5.4.7 Severe Storms

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

The hazard profile is organized as follows:	The vulnerability assessment is organized as follows:
• Description • Extent • Previous Occurrences and Losses • Probability of Future Occurrences • Climate Change Impacts	• Impact on Life and Safety • Impact on General Building Stock • Impact on Community Lifelines • Impact on Economy • Impact on Environment • Cascading Impacts on Other Hazards • Future Change that may Impact Vulnerability • Changes Since 2014 HMP • Identified Issues

5.4.7.1 Hazard 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.

Description

For this HMP the severe storm hazard includes thunderstorms, lightning, hail, tornadoes, high winds, and hurricanes/tropical storms, which are defined below.

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 2009). 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.. 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.

Lightning

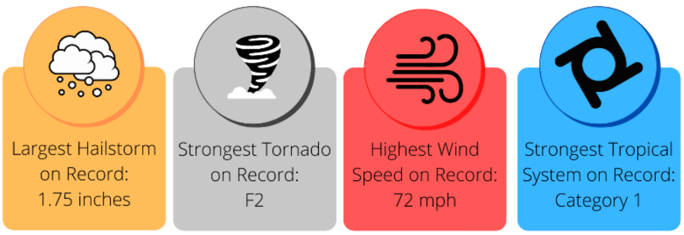
Lighting is a bright flash of electrical energy produced by a thunderstorm. The resulting clap of thunder is the result of a shock wave created by the rapid heating and cooling of the air in the lightning channel. All thunderstorms produce lightning and are very dangerous. Lightning ranks as one of the 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.

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. Figure 5.4.7-3 indicates global recorded event record extremes for storm events.

Figure 5.4.7-1. Recorded Event Records



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.

Tompkins County is located far inland from coastlines but can still experience impacts from hurricanes. (NYS DHSES 2019). Hurricanes and tropical storms can impact Tompkins 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 the County, due to the cooling of the North Atlantic Ocean waters (NYS DHSES 2014).

Location

Tompkins County is also exposed and vulnerable to thunderstorms, lightning, hail, high winds, tornadoes, and hurricanes/tropical storms. According to the FEMA Winds Zones of the United States map, Tompkins County is located in Wind Zone III, where wind speeds can reach up to 200 mph.

Figure 5.4.7-2. Storm Weather Category Thresholds

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.

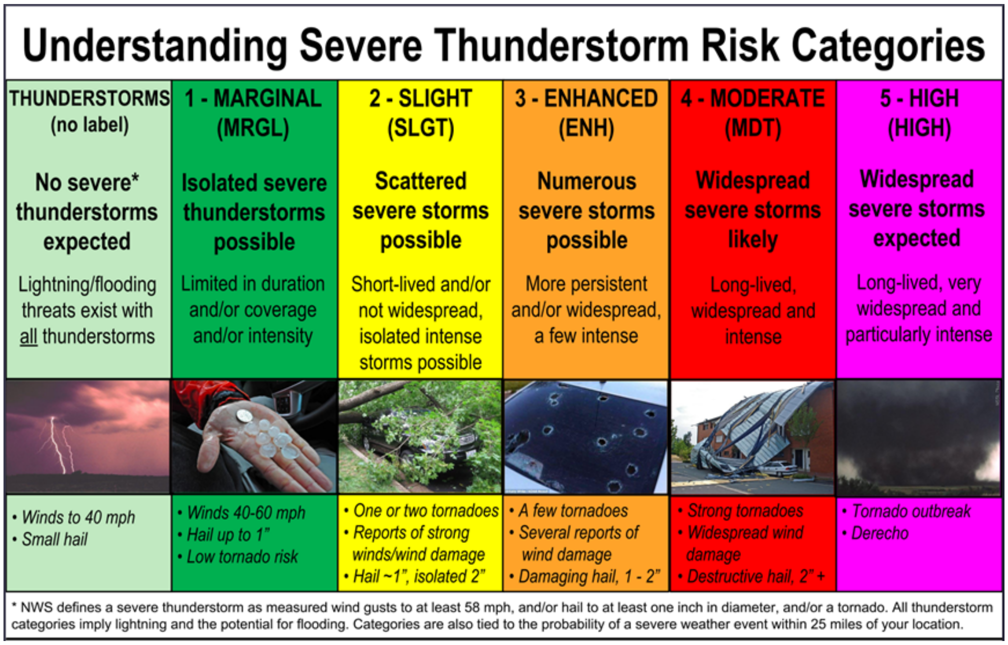
Extent

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 Tompkins 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 5.4.7-3 presents the severe thunderstorm risk categories, as provided by the SPC.

Figure 5.4.7-3. Severe Thunderstorm Risk Categories

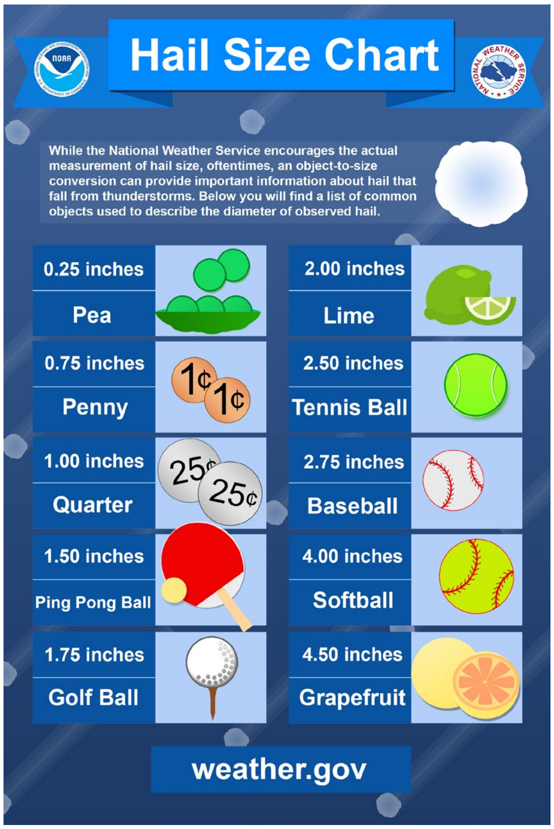


Source: NOAA SPC 2017

Lightning

Lightning is most often associated with moderate to severe thunderstorms. The severity of lightning refers to 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. Most hail stones from hailstorms are made up of variety of sizes. 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. Issuance is normally site-specific. High wind advisories, watches, and warnings are products issued by the NWS 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 (2018), 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.	

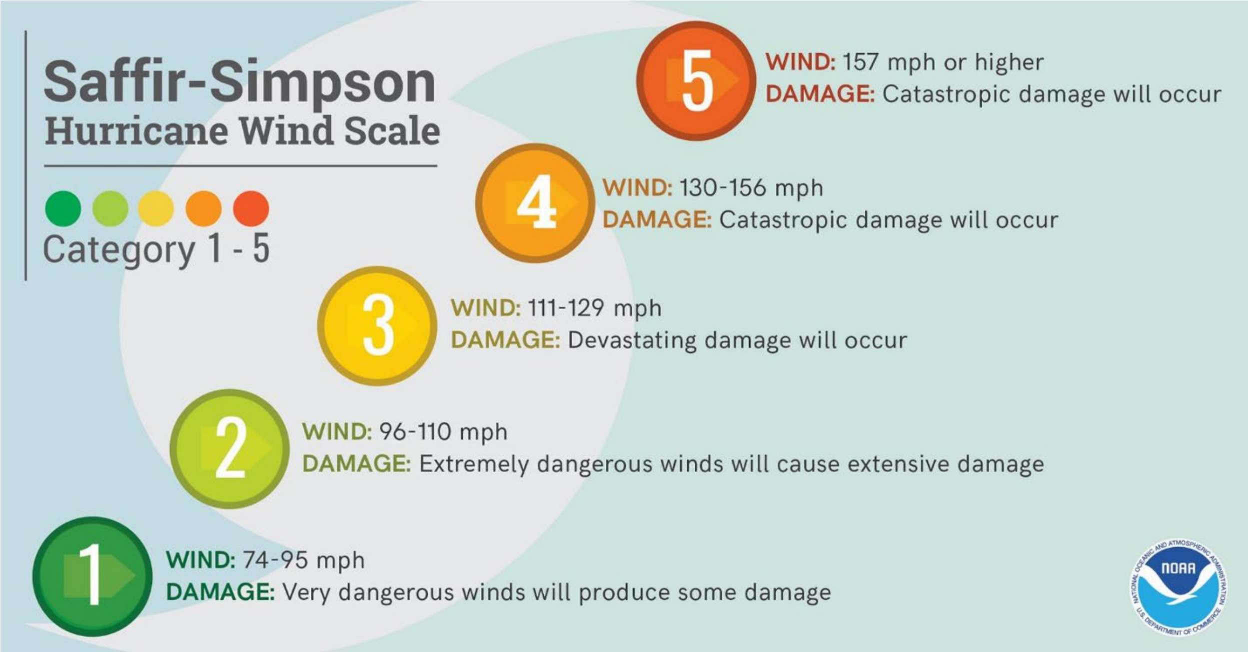
Source: Cornell University 2018

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 (FEMA 1997).

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). 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.

Figure 5.4.7-6. The Saffir-Simpson Scale

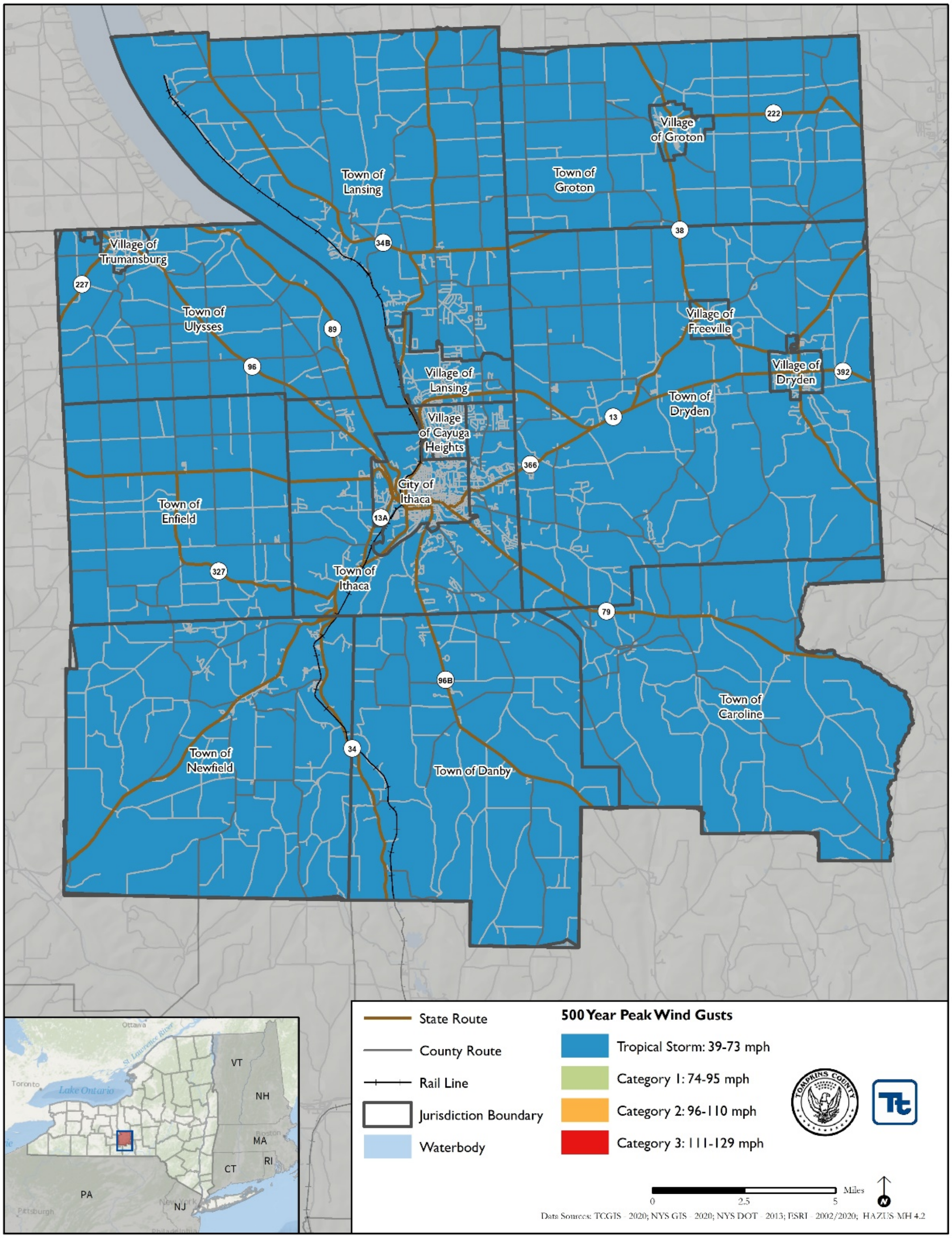


Source: Disaster Readiness Portal 2017

Peak wind speed projections were generated using Hazus-MH v4.2, which estimated the maximum 3-second gust wind speeds for Tompkins County to be below 39 mph for the 100-year MRP event and not strong enough to be considered a tropical storm. The maximum 3-second gust wind speeds for Tompkins County range from 51 to 55 mph for the 500-year MRP event (tropical storm). Figure 5.4.7-7 shows the estimated maximum 3-second gust wind speeds that can be anticipated in the study area associated with the 500-year MRP events.

Hazus-MH v4.2 did not generate the hurricane track for the 100- and 500-year probabilistic events. 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. Wind Speeds for the 500-Year MRP Hurricane Wind Event in Tompkins County



Previous Occurrences and Losses

Numerous sources have provided historical information regarding previous occurrences and losses associated with severe storm events in Tompkins County. According to NOAA-NCEI Storm Events Database, Tompkins County has been impacted by 332 severe storm events that caused no fatalities, two injuries, $4.16 million in property damage, and no crop damage.

Table 5.4.7-2. Severe Storm Events 1950-2020

Hazard Type	Number of Occurrences Between 1950 and 2020	Total Fatalities	Total Injuries	Total Property Damage ($)	Total Crop Damage ($)
Funnel Cloud	1	0	0	$0	$0
Hail	95	0	0	$1,085,000	$0
Heavy Rain	20	0	0	$0	$0
High Wind	8	0	0	$362,330	$0
Hurricane*	4	0	0	$0	$0
Lightning	7	0	2	$119,000	$0
Strong Wind	2	0	0	$10,000	$0
Thunderstorm Wind	188	0	0	$1,681,000	$0
Tornado	6	0	0	$927,500	$0
Tropical Depression*	0	0	0	$0	$0
Tropical Storm*	1	0	0	$0	$0
TOTAL	**332**	**0**	**2**	**$4,159,000**	**$0**

Source: NOAA-NCEI 2020; NHC 2020
**As shown on the Historical Hurricane Tracks mapper by NOAA*
Note: Incidents in multiple parts of the County occurring on the same day within the same time period are counted as a single event.
M: Million, K: Thousand

Between 1954 and 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, Tompkins County was included in eight declarations (FEMA 2018) all occurring between 1996 and 2012. Table 5.4.7-3 lists FEMA DR and EM declarations for Tompkins County.

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

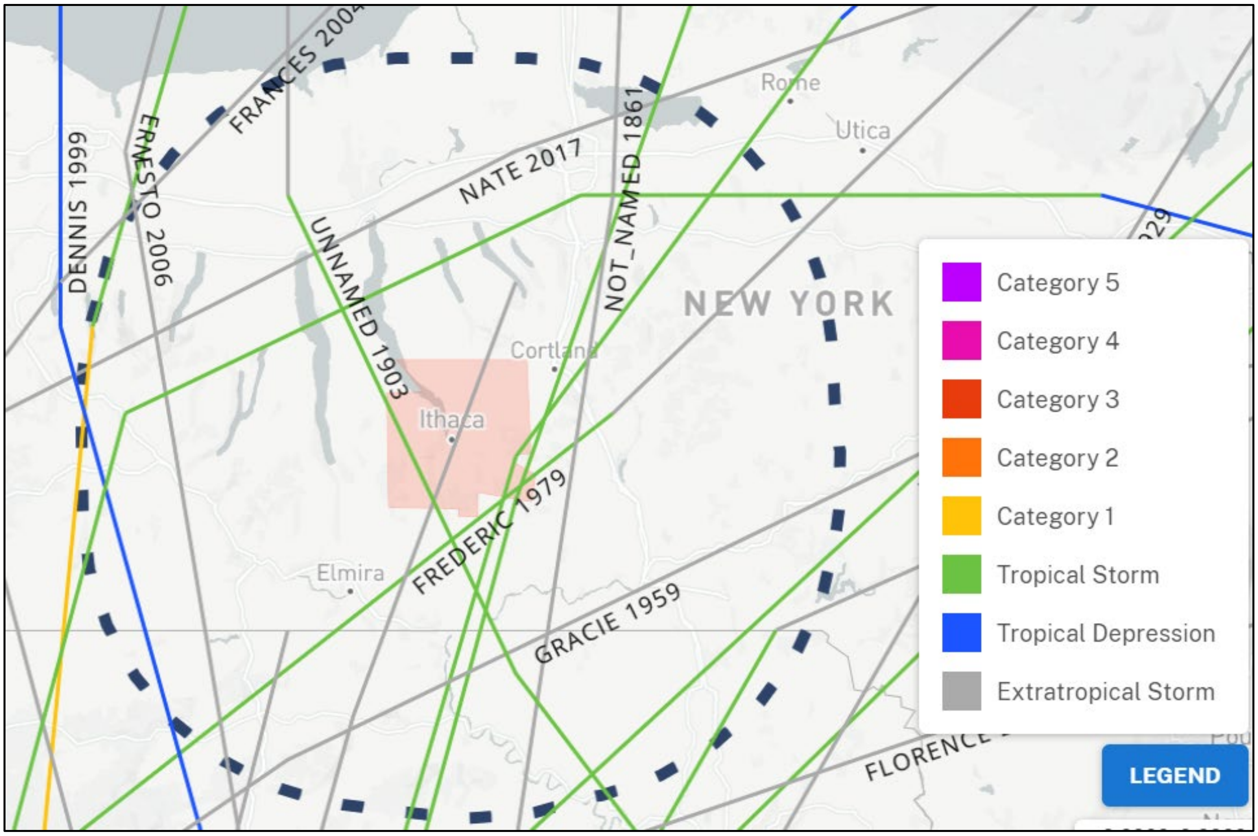
Disaster Number	Incident Duration	Declaration Date	Incident Type	Title
EM-3351	October 27-- November 8, 2012	10/28/2012	Hurricane	Hurricane Sandy
DR-4031	September 7-- September 11, 2011	9/13/2011	Severe Storm(s)	Remnants of Tropical Storm Lee

Disaster Number	Incident Duration	Declaration Date	Incident Type	Title
DR-1650	June 26-- July 10, 2006	7/1/2006	Severe Storm(s)	Severe Storms and Flooding
DR-1534	May 13-- June 17, 2004	8/3/2004	Severe Storm(s)	Severe Storms and Flooding
DR-1391	September 11, 2001	9/11/2001	Fire	Fires and Explosions
DR-1335	May 3-- August 12, 2000	7/21/2000	Severe Storm(s)	Severe Storms and Flooding
DR-1233	June 25-- July 10, 1998	7/7/1998	Severe Storm(s)	Severe Storms and Flooding
DR-1148	November 8-- November 15, 1996	12/9/1996	Severe Storm(s)	Severe Storms, High Winds, Rains, and Flooding

Source: FEMA 2020

Figure 5.4.7-8 illustrates storm tracks between 1842 and 2020 within 65 miles of Tompkins County as recorded in the NOAA Historical Hurricane Tracker. Tompkins County is not frequently impacted by hurricanes, tropical storms, or tropical depressions but has experienced the direct and indirect landward effects associated with hurricanes and tropical storms.

Figure 5.4.7-8. Historical Hurricane Tracks within 65 Miles of Tompkins County, 1878 to 2020



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

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 Tompkins County between 2012 and May 2020 are identified in Table 5.4.7-4. Not all sources have been identified or researched due to the quantity of available data. Therefore, Table 5.4.7-4 might not include all events that have occurred in the County. For events prior to 2012, 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 Tompkins County, 2012 to May 2020

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
5/3/2012	Hail	N/A	No	An upper level disturbance moving through upstate New York produced strong thunderstorms throughout the region. Near South Hill, the storm resulted in $1 million in damage after the two-inch diameter hail dented more than 1,000 cars. The Town of Newfield similarly experienced two-inch-diameter hail and more than $50,000 in damage. Communities across the County experienced hail in excess of one-inch diameter.
8/9/2012	Hail	N/A	No	The City of Ithaca experienced 0.75-inch-diameter hail following severe thunderstorms in the region.
9/6/2012	Hail	N/A	No	The region saw between 0.75 and 2 inches of hail ahead of a cold front that swept through the region and produced severe conditions. Village of Trumansburg and McKinney's Point each saw $10,000 in damage.
6/24/2013	Hail	N/A	No	1.75-inch-diameter wide hail was reported in the Town of Newfield during severe thunderstorms that swept through the area.
7/10/2013	Thunderstorm Wind	N/A	No	A strong cold front from the west led to strong winds that blew down trees and wires. Near McKinney's Point, 57 mph winds were reported.
8/8/2013	Hail	N/A	No	Severe thunderstorms moved through Central New York, causing 0.75-inch-wide hail near Town of Groton and 57 mph winds near McLean and the Town of Groton.
9/2/2013	Thunderstorm Wind/Hail	N/A	No	A significant cold front triggered severe thunderstorm in the region, blowing down trees near Hangar Theater, Cass Park, and the Cornell University area.
5/22/2014	Hail	N/A	No	Severe thunderstorms caused one-inch-diameter hail near the Town of Enfield and the Town of Newfield.
6/17/2014	Thunderstorm Wind	N/A	No	A 79.4 mph wind gust was recorded, and trees were blown down near the Village of Freeville following the arrival of unstable air to the region. 62.1 mph winds were recorded near the Village of Dryden.
7/2/2014	Thunderstorm Wind	N/A	No	Moist, unstable air resulting from a stalled frontal boundary caused severe thunderstorms in the region, bringing 57.5 mph winds and downed trees to the Town of Groton and 0.88-inch hail to the Town of Danby. 57.5 mph winds blew down trees and wires on Ellis Hollow Road in the City of Ithaca and bear Brooktondale.

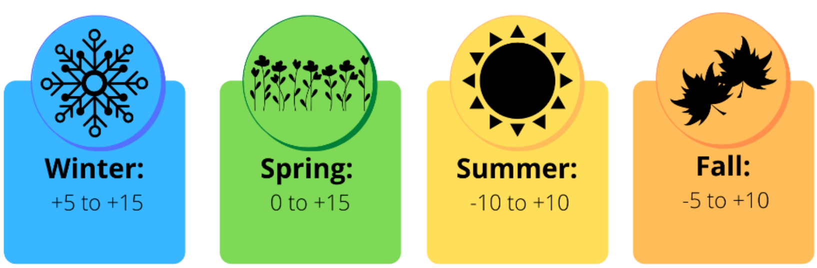
Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
7/8/2014	Thunderstorm Wind	N/A	No	Severe thunderstorms and tornadoes appeared in the region due to a strong upper-level system moving through New York. Large trees were toppled near the Village of Trumansburg and the Village of Freeville.
8/5/2014	Hail	N/A	No	Severe thunderstorms moving through Central New York brought 1.75-inch-diameter hail to the Town of Newfield and 50 knot winds to Cayuga Heights.
8/21/2014	Hail	N/A	No	One-inch-diameter hail appeared near Willow Creek during a severe thunderstorm that produced effects throughout the County.
10/25/2014	Hail	N/A	No	Ithaca saw 0.88-inch-diameter hail during isolated severe storms in the region.
6/8/2015	Thunderstorm Wind	N/A	No	Organized thunderstorms developed along a cold front advancing on the region. The thunderstorms became severe and caused 57.5 mph winds that toppled trees on East Shore Drive in the City of Ithaca.
6/10/2015	Thunderstorm Wind	N/A	No	Severe thunderstorms moving across the Finger Lakes produced 74.8 mph winds that toppled trees near the Town of Groton.
6/12/2015	Thunderstorm Wind	N/A	No	A southward-moving air mass caused severe thunderstorms in Tompkins County, knocking down trees in the City of Ithaca, the Town of Newfield and the Town of Caroline. Wind speeds reached 57.5.
4/16/2017	Thunderstorm Wind	N/A	No	Severe thunderstorms brought 59.8 mph winds and some damage to Trumansburg, Peruville, and Myers.
6/18/2017	Thunderstorm Wind	N/A	No	Damage was reported in Ithaca following a severe thunderstorm that produced 69 mph winds.
7/20/2017	Thunderstorm Wind	N/A	No	The combination of a weak cold front and unstable environment produced thunderstorms (some of which became severe) that produced 69 mph winds near the City of Ithaca.
8/22/2017	Thunderstorm Wind	N/A	No	Two lines of showers and thunderstorms moving through the region produced thunderstorms causing 63.3 mph winds that toppled trees and wires near the Town of Groton and McKinney's Point.
10/15/2017	Thunderstorm Wind	N/A	No	Near the Town pf Dryden, 57.8 mph winds were recorded which knocked over trees and powerlines.
5/4/2018	Thunderstorm Wind	N/A	No	A low-pressure system arriving off the Great Lakes caused 57.8 mph winds that blew down trees on Cayuga Heights Road. Wires and trees were also downed in the City of Ithaca and Slaterville Springs. Altogether this caused approximately $25,000 in damage.
5/28/2018	Thunderstorm Wind	N/A	No	Severe thunderstorms with 57.5 mph winds blew down trees in the Town of Dryden.
6/13/2018	Thunderstorm Wind	N/A	No	A strong low-pressure system shared electric poles in Lansingville and toppled power poles in Peruville.

Dates of Event	Event Type**	FEMA Declaration Number (if applicable)	County Designated?	Event Details*
6/20/2019	Thunderstorm Wind	N/A	No	A slow low-pressure system and slowing frontal boundary resulted in strong thunderstorm winds that brought down wires in the City of Ithaca.
7/16/2019	Thunderstorm Wind	N/A	No	In the Village of Freeville and the Town of Lansing, 57.5 mph winds from a strong thunderstorm downed trees.
7/28/2019	Hail	N/A	No	A mid-level shortwave moving through the County produced three-quarter-inch hail near the Town of Dryden.
7/30/2019	Thunderstorm Wind	N/A	No	Severe thunderstorms moving through the region caused 57.5 mph winds that downed wires near Newfield Station, the Town of Dryden, and Ithaca. All lanes of Route 366 were closed after winds brought down a tree and wires near the Village of Freeville.
8/8/2019	Thunderstorm Wind	N/A	No	Wind speeds up to 59.8 mph were reported near Town of Groton as a line of severe thunderstorms was passing through. In the City of Ithaca, winds downed poles and trees.
8/15/2019	Thunderstorm Wind	N/A	No	In the City of Ithaca, 57.5 mph wind speeds brought down wires and poles on Updike Road.
8/17/2019	Thunderstorm Wind	N/A	No	Severe thunderstorms brought down trees near a nature center in the City of Ithaca.

Source(s): FEMA 2020; NOAA-NCEI 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*
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 Impacts

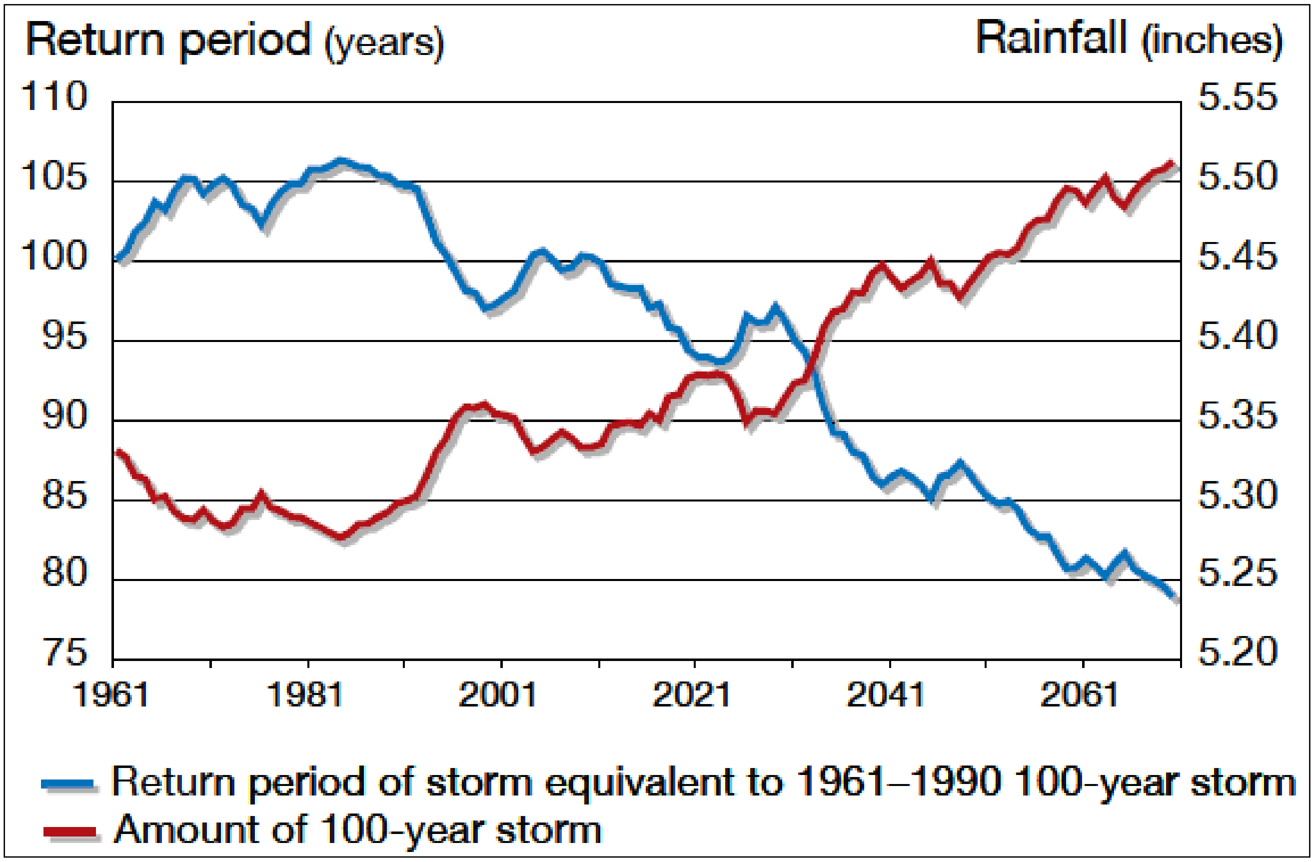
Figure 5.4.7-9. Projected Seasonal Precipitation Change in Region 3, 2050s (% change)



The anticipated increase in precipitation is expected to fall in heavy downpours and less in light rains. Downpours are very likely to increase in frequency and intensity, a change that has the potential to affect drinking water through flooding contaminating wells; heighten the risk of riverine flooding; flood rail lines, roadways, and transportation hubs; and increase delays and hazards related to extreme weather events (NYSERDA 2011). Less frequent rainfall during the summer months can the ability of water supply systems to provide water. Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent wastewater treatment plants and industrial discharges (NYSERDA 2011). The projected seasonal precipitation change in the County (NYSERDA Region 3) is illustrated in Figure 5.4.7-10.

Figure 5.4.7-1 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, 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 5.4.7-11. Projected Rainfall and Frequency of Extreme Storms



Source: NYSERDA 2011

Total precipitation amounts have slightly increased in the Northeast U.S., by approximately 3.3 inches over the last 100 years. There has also been an increase in the number of two-inch rainfall events over a 48-hour period since the 1950s (a 67-percent increase). The number and intensity of extreme precipitation events are increasing in New York State as well. More rain heightens the danger of localized flash flooding, streambank erosion and storm damage (Cornell University College of Agriculture and Life Sciences 2011).

NASA scientists suggest that the U.S. will face more severe thunderstorms in the future, with deadly lightning, damaging hail and the potential for tornadoes in the event of climate change (Borenstein, 2007). A recent study conducted by NASA predicts that smaller storm events like thunderstorms will be more dangerous due to climate change. 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 2005).

Probability of Future Occurrences

Table 5.4.7-5 summarizes data regarding the probability of occurrences of severe storm events in Tompkins County based on the historic record. Thunderstorm events are the most common in Tompkins 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 5.4.7-5. Probability of Future Occurrence of Severe Storm Events

Hazard Type	Number of Occurrences Between 1954 and 2020	% chance of occurrence in any given year
Funnel Cloud	1	1.5%
Hail	95	100%
Heavy Rain	20	29.8%
High Wind	8	11.9%
Hurricane*	4	5.9%
Lightning	7	10.4%
Strong Wind	2	2.9%
Thunderstorm Wind	188	100%
Tornado	6	8.9%
Tropical Depression*	0	0%
Tropical Storm*	1	1.5%
TOTAL	**332**	**100%**

Source: NOAA-NCEI 2020; NHC 2020
**As shown on the Historical Hurricane Tracks mapper by NOAA*
Note: Hazard occurrences include federally declared disasters since the 1950 Federal Disaster Relief Act. 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

Tompkins 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. In Section 5.3 (Hazard Ranking), the identified hazards of concern for Tompkins 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 Partnership, 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 and wind event 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 hazard mitigation plan, all of Tompkins County is considered vulnerable to a severe weather event and wind impacts (i.e. 102,962 persons total, American Community Survey 2018). Hazus-MH v4.2 estimates that zero persons will be displaced from their homes or will seek shelter during a 100-year or 500-year MRP hurricane wind event. 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. The population over the age of 65 is 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 13,561 persons over 65.

Individuals most vulnerable to severe storm events include those: Over 65 Years Old, Infants and Children, With Underlying Medical Conditions, Homeless, With Difficulty Communicating

Infants and children and individual with underlying medical conditions are vulnerable in severe storm events due to potential disruptions in care needs. Also, those that have difficulty communicating, including non-native speakers and those with intermittent internet and cellular service are vulnerable because of potential missed warning messages. Lastly, people located outdoors (i.e., recreational activities, farming, homeless) 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 severe storm and wind event. Due to differences in construction, residential structures are generally more susceptible to wind damage than commercial and industrial structures. Wood and masonry buildings, in general, regardless of their occupancy class, tend to experience more damage than concrete or steel buildings. 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 5.4.7-6 summarizes the definition of the damage categories. In summary, the specific types of wind damage categories include: no damage/very minor damage, minor damage, moderate damage, severe damage, and total destruction. Hazus-MH v4.2 estimates that no structures will experience damages during the 100-year MRP hurricane wind event. Further, Hazus-MH v4.2 estimates that 24 structures would experience minor damage during a 500-year MRP hurricane wind event (refer to Table 5.4.7-6). Additionally, Hazus-MH v4.2 estimated damages for the 500-year MRP hurricane wind event are summarized by general occupancy classes in Table 5.4.7-8. 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 $803,794.

Table 5.4.7-6. 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 Little or no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very Limited water penetration.	≤2%	No	No	No	No	No
Minor Damage Maximum of one broken window, door or garage door. Moderate roof cover loss that can be covered to prevent additional water entering the building. Marks or dents on walls requiring painting or patching for repair.	>2% and ≤15%	One window, door, or garage door failure	No	<5 impacts	No	No
Moderate Damage Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water.	>15% and ≤50%	> one and ≤ the larger of 20% & 3	1 to 3 panel s	Typically 5 to 10 impacts	No	No
Severe Damage Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	>50%	> the larger of 20% & 3 and ≤50%	>3 and ≤25%	Typically 10 to 20 impacts	No	No
Destruction Complete roof failure and/or, failure of wall frame. Loss of more than 50% of roof sheathing.	Typically >50%	>50%	>25%	Typically >20 impacts	Yes	Yes

Source: Hazus-MH Hurricane Technical Manual

Table 5.4.7-7. Damage State Categories for Buildings During a 500-Year MRP Hurricane Wind Event in Tompkins County

Occupancy Class	Total Number of Buildings in Occupancy	Severity of Expected Damage	500-year Building Count	Percent Buildings in Occupancy Class
Residential Exposure (Single and Multi-Family Dwellings)	43,800	None	43,788	100.0%
		Minor	12	<0.1%
		Moderate	0	0.0%
		Severe	0	0.0%
		Complete Destruction	0	0.0%
Commercial Buildings	7,093	None	7,084	99.9%
		Minor	9	0.1%
		Moderate	0	0.0%
		Severe	0	0.0%
		Complete Destruction	0	0.0%
Industrial Buildings	220	None	219	99.7%
		Minor	1	0.5%
		Moderate	0	0.0%
		Severe	0	0.0%
		Complete Destruction	0	0.0%
Government, Religion, Agricultural, and Education Buildings	4,535	None	4,533	99.9%
		Minor	2	<0.1%
		Moderate	0	0.0%
		Severe	0	0.0%
		Complete Destruction	0	0.0%

Source: Hazus-MH v4.2

Table 5.4.7-8. Expected Building Damage for All Occupancies and General Occupancy Types for the 500-Year MRP Hurricane Wind Event for Tompkins County

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Total Damages 500-Year	Percent of Total Replacement Cost Value 500-Year	Estimated Residential Damages 500-Year	Estimated Commercial Damages 500-Year	Estimated Damages for All Other Occupancies 500-Year
Caroline (T)	$2,523,108,347	$129,139	0.0%	$129,139	$0	$0
Cayuga Heights (V)	$1,548,665,909	$0	0.0%	$0	$0	$0
Danby (T)	$2,188,454,321	$117,097	0.0%	$117,097	$0	$0
Dryden (T)	$8,740,906,102	$164,691	0.0%	$164,691	$0	$0
Dryden (V)	$1,135,109,100	$42,688	0.0%	$42,688	$0	$0
Enfield (T)	$2,736,468,231	$17,035	0.0%	$17,035	$0	$0
Freeville (V)	$356,699,295	$1,155	0.0%	$1,155	$0	$0
Groton (T)	$2,804,801,342	$8,878	0.0%	$8,878	$0	$0
Groton (V)	$1,203,171,190	$2,973	0.0%	$2,973	$0	$0

Jurisdiction	Total Replacement Cost Value (All Occupancies)	Estimated Total Damages 500-Year	Percent of Total Replacement Cost Value 500-Year	Estimated Residential Damages 500-Year	Estimated Commercial Damages 500-Year	Estimated Damages for All Other Occupancies 500-Year
Ithaca (C)	$19,712,305,674	$70,429	0.0%	$70,429	$0	$0
Ithaca (T)	$10,868,181,586	$85,463	0.0%	$85,463	$0	$0
Lansing (T)	$6,270,191,033	$11,402	0.0%	$11,402	$0	$0
Lansing (V)	$3,436,043,635	$718	0.0%	$718	$0	$0
Newfield (T)	$3,848,204,673	$146,370	0.0%	$146,370	$0	$0
Trumansburg (V)	$1,241,549,970	$1,082	0.0%	$1,082	$0	$0
Ulysses (T)	$3,372,144,448	$4,675	0.0%	$4,675	$0	$0
Tompkins County (Total)	**$71,986,004,856**	**$803,794**	**0.0%**	**$803,794**	$0	**$0**

Sources: Hazus-MH v4.2; Tompkins County GIS 2020; Microsoft 2018; RS Means 2019
Note: C = City; T = Town; V = Village; % = Percent

Impact on Community Lifelines

Community lifeline 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 Tompkins 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 those community lifeline 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 the 100-year and 500-year MRP hurricane wind events. Additionally, Hazus-MH v4.2 estimates the loss of use for each facility in number of days. Overall, Hazus-MH v4.2 estimates that none of the critical facilities in Tompkins County will experience damage or loss of functionality due to a 100-year or 500-year MRP hurricane wind event.

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 500-year MRP hurricane wind events (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 Tompkins County caused by the 100-year or 500-year MRP hurricane wind event.

Debris management can be costly and may also impact the local economy. Hazus-MH v4.2 estimates the amount of building and tree debris that may be produced as result of the 100-year and 500-year MRP hurricane 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. Hazus-MH v4.2 estimates that the 100-year and 500-year MRP hurricane wind event will not cause any debris for Tompkins County.

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, and erosion (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 (CDC 2020). 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 Tompkins County.

Cascading Impacts on Other Hazards

Severe storms can escalate the impacts of flooding, harmful algal blooms, and wildfire events. For example, severe weather may carry extreme rainfall that could exacerbate flooding. These flood waters may be saturated in chemicals and nutrients that cause harmful algal blooms. Furthermore, lightning from severe weather events may strike a wooded part of Tompkins County, consequentially setting the habitat on fire putting the environment at risk for a wildfire event. More information about flooding, harmful algal blooms, and wildfire events can be found in Section 5.4.4, Section 5.4.5, and Section 5.4.10, respectively.

Future Changes that May Impact Vulnerability

Understanding future changes that affect 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 population projections from the Cornell Program on Applied Demographics, Tompkins County will experience a continual population increase from 2020 through 2040 (over 6,040 people in total by 2040). The U.S. Census Bureau also shows that the population in Tompkins County has increased 0.6-percent between 2010 and 2019 (U.S. Census Bureau 2020). An increase of the population indicates that the number of persons vulnerable to a severe weather and severe wind event is also increasing for Tompkins County. Refer to Section 4 (County Profile) for additional discussion on population trends.

Climate Change

As displayed in Figure 5.4.7-1, the entire State of New York is projected to experience an increase in the frequency and severity of extreme storms and rainfall. 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, an increase in temperature could provide more energy to produce storms that generate tornadoes. 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 Since the 2014 HMP

The 2014 analysis was performed using a parcel exposure analysis. Since the 2014 analysis, population statistics have been updated using the 5-year 2014-2018 American Community Survey Population Estimates. Additionally, this updated analysis estimated exposure and losses at the structure level with updated building stock data. The general building stock was updated using building stock data provided by the County to update the user-defined facility inventory and critical facility inventory dataset. The replacement cost value of these structures was updated using RS Means 2019 building valuations. Last, an updated version of FEMA's Hazus-MH flood module v4.2 was used to estimate potential losses for the 100-year and 500-year MRP hurricane wind events.

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

Identified Issues

- Severe storms occur frequently in Tompkins County, leading to power outages and disruptions to life, economy and government operations in the County. Power outages due to downed trees as a serious hazard impacting communities. Critical facilities without a source of backup power may not function have the ability to properly or provide the necessary needs to the County during power outages.
- Older building stock in the County, which is quite extensive, could be more vulnerable to severe storm events, such as windstorms, as they may have been built to low or no code standards.
- The impacts of drought and invasive species might lead to dead or dying trees. These trees are more susceptible to falling during severe storm events. This can cause power outages, close roadways, and damage buildings and property.
- Not all municipalities have debris management, tree inventories or tree maintenance plan in place. Debris from downed trees must be addressed, as it can impact the severity of severe storm events, requires coordination efforts, and could require additional funding.