5.4.7 Severe Storms

The following section provides the hazard profile and vulnerability assessment for the severe storm hazard in Putnam County.

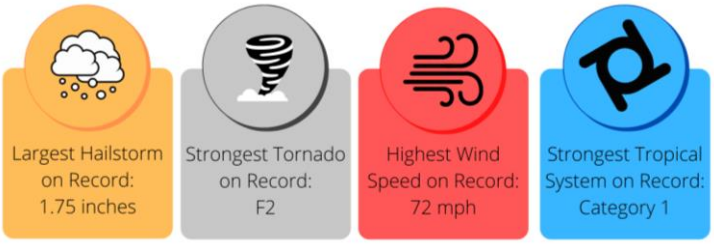
5.4.7.1 Profile

This section presents information regarding the description, extent, location, previous occurrences and losses, climate change projections and probability of future occurrences for the severe storm hazard.

Hazard Description

Severe storm events are a common occurrence in Putnam County. A variety of severe storm types, such as thunderstorms, lightning, hail, tornadoes, high winds, and hurricanes/tropical storms, have damaged property and infrastructure, disrupt power, downing trees and power lines, and causing injuries and fatalities. The following section describes the different severe storm types that impact Putnam County.

Figure 5.4.7-1 . Severe Storm Records



Thunderstorms

Thunderstorms can lead to flooding, landslides, strong winds, and lightning. Roads could become impassable from flooding, downed trees or power lines, or a landslide. Downed utility poles can lead to utility losses, such as electricity, phone, and water (from loss of pumping and filtering capabilities).

A thunderstorm is a local storm produced by a cumulonimbus cloud and accompanied by lightning and thunder (NWS 2009d). A thunderstorm forms from a combination of moisture, rapidly rising warm air, and a force capable of lifting air, such as a warm and cold front, a sea breeze, or a mountain. Thunderstorms form from the equator to as far north as Alaska. Although thunderstorms generally affect a small area when they occur, they have the potential to become dangerous due to their ability in generating tornadoes, hailstorms, strong winds, flash flooding, and lightning. The NWS considers a thunderstorm *severe* only if it produces damaging wind gusts of 58 mph or higher or large hail one inch (quarter size) in diameter or larger or tornadoes (NWS 2020).

Lightning

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

Lightning can damage homes and injure people. In the United States, an average of 300 people are injured and 80 people are killed by lightning each year. Typical thunderstorms are 15 miles in diameter and last an average of 30 minutes. An estimated 100,000 thunderstorms occur each year in the United States, with approximately 10 percent of them classified as severe. During the warm season, thunderstorms are responsible for most of the rainfall.

Hailstorms

Hail forms inside a thunderstorm where there are strong updrafts of warm air and downdrafts of cold water. If a water droplet is picked up by the updrafts, it can be carried well above the freezing level. Water droplets freeze when temperatures reach 32 °F or colder. As the frozen droplet begins to fall, it might thaw as it moves into warmer air toward the bottom of the thunderstorm, or the droplet might be picked up again by another updraft and carried back into the cold air to re-freeze. With each trip above and below the freezing level, the frozen droplet adds another layer of ice. The frozen droplet, with many layers of ice, falls to the ground as hail(NWS 2009c).

High Winds

Wind begins with differences in air pressures. It is rough horizontal movement of air caused by uneven heating of the earth's surface. Wind occurs at all scales, from local breezes lasting a few minutes to global winds resulting from solar heating of the earth (Rosenstiel School of Marine & Atmospheric Science 2005). High winds are often associated by other severe weather events such as thunderstorms, tornadoes, hurricanes, and tropical storms.

Tornadoes

A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 250 miles per hour (mph). Damage paths can be greater than 1 mile wide and 50 miles long. Tornadoes typically develop from either a severe thunderstorm or hurricane as cool air rapidly overrides a layer of warm air. Tornadoes typically move at speeds between 30 and 125 mph and can generate combined wind speeds (forward motion and speed of the whirling winds) exceeding 300 mph. The lifespan of a tornado rarely is longer than 30 minutes (FEMA 1997). Tornadoes can occur at any time of the year, with peak seasons at different times for different states (NSSL 2013).

Hurricanes/Tropical Storms

A tropical storm system is characterized by a low-pressure center and numerous thunderstorms that produce strong winds of 39 to 73 mph and heavy rain. A hurricane is a tropical storm that attains hurricane status when its wind speed reaches 74 mph or higher. Tropical systems can develop in the Atlantic between the Lesser Antilles and the African coast or in the warm tropical waters of the Caribbean Sea and Gulf of Mexico. These storms can move up the Atlantic coast of the United States, impacting 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 eastward offshore.

Though Putnam County is at some distance from open waters, the Hudson River is tidally influenced and coastal storms, such as hurricanes and tropical storms, can impact the County (NYS DHSES 2019). Hurricanes and tropical storms can impact Putnam County from June to November, the official eastern U.S. hurricane season; however, late July to early October is the most likely period for hurricanes and tropical storms to impact Putnam County, due to the cooling of the North Atlantic Ocean waters (NYS DHSES 2014).

Location

The totality of Putnam County is exposed to high wind, lightning, windstorms, thunderstorms, hail, tornadoes, hurricanes, and tropical storms. Additionally, all of the county is subject to high winds from severe weather events. According to the FEMA Winds Zones of the United States map, Putnam County is located in Wind Zone II. In this zone, wind speeds can reach up to 160 mph. Additionally, the County is located within a "Hurricane Susceptible Region", meaning Putnam county is susceptible to hurricanes and other tropical cyclone events.

Extent

The extent (severity or magnitude) of a severe storm is largely dependent upon the most damaging aspects of each type of severe weather. This section describes the extent of thunderstorms, lighting, hail, windstorms, tornadoes, hurricanes, and tropical storms in Putnam County.

Thunderstorms

Severe thunderstorm watches and warnings are issued by the local NWS office and the Storm Prediction Center (SPC). The NWS and SPC will update the watches and warnings and notify the public when they are no longer in effect. Figure 5.4.6.2 illustrates the warnings and watches NWS issues for thunderstorms. Figure 5.4.7-3 presents the severe thunderstorm risk categories, as provided by the SPC.

Figure 5.4.7-2. NWS Watches for Thunderstorms

Severe Thunderstorm Warning

Issued when there is evidence based on radar or a reliable spotter report that a thunderstorm is producing, or forecast to produce, wind gusts of 58 mph or greater, structural wind damage, or hail one inch in diameter or greater.

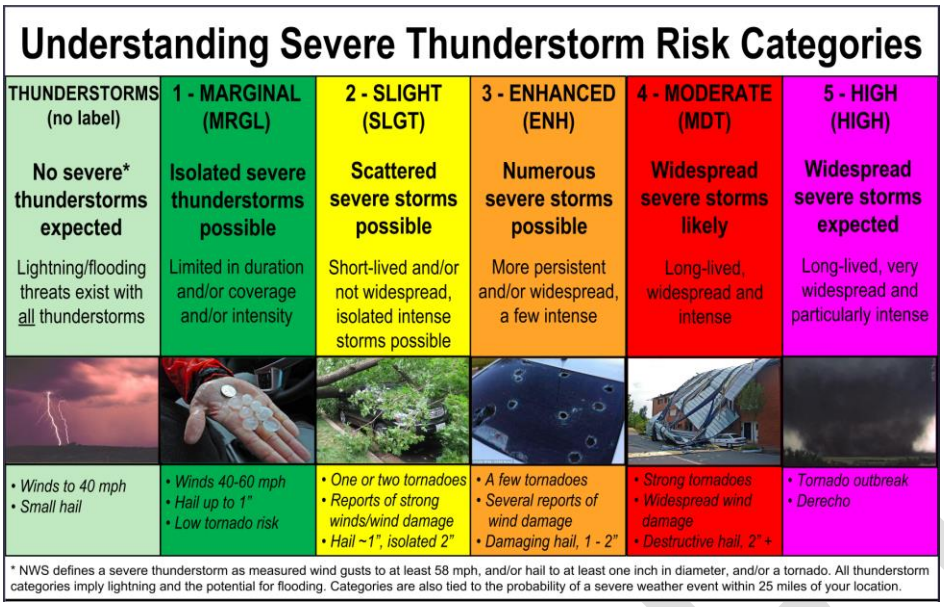
Severe Thunderstorm Watch

Issued by the SPC when conditions are favorable for the development of severe thunderstorms over a larger-scale region for a duration of at least three hours. Tornadoes are not expected in such situations, but isolated tornado development can also occur. Watches are normally issued well in advance of the actual occurrence of severe weather.

Special Weather Statement

Issued by the SPC when conditions are favorable for the development of severe thunderstorms over a larger-scale region for a duration of at least three hours. Tornadoes are not expected in such situations, but isolated tornado development can also occur. Watches are normally issued well in advance of the actual occurrence of severe weather.

Figure 5.4.7-3. Severe Thunderstorm Risk Categories.

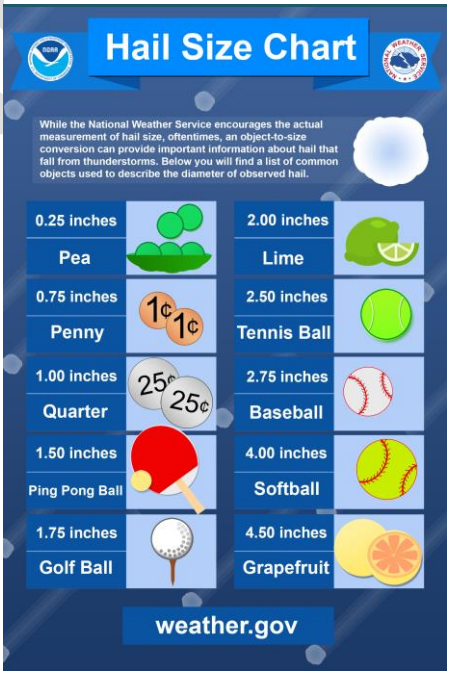


Source: NOAA SPC 2017

Lightning

Lightning is associated with moderate to severe thunderstorms. Lightning severity is determined by the frequency of lightning strikes during a storm. The New York City Office of Emergency Management notes that lightning strikes occur with moderate frequency in the State of New York, with 3.8 strikes occurring per square mile each year. Multiple devices are available to track and monitor the frequency of lightning (NYC Emergency Management, 2020).

Figure 5.4.7-4. Hail Size Chart



Hailstorms

The severity of hail is measured by duration, hail size, and geographic extent. Hail can exhibit a variety of sizes, though only the very largest hail stones pose serious risk to people, if exposed (NYS DHSES 2019). The size of hail is estimated by comparing it to a known object. The Tornado and Storm Research Organization (TORRO) Hailstorm Intensity Scale (H0 to H10) relates typical damage and hail sizes. Refer to Appendix E (Supplementary Data) for a table that outlines the TORRO scale.

High Winds

The following table provides the descriptions of winds and their associated sustained wind speed used by the NWS during wind-producing events. The Beaufort wind scale, developed in 1805, is also used today to classify wind conditions, and is provided in Appendix E (Supplementary Data).

Table 5.4.7-1. NWS Wind Descriptions

Descriptive Term	Sustained Wind Speed (mph)
Strong, dangerous, or damaging	≥40
Very Windy	30-40
Windy	20-30
Breezy, brisk, or blustery	15-25
None	5-15 or 10-20
Light or light and variable wind	0-5

Source: NWS 2010
mph miles per hour

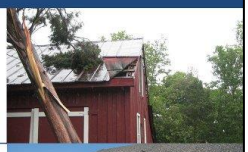
The NWS issues advisories and warnings for winds that are typically site-specific. The NWS issues high wind advisories, watches, and warnings when wind speeds can pose a hazard or are life threatening. The criterion for each of these varies from state to state. According to the NWS (2020), wind warnings and advisories for New York State are as follows:

- *High Wind Warnings* are issued when sustained wind speeds of 40 mph or greater lasting for one hour or longer or for winds of 58 mph or greater for any duration or widespread damage are possible.
- *Wind Advisories* are issues when sustained winds of 30 to 39 mph are forecast for one hour or longer, or wind gusts of 46 to 57 mph for any duration.

Tornadoes

The magnitude or severity of a tornado is categorized using the Enhanced Fujita Tornado Intensity Scale (EF Scale). This is the scale now used exclusively for determining tornado ratings by comparing wind speed and actual damage. Figure 5.4.7-5 illustrates the relationship between EF ratings, wind speed, and expected tornado damage.

Figure 5.4.7-5 Explanation of EF-Scale Ratings

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

Source: NOAA, 2020

Tornado watches and warning are issued by the local NWS office. A tornado watch is released when tornadoes are possible in an area. A tornado warning means a tornado has been sighted or indicated by weather radar. The current average lead time for tornado warnings is 13 minutes. Occasionally, tornadoes develop so rapidly, that little, if any, advance warning is possible (NOAA SPC 2018).

Hurricanes/Tropical Storms

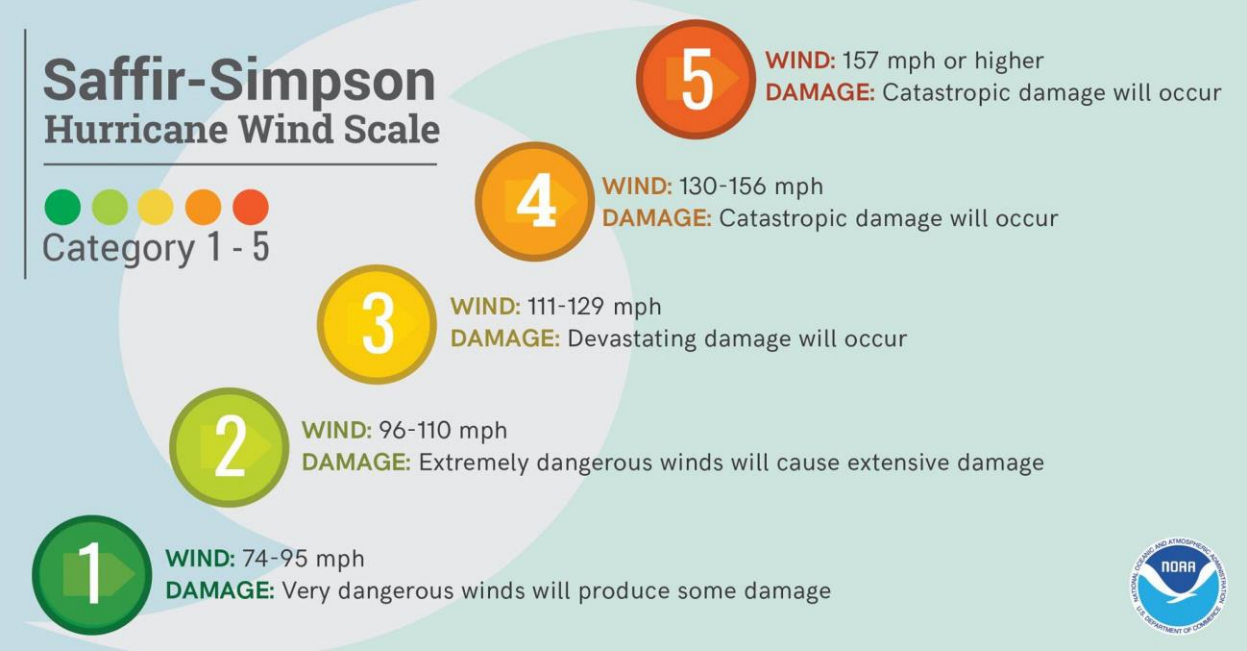
The extent of a hurricane or tropical storm is commonly categorized in accordance with the Saffir-Simpson Hurricane Wind Scale, which assigns a designation of tropical storm for storms with sustained wind speeds below 74 mph and a hurricane category rating of 1–5 based on a hurricane's increasing sustained 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. Tropical Storms and Category 1 and 2 storms are still dangerous and require preventative measures (NOAA 2013). Peak wind speed projections were generated using HAZUS-MH v4.2. HAZUS-MH v4.2 estimated the maximum 3-second gust wind speeds for Putnam County to be between 39 and 73 mph for the 100-year MRP event (tropical storm-force winds). The maximum 3-second gust wind speeds for Putnam County range from 74 to 95 mph for the 500-year MRP event (Category 1-force winds). The associated impacts and losses from these 100-year and 500-year MRP hurricane event model runs are reported in the Vulnerability Assessment. Figure 5.4.7-7 and Figure 5.4.7-8 shows the

estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100-year and 500-year MRP events, respectively.

Figure 5.4.7-6 presents this scale, which is used to estimate the potential property damage and flooding expected when a hurricane makes landfall.

Peak wind speed projections were generated using HAZUS-MH v4.2. HAZUS-MH v4.2 estimated the maximum 3-second gust wind speeds for Putnam County to be between 39 and 73 mph for the 100-year MRP event (tropical storm-force winds). The maximum 3-second gust wind speeds for Putnam County range from 74 to 95 mph for the 500-year MRP event (Category 1-force winds). The associated impacts and losses from these 100-year and 500-year MRP hurricane event model runs are reported in the Vulnerability Assessment. Figure 5.4.7-7 and Figure 5.4.7-8 shows the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 100-year and 500-year MRP events, respectively.

Figure 5.4.7-6 The Saffir-Simpson Scale



Source: NOAA, 2020

Figure 5.4.7-7 Wind Speeds for the 100-Year MRP Event

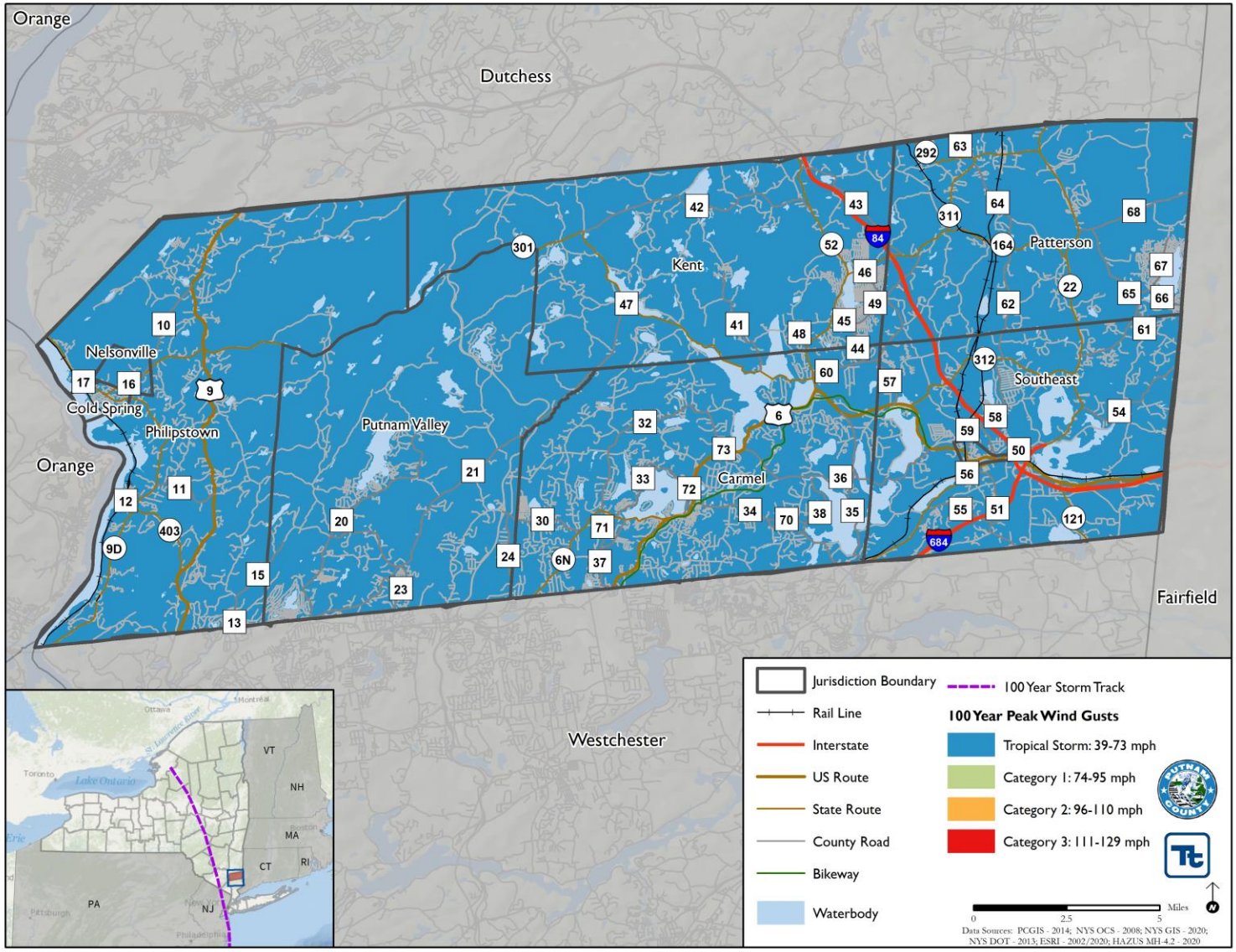
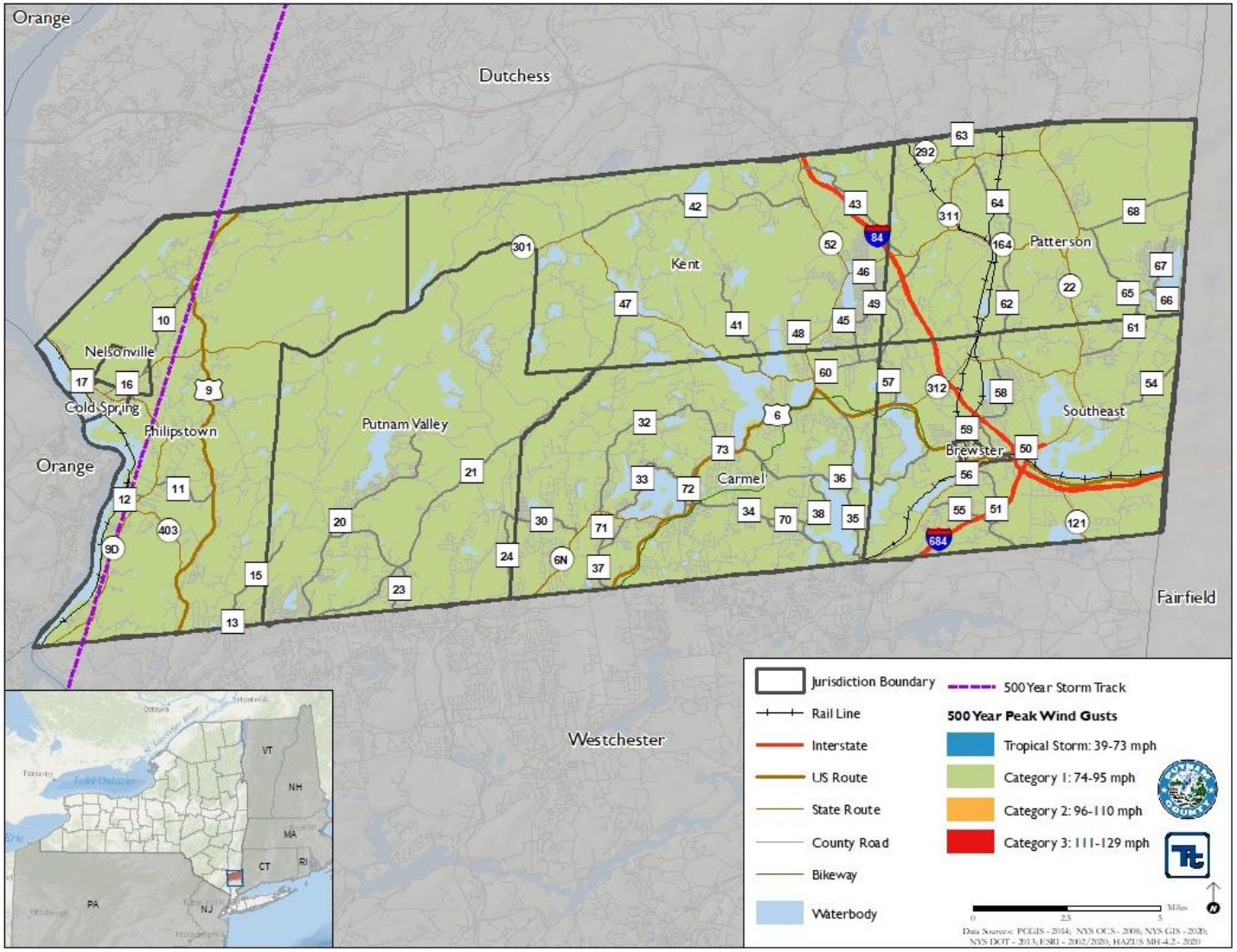


Figure 5.4.7-8 Wind Speeds for the 500-Year MRP Event



Previous Occurrences and Losses

Several sources have provided historical information regarding previous occurrences and losses associated with severe storm events in Putnam County. According to NOAA-NCEI Storm Events Database, Putnam County has been impacted by 203 severe storm events that caused no fatalities, 12 injuries, $26.5 million in property damage, and $0 in crop damage. However, these numbers only include events that were reported to NOAA-NCEI and may not represent all severe storms that impacted the County.

Table 5.4.7-2. Severe Storm Events 1950-April 2020

Hazard Type	Number of Occurrences Between 1950 and 2018	Total Fatalities	Total Injuries	Total Property Damage ($)	Total Crop Damage ($)
Funnel Cloud	2	0	0	$0	$0
Hail	31	0	0	$0	$0
Heavy Rain	16	0	0	$1,000	$0
High Wind*	14	0	0	$0	$0
Hurricane**	0	0	0	$0	$0
Lightning	6	0	1	$575,000	$0
Strong Wind	5	0	0	$150,000	$0
Thunderstorm Wind	122	0	7	$162,000	$0
Tornado	6	0	5	$25.65 million	$0
Tropical Depression**	0	0	0	$0	$0
Tropical Storm***	1	0	0	$4,000	$0
TOTAL	**203**	**0**	**12**	**$26.5 million**	**$0**

Source: NOAA-NCEI 2020; NHC 2020

** Includes Hurricane Sandy event*

*** Number of events were collected from NOAA-NCEI.*

**** Tropical Storm includes one extra-tropical storm.*

M: Million, K: Thousand

Between 1954 and April 2020, New York State was included in 68 FEMA declared severe storm-related major disaster declarations (DR) or emergencies (EM) classified as one or a combination of the following hazards: coastal storm, high tides, heavy rain, flooding, hurricane, ice storm, severe storms, thunderstorms, tornadoes, tropical storm, straight-line winds, and landslides. Of those declarations, Putnam County was included in 12 declarations (FEMA 2020). Table 5.4.7-3 lists FEMA DR and EM declarations for Putnam County.

Table 5.4.7-3. Severe Storm-Related FEMA Declarations for Putnam County, 1954 to April 2020

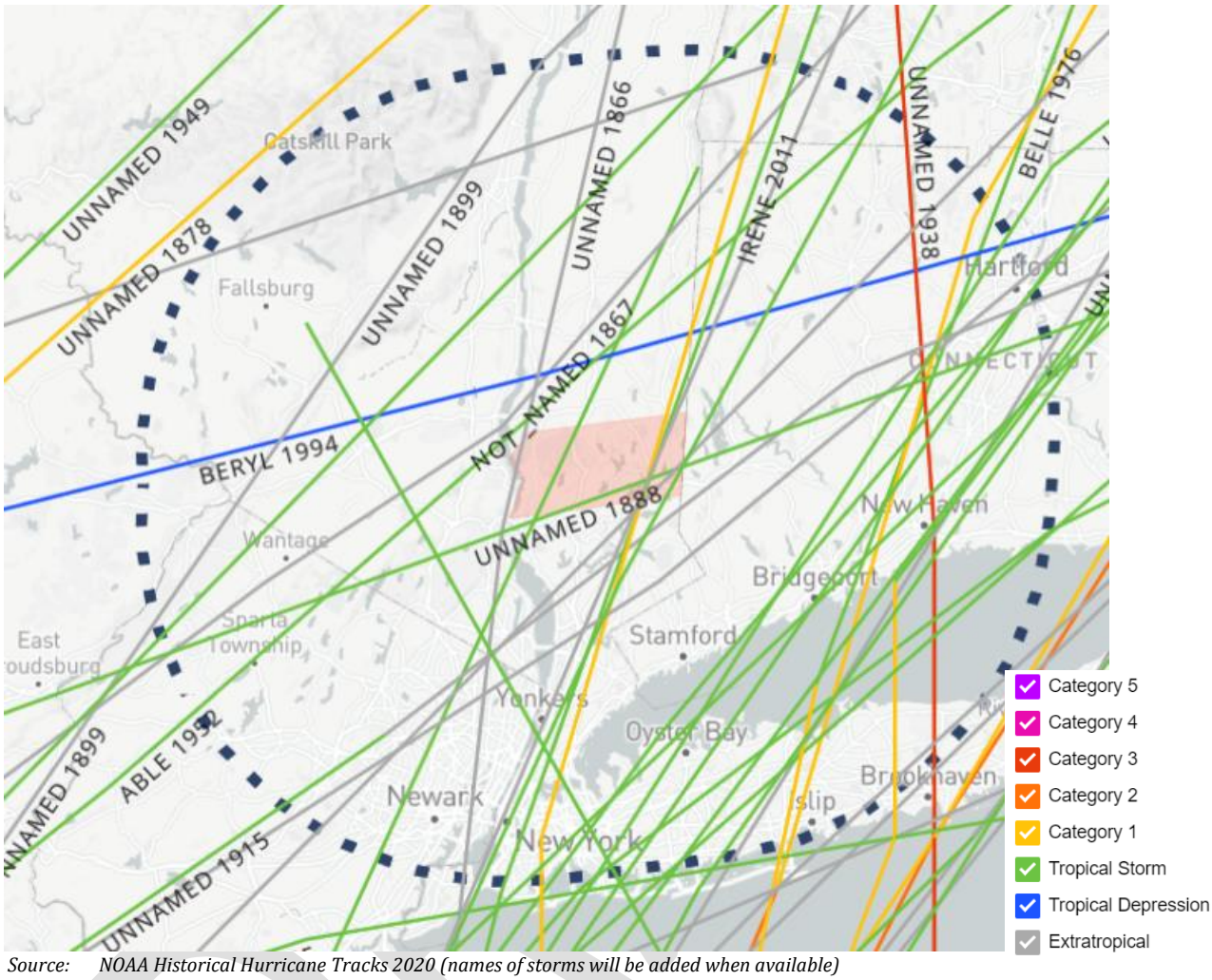
Disaster Number	Declaration Date	Event Date	Incident Type	Title
DR-4085	10/30/2012	October 27, 2012 -- November 8, 2012	Hurricane	Hurricane Sandy
EM-3351	10/28/2012	October 27, 2012 -- November 8, 2012	Hurricane	Hurricane Sandy
DR-4020	8/31/2011	August 26, 2011 -- September 5, 2011	Hurricane	Hurricane Irene
EM-3328	8/26/2011	August 25, 2011 -- September 5, 2011	Hurricane	Hurricane Irene
DR-1692	4/24/2007	April 14, 2007 -- April 18, 2007	Severe Storm(s)	Severe Storms and Inland Coastal Flooding
DR-1589	4/19/2005	April 2, 2005 -- April 4, 2005	Severe Storm(s)	Severe Storms and Flooding
DR-1534	8/3/2004	May 13, 2004 -- June 17, 2004	Severe Storm(s)	Severe Storms and Flooding

Disaster Number	Declaration Date	Event Date	Incident Type	Title
DR-1296	9/19/1999	September 16, 1999 -- September 18, 1999	Hurricane	Hurricane Floyd Major Disaster Declaration
EM-3149	9/18/1999	September 16, 1999 -- September 18, 1999	Hurricane	Hurricane Floyd Disaster Declaration
DR-1095	1/24/1996	January 19, 1996 -- January 30, 1996	Flood	Severe Storms and Flooding
DR-487	10/2/1975	October 2, 1975	Flood	Storms, Rains, Landslides, and Flooding
DR-311	9/13/1971	September 13, 1971	Flood	Severe Storms & Flooding

Source: FEMA 2020

Figure 5.4.7-9 from the NOAA Historical Hurricane Tracker illustrates the tracks of storms between 1842 and 2018 within 65 miles of Putnam County. Putnam County is occasionally impacted by hurricanes, tropical storms, or tropical depressions. The County experiences the direct and indirect landward effects associated with hurricanes and tropical storms, including Hurricane Irene and Tropical Storm Lee in 2011 and Superstorm Sandy in 2012. The figure does not show Hurricane Sandy passing within 65 nautical miles of the county. To date, there have been 42 storms known to come within 65 miles of the County, including eight that crossed the County's boundary. The strongest of these was an unnamed Category 1 hurricane in 1893, which made landfall near Breezy Point and traveled northwest, crossing the county near Brewster. The most recent storm to directly strike the County was Hurricane Irene in 2011, which made landfall near Coney Island and crossed the County near Brewster as a tropical storm. Of the eight storms to strike Putnam County, one has been as a hurricane, four have been as tropical storms, and three have been as extratropical storms.

Figure 5.4.7-9 Historical Hurricane Tracks within 65 miles of Putnam County, 1878 to 2020



Source: NOAA Historical Hurricane Tracks 2020 (names of storms will be added when available)

Note: Category refers to tropical cyclone strength. TS: Tropical Storm, TD: Tropical Depression, ET: Extra-tropical Storm, H1: Category 1 Hurricane, H2: Category 2 Hurricane, H3: Category 3 Hurricane, H4: Category 4 Hurricane.

The NOAA National Centers for Environmental Information (NCEI) Storm Events database records severe storm events. For this HMP update, known severe storm events that have impacted Putnam County between 2015 and 2020 are identified in Table 5.4.7-4. With documentation of severe storms for New York State and Putnam County being extensive, not all sources have been identified or researched. Therefore, Table 5.4.7-4 may not include all events that have occurred in the county. For events prior to 2015, refer to Appendix E (Supplementary Data). For detailed information on damages and impacts to each municipality, refer to Section 9 (Jurisdictional Annexes).

Table 5.4.7-4. Severe Storm Events in Putnam County, 2015 to April 2020

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
July 18, 2016	Thunderstorm Wind	N/A	N/A	A cold front caused severe thunderstorms in the region, resulting in 60 mph winds that brought down trees and power lines in Lake Secor.
August 11, 2016	Thunderstorm Wind	N/A	N/A	Isolated severe storms brought down trees along Interstate 84 near Milltown (Town of Southeast).
February 13, 2017	Wind	N/A	N/A	A 51 mph wind gust was measured near Peach Lake in the Town of Southeast following a deepening low pressure system.
June 13, 2017	Thunderstorm Wind	N/A	N/A	Severe thunderstorms impacting Putnam and Orange Counties resulted in 59 mph winds and a downed tree near Milltown at the intersection of Routes 312 and 22.
June 19, 2017	Thunderstorm Wind	N/A	N/A	A shortwave and surface cold front triggered severe thunderstorms in the region, resulting in 49 mph winds and downed trees and wires near Oscawana Lake and along Route 311 in Patterson. A tree was also reported down in Fahnestock State Park and along Route 312 in Brewster.
September 5, 2017	Thunderstorm Wind	N/A	N/A	A cold front resulted in severe isolated storms in the County, causing downed trees on Canopus Hill Road near Oscawana Corners (Town of Putnam Valley), Putnam Lake (Town of Patterson), and along Route 9D in Manitou (Town of Philipstown).
October 24, 2017	Strong Wind	N/A	N/A	An arriving cold front brought strong 51 mph winds, causing a drowned tree in the Town of Patterson.
May 15, 2018	Tornado	N/A	N/A	Severe thunderstorms and tornadoes followed a cold front in the lower Hudson Valley. The Town of Kent experienced an EF2 tornado with peak winds of 115 mph. Structures in the Town of Kent saw damage in the form of damaged roofs and uprooted trees. Schuykill Court saw the most extensive damage. Patterson experienced an EF1 tornado with 100 mph winds that snapped trees.
May 15, 2018	Thunderstorm Wind	N/A	N/A	A bank sign in Lake Carmel (Town of Carmel) was damaged in 60 mph winds resulting from a severe thunderstorm system that produced tornadoes, microbursts, and macrobursts in the lower Hudson Valley. Wind speeds reaching 70 mph uprooted trees on Woodstock Road in the Town.
June 18, 2018	Thunderstorm Wind	N/A	N/A	Trees and wires were brought down in 58 mph winds in the Village of Brewster following a cold front in the region. In Sodom, winds brought down wires near Route 202.
June 30, 2018	Hail	N/A	N/A	Hail one-inch in diameter was reported in Milltown (Town of Southeast) during severe thunderstorms affecting the region.
July 22, 2018	Thunderstorm Wind	N/A	N/A	Wind speeds of 60 mph were recorded near Crafts (Town of Carmel). The winds brought down trees on Route 6.
April 13, 2020	High Wind	N/A	N/A	Strong winds downed trees on US 6 in the Town of Carmel, causing electrical surges requiring critical water infrastructure to be replaced. In the Village of Cold Spring, the winds downed trees and wires on NY 9D. The County faced approximately $50,000 in property damage from this event.

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
May 15, 2020	Thunderstorm Wind	N/A	N/A	Severe thunderstorms triggered by a cold front swept into the region. According to the Sheriff's dispatcher, multiple power lines and trees were downed along Route 9 outside of Garrison in the Town of Philipstown. Winds reached approximately 70 mph.
August 3, 2020	Tropical Storm			Tropical Storm Isaias passed through the region. In Putnam Valley, downed trees left the Town Hall without power and cable for two days. Damages to Town roads exceeded $122,000. Nearly all of the County, including 90% of NYSEG customers, was left without power, and the County was in a Declared State of Emergency. The National Guard was deployed to distribute water to municipalities and the damage was reported to exceed that of Superstorm Sandy.

Source(s): FEMA 2020; NOAA-NCDC 2020; NYS HMP 2019

** Many sources were consulted to provide an update of previous occurrences and losses; event details and loss/impact information may vary and has been summarized in the above table*

*** Only thunderstorm wind events with property damages of $10K or greater are listed. There were 26 days of thunderstorm winds with 59 individual reports and a total of $359,000 in property damages.*

FEMA Federal Emergency Management Agency
HMP Hazard Mitigation Plan
NCDC National Climatic Data Center
NOAA National Oceanic and Atmospheric Administration
NWS National Weather Service
NYS New York State

Climate Change Projections

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). Putnam County is located in ClimAID Region 5, which includes the East Hudson and Mohawk River Valleys. Table 5.4.7-5 provides the projected seasonal precipitation changes for Region 5 (NYSERDA 2014).

Table 5.4.7-5. Projected Seasonal Precipitation Change in Region 5, 2050s (% change)

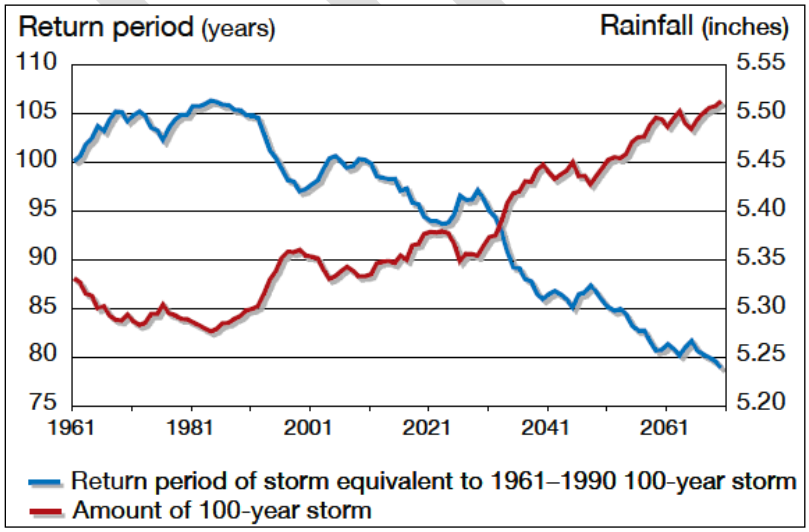
Winter	Spring	Summer	Fall
+5 to +15	-5 to +10	-5 to +5	-5 to +10

Source: NYSERDA 2011

The projected increase in precipitation is expected to fall in heavy downpours and less in light rains. The distribution of precipitation is expected to become less even with climate change. Increased precipitation will likely be experienced in the winter months as rain, with potentially less precipitation in the summer and fall. Downpours will likely increase in intensity and frequency. This may impact drinking water through flooding contaminating wells; heighten the risk of riverine flooding; flood key rail lines, roadways, and transportation hubs; and increase delays and hazards related to extreme weather events (NYSERDA 2011, 2014). Less frequent rainfall during the summer months may hamper water supply provision during these months. Furthermore. increased water temperatures in rivers and streams will have impacts upon aquatic health and reduce the capacity of streams to assimilate effluent wastewater treatment plants and industrial discharges (NYSERDA 2011).

Figure 5.4.7-10 displays the projected rainfall and frequency of extreme storms in New York State. The amount of rainfall in a 100-year event is projected to increase. However, the return period (or number of years between storms) is projected to decrease. Rainstorms are anticipated to be more severe and more frequent (NYSERDA 2011).

Figure 5.4.7-10 Projected Rainfall and Frequency of Extreme Storms



Source: NYSERDA 2011

Probability of Future Occurrences

Table 5.4.7-6 summarizes data regarding the probability of occurrences of severe storm events in Putnam County based on the historic record. Of severe storm hazards, thunderstorm events are the most commonly occurring in Putnam County, followed by hail events. The information used to calculate the probability of occurrences is based solely on NOAA-NCEI storm events database results.

Table 5.4.7-6. Probability of Future Occurrence of Severe Storm Events

Hazard Type	Number of Occurrences Between 1950 and 2020	% Chance of Occurring in Any Given Year
Funnel Cloud	2	3%
Hail	24	34%
Heavy Rain	16	23%
High Wind	15	21%
Hurricane	0	0%
Lightning	6	9%
Strong Wind	5	7%
Thunderstorm Wind	90	129%
Tornado	5	7%
Tropical Depression	0	0%
Tropical Storm	2	3%
TOTAL	**165**	**100.0**

Source: NOAA-NCEI 2020; NHC 2020
Note: Disaster occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act, and selected storm events since 1968.Due to limitations in data, not all severe storm events occurring between 1954 and 1996 are accounted for in the tally of occurrences. As a result, the number of hazard occurrences is underestimated.

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Putnam County is expected to continue experiencing direct and indirect impacts of severe storms annually. These storms may induce secondary hazards such as flooding and utility failure. The identified hazards of concern for Putnam County were ranked in Section 5.3 (Hazard Ranking). The probability of occurrence, or likelihood of the event, is among the parameters used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for severe storms in the county is considered *frequent* (event has 100 percent annual probability and might occur multiple times per year).

5.4.7.2 Vulnerability Assessment

A probabilistic assessment was conducted for the 100-year and 500-year MRP hurricane wind event through a Level 2 analysis in HAZUS-MH v4.2 to analyze the severe storm hazard and provide a range of loss estimates due to wind impacts. Refer to Section 5.1 (Methodology and Tools) for additional details on the methodology used to assess the severe storm risk.

Impact on Life, Health, and Safety

The impact of a severe weather event and wind on life, health and safety is dependent upon several factors including the severity of the event and whether adequate warning time was provided to residents. For the purposes of this HMP, all of Putnam County is considered vulnerable to a severe weather event and wind impacts (i.e. 99,070 persons total, American Community Survey 2018). HAZUS-MH v4.2 estimates that 4 persons will be displaced from their homes or and 3 will seek shelter during a 500-year MRP hurricane wind event and no persons will be displaced or will need to seek shelter during the 100-year MRP hurricane. Secondary impacts caused by extreme

wind events include downed trees, damaged buildings, and debris carried by high winds, which can lead to injury or loss of life.

Socially vulnerable populations are most susceptible to severe weather events, 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. Vulnerable populations include homeless persons, elderly (over 65 years old), low income or linguistically isolated populations, people with life-threatening illnesses, and residents living in areas that are isolated from major roads. The population over the age of 65 is also more vulnerable and, physically, they may have more difficulty evacuating. They may 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. According to the 5-Year 2018 American Community Survey Population Estimates, there are 16,053 persons over 65 and 5,191 persons living in poverty in Putnam County.

Additionally, 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. Refer to Section 4 (County Profile) for population statistics for each participating jurisdiction.

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 also plays a major role in the extent of damage resulting from a coastal storm. 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. Furthermore, high-rise buildings are also very vulnerable structures.

To better understand these risks, HAZUS-MH v4.2 was used to estimate the expected wind-related building damages. Table 5.4.6-7 and Table 5.4.6-8 summarize the definition of the damage categories and extent of damage caused by category for the 100-year and 500-year events.

HAZUS-MH v4.2 estimates there will be approximately $9.5 million and $74.2 million of replacement cost damages caused by the 100-year and 500-year MRP hurricane wind event, respectively (Table 5.4.6-9). Specific types of wind damages are also summarized in HAZUS-MH v4.2 at the following wind damage categories: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction.

HAZUS-MH v4.2 estimates that 5 commercial structures and 36 residential structures would experience minor damage during a 100-year MRP hurricane wind event. Additionally, HAZUS-MH v4.2 estimates that 26 commercial structures and 1,466 residential structures will experience minor damage during a 500-year MRP hurricane wind event. Refer to Table 5.4.6-10 for details on damage for all occupancy classes. HAZUS-MH v4.2 estimates that all the damages caused by severe wind will occur to residential structures in the County for the 500-year MRP wind events; approximately $73.2 million.

Table 5.4.6-7 Description of Damage Categories

Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
No Damage or Very Minor Damage; Little or no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very. Limited water penetration.						
	≤2%	No	No	No	No	No

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

Source: HAZUS-MH Hurricane Technical Manual

Table 5.4.6-8 Expected Damage State by Category for Buildings During 100-Year and 500-Year MRP Hurricane Wind Event in Putnam County

Occupancy Class	Total Number of Buildings in Occupancy	Severity of Expected Damage	100-year		500-year	
			Building Count	Percent Buildings in Occupancy Class	Building Count	Percent Buildings in Occupancy Class
Residential Exposure (Single and Multi-Family Dwellings)	29,999	None	29,963	99.9%	28,467	94.9%
		Minor	36	0.1%	1,466	4.9%
		Moderate	0	0.0%	66	<0.1%
		Severe	0	0.0%	0	0.0%
		Complete Destruction	0	0.0%	0	0.0%
Commercial Buildings	944	None	939	99.5%	917	97.1%
		Minor	5	0.5%	26	2.8%
		Moderate	0	0.0%	1	0.1%
		Severe	0	0.0%	0	0.0%
		Complete Destruction	0	0.0%	0	0.0%
Industrial Buildings	141	None	140	99.3%	136	96.6%
		Minor	1	0.7%	5	3.5%
		Moderate	0	0.0%	0	0.0%

Occupancy Class	Total Number of Buildings in Occupancy	Severity of Expected Damage	100-year		500-year	
			Building Count	Percent Buildings in Occupancy Class	Building Count	Percent Buildings in Occupancy Class
		Severe	0	0.0%	0	0.0%
		Complete Destruction	0	0.0%	0	0.0%
Government, Religion, Agricultural, and Education Buildings	261	None	260	99.8%	254	97.3%
		Minor	1	0.4%	7	2.7%
		Moderate	0	0.0%	0	0.0%
		Severe	0	0.0%	0	0.0%
		Complete Destruction	0	0.0%	0	0.0%

Source: HAZUS v4.2

Table 5.4.6-9 Expected Building Damage for All Occupancies for 100-Year and 500-Year MRP Hurricane Wind Events for Putnam County

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
Brewster (V)	$665,633,363	$114,819	$1,317,602	<0.1%	0.2%
Carmel (T)	$9,304,370,987	$3,434,404	$25,421,828	<0.1%	0.3%
Cold Spring (V)	$790,405,963	$166,604	$881,564	<0.1%	0.1%
Kent (T)	$2,983,284,562	$1,108,774	$8,017,818	<0.1%	0.3%
Nelsonville (V)	$209,404,256	$64,054	$338,723	<0.1%	0.2%
Patterson (T)	$2,927,865,178	$1,043,661	$10,120,311	<0.1%	0.3%
Philipstown (T)	$2,629,391,554	$749,008	$4,517,308	<0.1%	0.2%
Putnam Valley (T)	$3,314,750,529	$1,203,824	$7,449,862	<0.1%	0.2%
Southeast (T)	$4,717,511,487	$1,586,358	$16,172,902	<0.1%	0.3%
Putnam County (TOTAL)	**$27,542,617,878**	**$9,471,506**	**$74,237,918**	**<0.1%**	**0.3%**

Sources: HAZUSv4.2; Putnam County GIS Services 2020; RS Means 2019
Note: T= Town; V= Village

Table 5.4.6-10 Expected Building Damage by Occupancy Class for 100-Year and 500-Year MRP Hurricane Wind Events for Putnam County

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Residential Damages		Estimated Commercial Damages		Estimated Damages for All Other Occupancies	
		100-Year	500-Year	100-Year	500-Year	100-Year	500-Year
Brewster (V)	$665,633,363	$109,498	$1,282,977	$2,368	$14,315	$2,953	$20,310
Carmel (T)	$9,304,370,987	$3,364,229	$25,105,300	$41,770	$176,142	$28,405	$140,387
Cold Spring (V)	$790,405,963	$159,463	$867,244	$2,818	$5,667	$4,323	$8,654
Kent (T)	$2,983,284,562	$1,093,529	$7,957,588	$9,343	$33,180	$5,903	$27,051
Nelsonville (V)	$209,404,256	$61,310	$333,223	$1,082	$2,176	$1,661	$3,323

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Residential Damages		Estimated Commercial Damages		Estimated Damages for All Other Occupancies	
		100-Year	500-Year	100-Year	500-Year	100-Year	500-Year
Patterson (T)	$2,927,865,178	$1,017,733	$9,964,405	$16,626	$87,423	$9,302	$68,482
Philipstown (T)	$2,629,391,554	$729,319	$4,472,895	$14,252	$28,505	$5,437	$15,908
Putnam Valley (T)	$3,314,750,529	$1,190,980	$7,418,805	$7,893	$16,073	$4,952	$14,984
Southeast (T)	$4,717,511,487	$1,523,654	$15,763,774	$44,290	$266,147	$18,414	$142,981
Putnam County (TOTAL)	**$27,542,617,878**	**$9,249,714**	**$73,166,212**	**$140,441**	**$629,627**	**$81,350**	**$442,079**

Sources: HAZUSv4.2; Putnam County GIS Services 2020; RS Means 2019
Note: T= Town; V= Village

Impact on Critical Facilities

Critical facilities are at risk of being impacted by high winds associated with structural damage, or falling tree limbs/flying debris, which can result in the loss of power. Power loss can greatly impact households, business operations, public utilities, and emergency personnel. For example, vulnerable populations in Putnam County are at risk 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 will not be able to effectively respond in a power loss event to maintain the safety of its citizens.

HAZUS-MH v4.2 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 minor damage as a result of the 100-year and 500-year MRP hurricane wind event. Additionally, HAZUS-MH v4.2 estimates the loss of use for each facility in number of days. Table 5.4.6-11 and Table 5.4.6-12 list the estimated loss of use in days for each critical facility and the probability of sustaining the damage category as defined by the column heading for the 100-year and 500-year wind-only events, respectively.

Overall, HAZUS-MH v4.2 estimates that all critical facilities in Putnam County are estimated to experience minor damage (less than 4-percent) and zero loss of functionality due to a 100-year or 500-year MRP hurricane wind event.

Table 5.4.6-11 Estimated Impacts to Critical Facilities for Mean Return Period Hurricane-Related Storm Events

Facility Type	100-Year Event				
	Loss of Days	Percent-Probability of Sustaining Damage			
		Minor	Moderate	Severe	Complete
EOC	0	1.0%	0.0%	0.0%	0.0%
Medical	0	0.0%	0.0%	0.0%	0.0%
Police	0	0.0%-1.0%	0.0%	0.0%	0.0%
Fire	0	0.0%	0.0%	0.0%	0.0%
Schools	0	0.0%	0.0%	0.0%	0.0%

Source: HAZUS-MH v4.2, Putnam County GIS 2020
Notes: % = Percent, EOC = Emergency Operation Center

Table 5.4.6-12 Estimated Impacts to Critical Facilities for Mean Return Period Hurricane-Related Storm Events

Facility Type	500-Year Event				
		Percent-Probability of Sustaining Damage			
	Loss of Days	Minor	Moderate	Severe	Complete
EOC	0	2.0%	0.0%	0.0%	0.0%
Medical	0	1.0%	0.0%	0.0%	0.0%
Police	0	2.0%-4.0%	0.0%	0.0%	0.0%
Fire	0	1.0%-2.0%	0.0%	0.0%	0.0%
Schools	0	1.0%-3.0%	0.0%	0.0%	0.0%

Source: HAZUS-MH v4.2, Putnam County GIS 2020
Notes: % = Percent, EOC = Emergency Operation Center

Impact on Economy

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

Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting and goods transport) transportation needs. Utility infrastructure (power lines, gas lines, electrical systems) could suffer damage and impacts can result in the loss of power, which can impact business operations and can impact heating or cooling provision to the population.

HAZUS-MH v4.2 estimates the total economic loss associated with the 100-year and the 500-year MRP hurricane wind event (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" section 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. HAZUS-MH v4.2 estimates that there are no economic losses for Putnam County caused by the 100-year MRP hurricane wind event. Refer to Table 5.4.6-13 for a summary of HAZUS-MH v4.2 estimated economic losses for Putnam County caused by the 500-year MRP hurricane wind event.

Table 5.4.6-13 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	$0	$0	$0	$0	$0
500-year MRP	$0	$1,376	$73,166	$36	$490	$15

Source: HAZUS-MH v4.2

Debris management can be costly and may also impact the local economy. HAZUS-MH estimates the amount of building and tree debris that may be produced as result of the 100- and 500-year MRP wind events. 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, estimates of weight and volume of eligible tree debris consist of downed trees that would likely be collected and disposed at public

expense. Refer to the User Manual for additional details regarding these estimates. Table 5.4.6-14 summarizes debris production estimates for the 100- and 500-year MRP wind events.

Table 5.4.6-14 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
Brewster (V)	3	75	0	0	0	525	0	1,462
Carmel (T)	66	1,293	0	0	0	9,612	0	29,332
Cold Spring (V)	5	38	0	0	0	121	0	538
Kent (T)	18	406	0	0	0	9,840	0	14,025
Nelsonville (V)	2	15	0	0	0	47	0	206
Patterson (T)	15	535	0	0	0	9,346	0	12,688
Philipstown (T)	14	167	0	0	0	7,429	0	7,952
Putnam Valley (T)	19	297	0	0	0	9,190	0	13,387
Southeast (T)	29	853	0	0	0	10,261	0	20,855
Putnam County (TOTAL)	**171**	**3,678**	**0**	**0**	**0**	**56,371**	**0**	**100,445**

Source: HAZUS-MH 4.2
Notes: V = Village, T = Town

Impact on the Environment

The impact of severe weather events on the environment varies, but researchers are finding that the long-term impacts of more severe weather can be destructive to the natural and local environment. National organizations such as USGS and NOAA have been studying and monitoring the impacts of extreme weather phenomena as it impacts long term climate change, streamflow, river levels, reservoir elevations, rainfall, floods, landslides, erosion, etc. (USGS 2020). For example, severe weather that creates longer periods of rainfall can erode natural banks along waterways and degrade soil stability for terrestrial species. Tornadoes can tear apart habitats causing fragmentation across ecosystems. Researchers also believe that a greater number of diseases will spread across ecosystems because of impacts that severe weather and climate change will have on water supplies (NOAA 2013). Overall, as the physical environment becomes more altered, species will begin to contract or migrate in response, which may cause additional stressors to the entire ecosystem within Putnam County.

Cascading Impacts on Other Hazards

Severe weather events and severe wind events can escalate the impacts of flooding and severe winter weather. Severe weather may carry extreme rainfall that could exacerbate flooding and could increase the intensity of snow and blizzard events. In particular, wind speeds and gusts associated with severe weather events can cause significant utility interruption due to fallen trees which not only interrupt power supplies and communications but hamper the timely repair of utility infrastructure.

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. Changes in the natural environment and built environment and how they interact can also provide insight about ways to plan for the future.

Projected Development

Any areas of growth could be potentially impacted by the severe storm hazard because the entire County is exposed and vulnerable to the wind hazard associated with severe storms. However, due to increased standards and codes, new development may be less vulnerable to the severe storm hazard compared to the aging building stock in the County.

Projected Changes in Population

According to the U.S. Census Bureau, the population in Putnam County has decreased by approximately 0.7-percent between 2010 and 2018 (US Census Bureau 2020). However, estimated population projections provided by the 2017 Cornell Program on Applied Demographics indicates that the County's population will increase slowly into 2040s (Cornell Program on Applied Demographics 2017). With an increase in population in the County, there could be more persons vulnerable to severe weather and severe wind events. Refer to Section 4 (County Profile) for additional discussion on population trends.

Climate Change

As displayed in Figure 5.4.7-9 the entire State of New York is projected to experience an increase in the frequency and severity of extreme storms and rainfall. 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 (NCA, 2020). Refer to Section 5.4.4 (Flood) for a discussion related to the impact of climate change due to increases in rainfall. An increase in storms will produce more wind events and may increase tornado activity. Additionally, thunderstorms and increase in temperature can relate to the strength of a storm resulting in tornadoes (NOAA, 2020). With an increased likelihood of strong winds and tornado events, all of the County's assets will experience additional risk for losses as a result of extreme wind events.

Changes in Vulnerability Since the 2014 HMP

Since the 2014 analysis, population statistics have been updated using the 5-Year 2014-2018 American Community Survey Population Estimates. The general building stock was also updated using RS Means 2019 building valuations that estimated replacement cost value for each building in the inventory. The 2014 critical facility inventory dataset was updated. The updated building stock inventory was imported into HAZUS-MH v4.2 to complete a hurricane wind analysis for the 100-year and 500-year MRP hurricane wind event. Overall, this vulnerability assessment uses a more accurate and updated building inventory which provides more accurate estimated exposure and potential losses for Putnam County.