sea level rise projections that do not include significant melting of polar ice sheets suggest one to five inches of rise by the 2020s; five to 12 inches by the 2050s; and eight to 23 inches by the 2080s. Scenarios that include rapid melting of polar ice projects four to 10 inches by the 2020s; 17 to 29 inches by the 2050s; and 37 to 55 inches by the 2080s (NYSERDA, 2011).

In Region 5, it is estimated that temperatures will increase by 3.5ºF to 7.1ºF by the 2050s and 4.1ºF to 11.4ºF by the 2080s (baseline of 47.6ºF). Precipitation totals will increase between 2 and 15% by the 2050s and 3 to 17% by the 2080s (baseline of 38.6 inches). Table 5.4.1-4 displays the projected seasonal precipitation change for the East Hudson and Mohawk River Valleys ClimAID Region (NYSERDA, 2011).

Table 5.4.1-4. Projected Seasonal Precipitation Change in Region 5, 2050s (% change)

Winter	Spring	Summer	Fall
5 to +15	-5 to +10	-5 to +5	-5 to +10

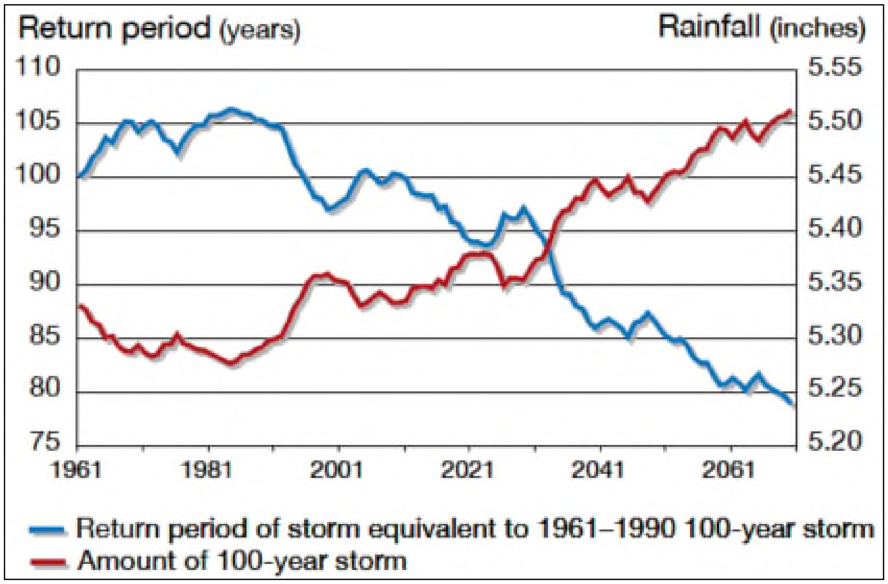
Source: NYSERDA, 2011

The projected increase in precipitation is expected to fall in heavy downpours and less in light rains. The increase in heavy downpours has the potential to affect drinking water; heighten the risk of riverine flooding; flood key rail lines, roadways and transportation hugs; and increase delays and hazards related to extreme weather events

(NYSERDA, 2011). Less frequent rainfall during the summer months may impact the ability of water supply systems. Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent wastewater treatment plants (NYSERDA, 2011).

Figure 5.4.1-4 displays the project rainfall and frequency of extreme storms in New York State. The amount of rain fall in a 100-year event is projected to increase, while the number of years between such storms (return period) is projected to decrease. Rainstorms will become more severe and more frequent (NYSERDA, 2011).

Figure 5.4.1-4. Projected Rainfall and Frequency of Extreme Storms



Source: NYSERDA, 2011

5.4.1.2 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 Dutchess 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
- Change of vulnerability as compared to that presented in the 2006 Dutchess County Hazard Mitigation Plan and 2010 Eastern Dutchess All-Hazard Mitigation Plan
- Effect of climate change on vulnerability
- 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.

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 Dutchess 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 Dutchess 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 Dutchess County (297,488 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 zero people will require temporary shelter due to a 100-year MRP event. For a 500-year MRP event, HAZUS-MH estimates 2 households will be displaced, while no people will require short-term sheltering. Refer to Table 5.4.1-5 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 5.4.1-5. Sheltering Needs for the 100- and 500-year MRP Hurricane Event

Municipality	500-Year MRP	
	Displaced Households	People Requiring Short-Term Shelter
Amenia (T)	0	0
Beacon (C)	0	0
Beekman (T)	0	0
Clinton (T)	0	0
Dover (T)	0	0
East Fishkill (T)	0	0
Fishkill (T)	1	0
Fishkill (V)	0	0
Hyde Park (T)	0	0
LaGrange (T)	0	0
Milan (T)	0	0
Millbrook (V)	0	0
Millerton (V)	0	0
Northeast (T)	0	0
Pawling (T)	0	0
Pawling (V)	0	0
Pine Plains (T)	0	0
Pleasant Valley (T)	0	0
Poughkeepsie (C)	0	0
Poughkeepsie (T)	0	0
Red Hook (T)	0	0

Municipality	500-Year MRP	
	Displaced Households	People Requiring Short-Term Shelter
Red Hook (V)	0	0
Rhinebeck (T)	0	0
Rhinebeck (V)	0	0
Stanford (T)	0	0
Tivoli (V)	0	0
Union Vale (T)	0	0
Wappinger (T)	1	0
Wappinger Falls (V)	0	0
Washington (T)	0	0
Dutchess County (TOTAL)	**2**	**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 Dutchess 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 5.4.1-6 summarizes the definition of the damage categories.

Table 5.4.1-6. 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	≤2%	No	No	No	No	No

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
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.						
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

Tables 5.4.7-7 and 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 5.4.1-7. Estimated Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Hurricane-Related Winds

Municipality	Total RCV (Structure Only)	Estimated Total Damages*			Percent of Total Building Replacement Cost Value		
		Annualized Loss	100-Year	500-Year	Annualized Loss	100-Year	500-Year
Amenia (T)	$1,173,643,243	$127,300	$1,460,700	$11,034,383	<1%	<1%	<1%
Beacon (C)	$2,064,232,682	$139,554	$1,718,781	$11,660,170	<1%	<1%	<1%
Beekman (T)	$2,449,459,966	$320,715	$3,629,395	$27,631,905	<1%	<1%	1.1%
Clinton (T)	$1,341,651,069	$86,966	$1,431,929	$7,294,404	<1%	<1%	<1%
Dover (T)	$1,677,602,978	$182,167	$1,966,069	$15,685,142	<1%	<1%	<1%
East Fishkill (T)	$6,390,057,444	$629,345	$7,704,555	$52,531,633	<1%	<1%	<1%
Fishkill (T)	$3,949,240,855	$242,305	$2,889,202	$19,967,505	<1%	<1%	<1%
Fishkill (V)	$402,859,104	$31,605	$242,581	$2,370,887	<1%	<1%	<1%
Hyde Park (T)	$3,781,227,152	$182,746	$2,766,139	$15,742,735	<1%	<1%	<1%
LaGrange (T)	$3,728,775,229	$309,935	$4,209,797	$24,971,423	<1%	<1%	<1%
Milan (T)	$791,142,073	$39,656	$658,137	$3,564,436	<1%	<1%	<1%
Millbrook (V)	$430,362,334	$32,764	$349,132	$2,525,406	<1%	<1%	<1%
Millerton (V)	$200,740,766	$15,903	$184,774	$1,280,923	<1%	<1%	<1%
Northeast (T)	$872,302,173	$90,719	$1,045,959	$7,298,210	<1%	<1%	<1%
Pawling (T)	$1,629,501,263	$200,109	$1,989,489	$17,785,873	<1%	<1%	1.1%
Pawling (V)	$462,892,825	$59,886	$508,048	$5,388,181	<1%	<1%	1.2%
Pine Plains (T)	$800,637,873	$63,931	$917,084	$5,065,033	<1%	<1%	<1%
Pleasant Valley (T)	$1,982,280,592	$146,749	$2,122,215	$12,260,505	<1%	<1%	<1%
Poughkeepsie (C)	$3,982,167,290	$192,268	$2,539,054	$16,784,333	<1%	<1%	<1%
Poughkeepsie (T)	$9,077,634,548	$486,618	$6,214,032	$39,439,100	<1%	<1%	<1%
Red Hook (T)	$1,967,030,033	$88,989	$1,327,375	$7,177,551	<1%	<1%	<1%
Red Hook (V)	$465,279,056	$17,407	$240,482	$1,340,301	<1%	<1%	<1%
Rhinebeck (T)	$1,564,600,397	$67,718	$1,108,914	$6,022,659	<1%	<1%	<1%
Rhinebeck (V)	$699,038,933	$24,597	$381,533	$2,135,542	<1%	<1%	<1%
Stanford (T)	$1,361,285,639	$113,565	$1,641,729	$9,364,347	<1%	<1%	<1%
Tivoli (V)	$222,466,402	$10,081	$153,178	$837,484	<1%	<1%	<1%
Union Vale (T)	$1,311,718,689	$137,152	$1,530,495	$11,371,088	<1%	<1%	<1%

Municipality	Total RCV (Structure Only)	Estimated Total Damages*			Percent of Total Building Replacement Cost Value		
		Annualized Loss	100-Year	500-Year	Annualized Loss	100-Year	500-Year
Wappinger (T)	$3,652,165,422	$278,214	$3,722,829	$22,535,723	<1%	<1%	<1%
Wappinger Falls (V)	$689,593,231	$38,816	$438,918	$3,196,366	<1%	<1%	<1%
Washington (T)	$1,392,014,229	$131,139	$1,608,902	$10,483,385	<1%	<1%	<1%
Dutchess County (TOTAL)	**$60,513,603,490**	**$4,488,919**	**$56,701,424**	**$374,746,634**	**<1%**	**<1%**	**<1%**

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.*

Table 5.4.1-8. Estimated Residential and Commercial Building Value (Structure Only) Damaged by the 100-Year and 500-Year MRP Hurricane-Related Winds

Municipality	Total RCV (Structure Only)	Estimated Residential Damage		Estimated Commercial Damage	
		100-Year	500-Year	100-Year	500-Year
Amenia (T)	$1,173,643,243	$1,403,390	$9,639,517	$31,436	$392,833
Beacon (C)	$2,064,232,682	$1,662,727	$10,907,701	$27,001	$327,132
Beekman (T)	$2,449,459,966	$3,576,642	$26,252,064	$21,504	$474,046
Clinton (T)	$1,341,651,069	$1,422,961	$7,142,827	$3,336	$31,472
Dover (T)	$1,677,602,978	$1,902,699	$13,878,341	$32,560	$704,867
East Fishkill (T)	$6,390,057,444	$7,571,996	$48,083,774	$44,140	$745,065
Fishkill (T)	$3,949,240,855	$2,757,040	$18,355,846	$105,918	$1,270,094
Fishkill (V)	$402,859,104	$198,479	$1,644,919	$41,327	$682,884
Hyde Park (T)	$3,781,227,152	$2,687,976	$15,212,783	$34,462	$226,018
LaGrange (T)	$3,728,775,229	$4,129,261	$23,903,188	$46,204	$553,636
Milan (T)	$791,142,073	$653,052	$3,482,799	$1,949	$12,473
Millbrook (V)	$430,362,334	$327,499	$2,138,543	$6,866	$97,959
Millerton (V)	$200,740,766	$177,772	$1,150,644	$4,299	$61,197
Northeast (T)	$872,302,173	$1,008,816	$6,073,227	$6,102	$68,713
Pawling (T)	$1,629,501,263	$1,961,869	$16,562,044	$16,382	$464,950
Pawling (V)	$462,892,825	$481,694	$4,437,245	$3,783	$129,405

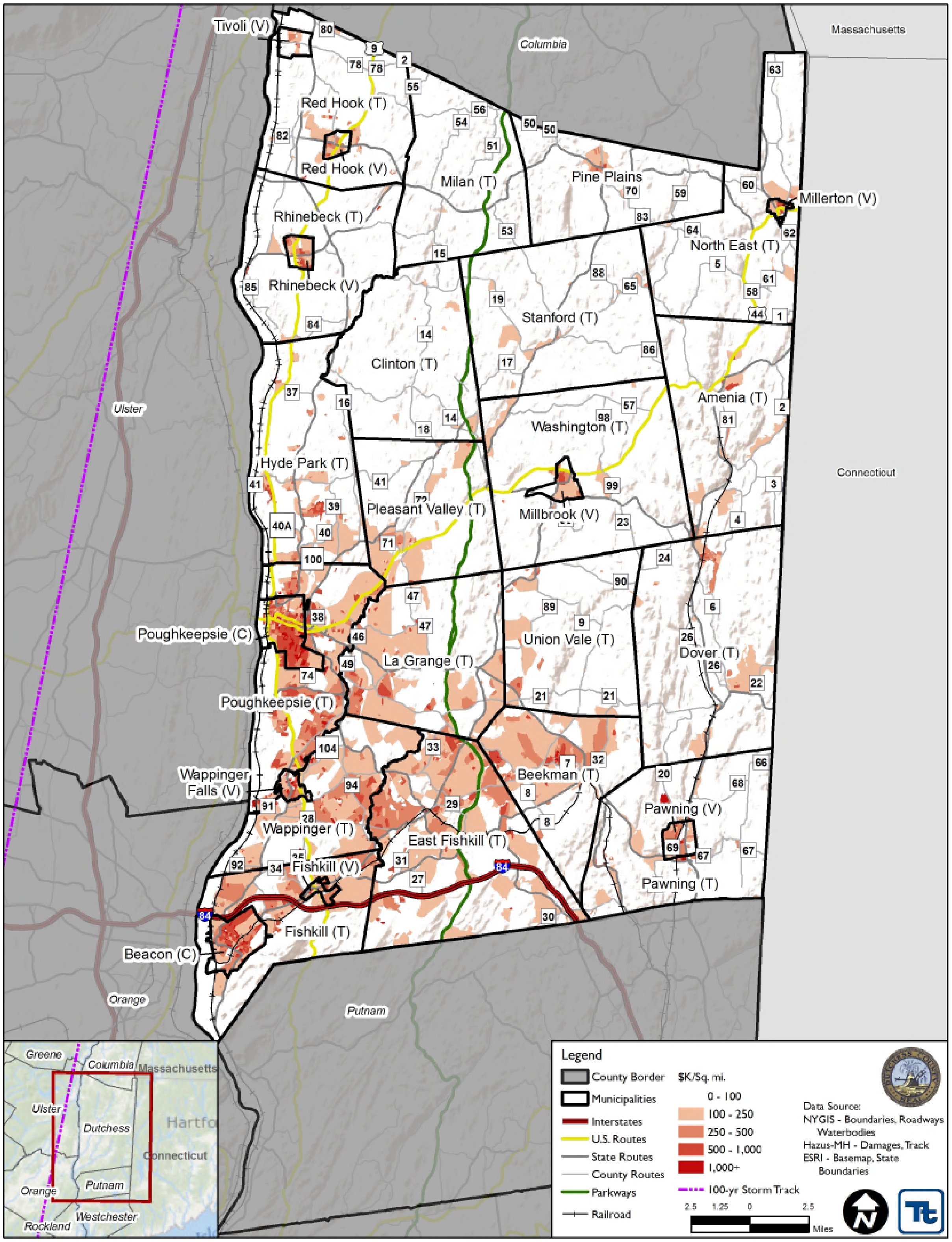
Municipality	Total RCV (Structure Only)	Estimated Residential Damage		Estimated Commercial Damage	
		100-Year	500-Year	100-Year	500-Year
Pine Plains (T)	$800,637,873	$893,630	$4,717,509	$12,818	$169,527
Pleasant Valley (T)	$1,982,280,592	$2,087,311	$11,860,161	$20,016	$204,983
Poughkeepsie (C)	$3,982,167,290	$2,426,146	$15,834,135	$71,269	$609,892
Poughkeepsie (T)	$9,077,634,548	$5,871,126	$36,083,123	$178,812	$1,593,071
Red Hook (T)	$1,967,030,033	$1,286,381	$6,911,839	$8,815	$49,499
Red Hook (V)	$465,279,056	$225,088	$1,240,862	$6,496	$38,215
Rhinebeck (T)	$1,564,600,397	$1,087,927	$5,841,263	$12,317	$66,613
Rhinebeck (V)	$699,038,933	$359,603	$2,009,099	$17,229	$98,595
Stanford (T)	$1,361,285,639	$1,620,200	$8,988,388	$3,429	$25,640
Tivoli (V)	$222,466,402	$151,917	$831,486	$526	$2,394
Union Vale (T)	$1,311,718,689	$1,492,054	$10,391,857	$9,198	$165,021
Wappinger (T)	$3,652,165,422	$3,650,971	$21,698,397	$49,794	$574,825
Wappinger Falls (V)	$689,593,231	$412,775	$2,897,551	$17,026	$155,310
Washington (T)	$1,392,014,229	$1,577,042	$9,556,635	$8,319	$118,779
Dutchess County (TOTAL)	**$60,513,603,490**	**$55,066,043**	**$347,727,769**	**$843,333**	**$10,115,106**

Source: HAZUS-MH 2.1

The total damage to buildings (structure only) for all occupancy types across the County is estimated to be $56.7 million for the 100-year MRP wind-only event, and approximately $375 million for the 500-year MRP wind-only event. The majority of these losses are to the residential building category.

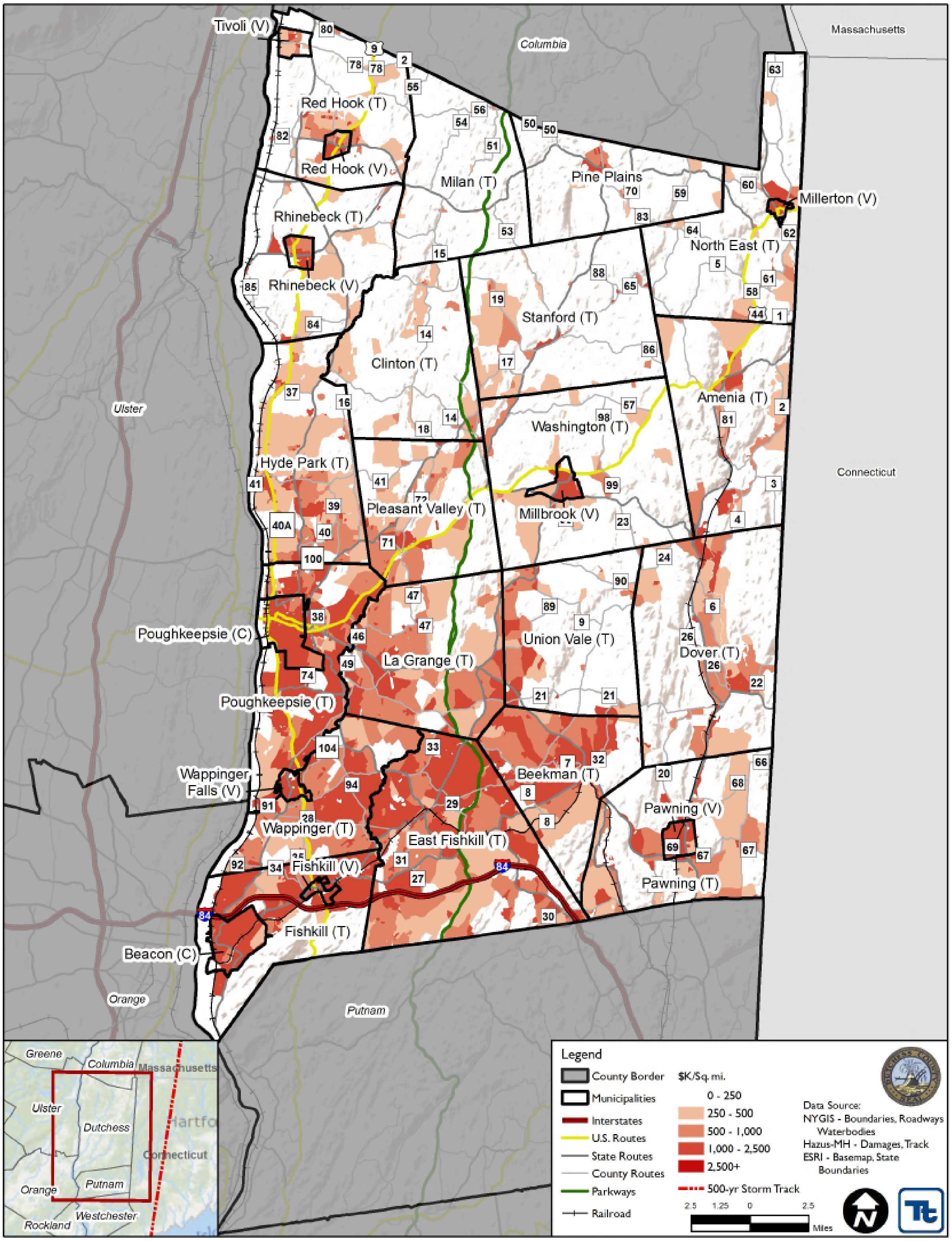
Because of differences in building construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. The damage counts include buildings damaged at all severity levels from minor damage to total destruction. Total dollar damage reflects the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

Figure 5.4.1-5. Density of Losses for Structures (All Occupancies) for the County 100-Year MRP Hurricane (Wind-Only) Event



Source: HAZUS-MH 2.1

Figure 5.4.1-6. 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 5.4.1-9 and Table 5.4.1-10 summarize the potential damages to the critical facilities in Dutchess County as a result of the 100- and 500-year MRP wind events.

Table 5.4.1-9. Estimated Impacts to Critical Facilities for the 100- Year Mean Return Period Hurricane-Related Winds

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

Source: HAZUS-MH 2.1

Table 5.4.1-10. Estimated Impacts to Critical Facilities for the 500-Year Mean Return Period Hurricane-Related Winds

Facility Type	500-Year Event				
		Percent-Probability of Sustaining Damage			
	Loss of Days	Minor	Moderate	Severe	Complete
Medical	0	5-6	6-11	4-11	0
Police	0	2-13	0-4	0	0
Fire	0	1-6	2	0	0
EOC	0	4	0	0	0
School	0-62	2-12	1-24	0-6	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 $179 thousand 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 $13.9 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 5.4.1-11 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 5.4.1-11. 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
Amenia (T)	60	817	0	2	2,427	20,944	172	1,384
Beacon (C)	48	900	0	1	250	1,820	122	975
Beekman (T)	100	1,816	0	7	1,239	15,011	267	2,904
Clinton (T)	21	380	0	0	845	11,525	71	909
Dover (T)	79	1,271	0	2	1,658	26,180	246	2,438
East Fishkill (T)	251	3,302	0	7	1,898	24,008	456	5,432
Fishkill (T)	114	1,528	0	0	495	9,878	155	1,979
Fishkill (V)	25	300	0	0	63	403	30	207
Hyde Park (T)	52	955	0	0	516	10,590	124	2,503
LaGrange (T)	125	1,543	0	0	994	14,183	201	2,823
Milan (T)	8	189	0	0	383	10,481	21	638
Millbrook (V)	16	205	0	0	105	781	20	256
Millerton (V)	4	113	0	0	25	252	19	172
Northeast (T)	36	519	0	1	1,440	16,236	85	813
Pawling (T)	59	1,222	0	3	780	19,482	81	1,590
Pawling (V)	21	437	0	1	117	1,270	49	546

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
Pine Plains (T)	30	328	0	0	781	9,889	77	651
Pleasant Valley (T)	83	858	0	0	819	11,055	157	1,674
Poughkeepsie (C)	105	1,416	0	0	179	1,384	137	1,085
Poughkeepsie (T)	215	2,762	0	0	747	8,923	353	4,219
Red Hook (T)	29	376	0	0	409	7,230	66	816
Red Hook (V)	7	79	0	0	45	261	28	158
Rhinebeck (T)	17	303	0	0	320	8,224	41	696
Rhinebeck (V)	7	134	0	0	22	337	16	235
Stanford (T)	44	583	0	0	1,289	16,713	76	1,022
Tivoli (V)	3	43	0	0	23	344	9	99
Union Vale (T)	50	773	0	2	749	14,407	75	1,053
Wappinger (T)	131	1,680	0	0	805	9,515	207	2,898
Wappinger Falls (V)	28	320	0	0	36	350	35	285
Washington (T)	53	686	0	0	1,317	21,128	78	1,046
Dutchess County (TOTAL)	**1,821**	**25,838**	**0**	**26**	**20,776**	**292,804**	**3,475**	**41,504**

Source: HAZUS-MH 2.1

Change of Vulnerability

Overall, the entire County remains vulnerable to coastal storms. A damage estimate was not conducted as part of the 2006 HMP and 2010 Eastern Dutchess AHMP risk assessment. The updated vulnerability assessment provides a more current risk assessment and analysis for the County.

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 extremes such as storms, including those which may bring precipitation high winds and tornado events. While predicting changes of wind and tornado events 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).

Refer to 'Climate Change Impacts' subsection earlier in this profile for more details on climate change pertaining to New York State.

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. 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, Dutchess 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, specific building information such as details on protective features (for example, hurricane straps). In addition, information on particular buildings or infrastructure age or year built would be helpful in future analysis of this hazard.