TABLES

FIGURES

SECTION 13. NOR'EASTERS

13.1 GENERAL BACKGROUND

A nor'easter gets its name from its continuously strong northeasterly winds blowing in from the ocean ahead of the storm and over the coastal areas. A northeast coastal storm, known as a nor'easter, is typically a large counter-clockwise wind circulation around a low-pressure center often resulting in heavy snow, high winds, and rain. The storm radius is often as much as 1000 miles. These storms occur most often in late fall and early winter. Sustained wind speeds of 20-40 mph are common during a nor'easter with short-term wind speeds gusting up to 50-60 mph. Nor'easters are among winter's most ferocious storms. These strong areas of low pressure often form either in the Gulf of Mexico or off the east coast in the Atlantic Ocean. The low will then either move up the east coast into New England and the Atlantic provinces of Canada, or out to sea. These winter weather events are notorious for producing heavy snow, rain, and oversized waves that crash onto Atlantic beaches, often causing beach erosion and structural damage. Wind gusts associated with these storms can exceed hurricane force in intensity. Nor'easters may also sit stationary for several days, affecting multiple tide cycles and extended heavy precipitation. The level of damage in a strong hurricane is often more severe than a nor'easter, but historically Massachusetts has suffered more damage from nor'easters because of the greater frequency of these coastal storms (1 or 2 per year). Nor'easters are commonly accompanied with a storm surge equal to or greater than 2.0 feet. The comparison of hurricanes to nor'easters reveals that the duration of high surge and winds in a hurricane is 6 to 12 hours while a nor'easter's duration can be from 12 hours to 3 days. Table 13-1 summarizes the similarities and differences of nor'easters and hurricanes.

TABLE 13-1.
COMPARISON CHART

	Nor'easters	Hurricanes
Similarities		
	Economic Impacts Winds Surge and Wave Action Inland Flooding potentials	
Differences		
Duration:	Lasting days on average	Lasting only hours
Season:	October-May	August-October
Evacuations:	Fewer coastal area evacuations, off season	Very populated coastal areas
Debris impacts:	Less foliage	Full foliage

Nor'easters are a common winter occurrence in New England and repeatedly result in flooding, various degrees of wave and erosion damage to structures, and erosion of natural resources, such as beaches, dunes, and coastal bluffs. The erosion of coastal features commonly results in greater potential for damage to shoreline development from future storms.

Detailed studies of satellite images and other readings suggest that some low pressure systems associated with nor'easters may develop tropical storm characteristics such as an eye in the center of the low.

13.1.1 Rating Scales

Northeast Snowfall Impact Scale

There is no widely used scale to classify snowstorms. The Northeast Snowfall Impact Scale (NESIS) developed by Paul Kocin of The Weather Channel and Louis Uccellini of the National Weather Service (Kocin and Uccellini, 2004) characterizes and ranks high-impact northeast snowstorms. These storms have large areas of 10-inch snowfall accumulations and greater. NESIS has five categories, as shown in Table 13-2.

TABLE 13-2.
NESIS CATEGORIES, CORRESPONDING NESIS VALUES, AND DESCRIPTION

Category	NESIS	Value Description
1	1—2.499	Notable
2	2.5—3.99	Significant
3	4—5.99	Major
4	6—9.99	Crippling
5	10.0+	Extreme

See Squires and Lawrimore for details on how NESIS scores are calculated at the National Climatic Data Center.

The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Thus, NESIS gives an indication of a storm's societal impacts. This scale was developed because of the impact northeast snowstorms can have on the rest of the country in terms of transportation and economics. NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. The aerial distribution of snowfall and population information are combined in an equation that calculates a NESIS score, which varies from 1 for smaller storms to over 10 for extreme storms. The raw score is converted into one of the five NESIS categories. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers. NOAA began using the NESIS in 2005 to determine impact from snow events.

Regional Snowfall Index

Since completion of the 2010 SHMP, NOAA has enhanced NESIS to a new tool, the Regional Snowfall Index (RSI), which differs from other indices as it includes societal impacts. As many of the local jurisdictional plans are still current, the Commonwealth has determined that it is in the best interest to include information on both the NESIS scale and the RSI scale. The RSI determines significance factors for snowstorms impacting the eastern two-thirds of the U.S. The Commonwealth of Massachusetts falls within the Northeast Region. The RSI ranks snowstorm impacts on a scale system from 1 to 5 as depicted in Table 13-3.

Based on established indices, the RSI is a regional index; a separate index is produced for each of the six NCDC climate regions in the eastern two-thirds of the nation. The indices are calculated in a similar fashion to NESIS, but the new indices require region-specific parameters and thresholds for the calculations.

**TABLE 13-3.
REGIONAL SNOWFALL INDEX (RSI)**

Category	RSI	Value Description
1	1-3	Notable
2	3-6	Significant
3	6-10	Major
4	10-18	Crippling
5	18.0+	Extreme

For further details on how RSI scores are calculated at the National Climatic Data Center, see Squires, et al. (2011). NOAA, http://www.ncdc.noaa.gov/snow-and-ice/rsi/

The RSI is important because of the need to place snowstorms and their societal impacts into a historical perspective on a regional scale. For example in February 1973, a major snowstorm hit the Southeast affecting areas not prone to snow. The storm stretched from the Louisiana and Mississippi Gulf coasts northeastward to the Carolinas. Over 11 million people received more than 5 inches of snow and three quarters of a million people in Georgia and South Carolina experienced over 15 inches of snow. This is currently the 10th highest ranked storm for the Southeast region. This storm would not even be ranked in NESIS. This example illustrates why it is important to discriminate impacts between the established six regions. For clarification purposes, thresholds are established for each of the six regions. Snowfall thresholds for the Northeast are 4, 10, 20, and 30 inches of snowfall amounts.

13.1.2 Coastal Storm Frequency Caveats

Similar to flood and hurricanes, storms are often categorized by return frequencies (e.g. this was a 100-year storm, etc.). As previously discussed within other hazard profiles, there are several shortcomings related to trying to categorize storms by return frequencies:

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

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

13.2 HAZARD PROFILE

13.2.1 Location

Massachusetts and its 78 coastal communities are all vulnerable to the damaging impacts of major storms, such as nor'easters, along more than 1,500 miles of varied coastline. As development and re-development increases, less-intense storms that occur more regularly and sea-level rise will also lead to costly storm damage. Similar to hurricane events, the coastal areas are more susceptible to damage due to the combination of high winds, waves, and tidal surge. However, nor'easters can also bring heavy snow which can paralyze a city to the entire New England region. Inland areas, especially those in floodplains, are also at risk for flooding, due to heavy rain or snow, and wind damage.

13.2.2 Previous Occurrences

Table 13-4 depicts the top 40 major winter storms in the Northeast and ranks them based on the NESIS scale. Based on all sources researched, known nor'easter events that have affected Massachusetts, and were declared a FEMA disaster, are identified in Table 13-5. This table provides detailed information concerning the FEMA declarations for the Commonwealth. The following sections provide descriptions of major events.

Coastal Storms, Flood, Ice, Snow (DR-546)—February 1978

The February 1978 Blizzard remains as the benchmark storm for comparison by all subsequent nor'easters. This life-threatening nor'easter crippled most of the Commonwealth with blizzard conditions, extraordinarily heavy snow, high winds, and devastating coastal flooding. The storm claimed 73 lives in Massachusetts and 26 in neighboring Rhode Island. Over 10,000 people had to be sheltered. An unprecedented ban on non-emergency vehicle traffic lasted for a week in much of eastern Massachusetts.

The timing of the storm exacerbated its impact. This blizzard grew to its full fury during the Monday evening rush hour and caused over 3500 vehicles to be stranded on route 128 alone in eastern Massachusetts with snowfall rates of at least 3 inches per hour and visibility near zero. Boston recorded a wind gust of 79 mph, and the wind peaked out at 93 mph in Chatham. Snowfall generally ranged from 1 to 3 feet with a large swath of 30+ inch amounts in the southwest suburbs of Boston. Snowfall reports included 32.5 inches in Rockport, 27.1 inches in Boston, 20.2 inches in Worcester, and 38.0 inches in Woonsocket, RI.

Major coastal flooding occurred over multiple high tide cycles and destroyed or severely damaged over 2000 homes. This storm set the all-time high water mark (to date) of 15.25 feet above Mean Lower Low Water at the Boston Harbor National Ocean Service tide gage. Mariner accounts refer to waves in excess of 30 feet just offshore. The storm triggered many harrowing evacuations and rescues along both the North and South Shores. This event did result in a federal disaster declaration (FEMA DR-546) (Strauss, date unknown).

TABLE 13-4.
NESIS STORMS DATA FOR MASSACHUSETTS 1953-2012

Rank	Year	Date	NESIS	Category	Description
1	1993	Mar 12 - 14	13.20	5	Extreme
2	1996	Jan 06 - 08	11.78	5	Extreme
3	2003	Feb 15 - 18	8.91	4	Crippling
4	1960	Mar 02 - 05	8.77	4	Crippling
5	1961	Feb 02 - 05	7.06	4	Crippling
6	1964	Jan 11 - 14	6.91	4	Crippling
7	2005	Jan 21 - 24	6.80	4	Crippling
8	1978	Jan 19 - 21	6.53	4	Crippling
9	1969	Dec 25 - 28	6.29	4	Crippling
10	1958	Feb 14 - 17	6.25	4	Crippling
11	1983	Feb 10 - 12	6.25	4	Crippling
12	1966	Jan 29 - 31	5.93	3	Major
13	1978	Feb 05 - 07	5.78	3	Major
14	2007	Feb 12-15	5.63	3	Major
15*	2010	Feb 23-28	5.46	3	Major
16	1987	Jan 21 - 23	5.40	3	Major
17	1994	Feb 08 - 12	5.39	3	Major
18*	2011	Jan 9-13	5.31	3	Major
19*	2011	Feb 1-3	5.30	3	Major
20*	2010	Dec 24-28	4.92	3	Major
21	1972	Feb 18 - 20	4.77	3	Major
22	1979	Feb 17 - 19	4.77	3	Major
23	1960	Dec 11 - 13	4.53	3	Major
24*	2010	Feb 22-28	4.38	3	Major
25	1969	Feb 22 - 28	4.29	3	Major
26*	2010	Feb 9-11	4.10	3	Major
27	2006	Feb 12 - 13	4.10	3	Major
28	1961	Jan 18 - 21	4.04	3	Major
29	2009	Dec 18-21	4.03	3	Major
30	1966	Dec 23 - 25	3.81	2	Significant
31	1958	Mar 18 - 21	3.51	2	Significant
32	1969	Feb 08 - 10	3.51	2	Significant
33	1967	Feb 05 - 07	3.50	2	Significant
34	1982	Apr 06 - 07	3.35	2	Significant
35	2007	Mar 15-18	2.55	2	Significant
36	2000	Jan 24 - 26	2.52	2	Significant
37	2000	Dec 30-31	2.37	1	Notable
38	1997	Mar 31-Apr 1	2.29	1	Notable
39*	2011	Jan 26-27	2.17	1	Notable
40	1956	Mar 18-19	1.87	1	Notable

* Storm is a new event added since the last plan update. Data as of Jan 2013.

TABLE 13-5.
FEMA NOR'EASTER-RELATED DISASTER DECLARATIONS (1954 TO 2012)

Disaster #	Disaster Type	Declaration Date	Incident Period	Barnstable	Berkshire	Bristol	Dukes	Essex	Franklin	Hampden	Hampshire	Middlesex	Nantucket	Norfolk	Plymouth	Suffolk	Worcester	Number of Counties Impacted
EM-3343	Severe Storm	11/1/11	10/29/11 – 10/30/11		X			X	X	X	X	X		X			X	8
DR-1959	Severe Winter Storm and Snowstorm	03/07/11	1/11/11 - 1/12/11		X			X		X	X	X		X		X		7
DR-1701	Severe Storms and Inland and Coastal Flooding	05/16/07	4/15/07 - 4/25/07	X	X		X	X	X	X	X				X			8
DR-1614	Severe Storms and Flooding	11/10/05	10/7/05 - 10/16/05		X	X		X	X	X	X	X		X	X		X	10
DR-975	Winter Coastal Storm	12/21/92	12/11/92 - 12/13/92	X			X	X				X	X	X	X	X	X	9
DR-920	Severe Coastal Storm	11/04/91	10/30/91 - 11/2/91	X			X	X					X	X	X	X		7
DR-546	Coastal Storms, Flood, Ice, Snow	02/10/78	2/6/78 - 2/8/78	X		X	X	X					X	X	X	X		8
Total				**4**	**4**	**2**	**4**	**7**	**3**	**4**	**4**	**4**	**3**	**6**	**5**	**4**	**3**	

Severe Coastal Storm (DR-920)—October-November 1991

This storm was unusual event, as the large nor'easter moved south and gained strength when it joined what remained of Hurricane Grace, becoming what some refer to as the Perfect Storm. Winds from this event were measured over 80 MPH, with waves over 30 feet in some parts of the coastline. This storm caused flooding and wind damage in several counties. This event resulted in a federal disaster declaration (FEMA DR-920).

Great Nor'easter of 1992 (DR-975)—December 1992

A strong nor'easter affected the Commonwealth from December 11 to 13, 1992. Impacts included deep and intense snowfall, freezing rain, heavy rainfall near the coast, coastal flooding, and damaging winds. Total snowfall in Massachusetts was as high as 4 feet over the higher elevations of the Berkshires, with 48 inches reported in Beckett, Savoy, and Peru. Drifts were as high as 12 feet in the Berkshires. Snowfall of 18 inches to 32 inches was common over central Massachusetts, with 6 to 20 inches over interior eastern Massachusetts. Some locations experienced a coating of ice. Strong winds combined with wet, heavy snow and ice caused considerable tree damage and widespread power outages. The weight of the snow taxed snow removal equipment in many communities and caused roof damage. There were 135,000 customers without power in the Commonwealth during the storm. The central part of the Commonwealth suffered the brunt of the outages where 30,000 households were without power, just in Worcester County.

Precipitation totals for this storm were extraordinary. Much of southern New England received up to 5 inches of liquid equivalent precipitation during a 2 to 3 day period, with locally close to 8 inches recorded in parts of southeast Massachusetts. Along coastal sections and in some interior valleys, much of the precipitation fell as rain or rain mixed with snow. This caused considerable ponding and localized flooding in poorly drained areas.

The greatest damage from this storm was due to coastal flooding. Serious coastal flooding occurred along the Massachusetts coastline during the 11th to 13th, the most damaging storm tide occurring early afternoon on the 12th. The Boston tide gage recorded a peak elevation of 14.21 feet above mean lower low water, 1 foot less than the highest elevation on record at that location, from the Blizzard of '78. A 350-foot breach of Hull's Nantasket Beach seawall occurred. Most east-facing shoreline communities from Chatham to Provincetown and Plymouth to the North Shore, as well as Nantucket Island, experienced some level of coastal flood damage. Dunes were washed away in Hull and Duxbury. As much as 20 feet of dune was lost in Sandwich and up to 25 feet in Ipswich. Many coastal road closings occurred. Dock damage occurred, and some cottages were destroyed by the sea (Marine, 1994).

Heavy Snow / Nor'easter—March 1994

A strong nor'easter passed to the southeast of Cape Cod, resulting in heavy snow and blowing and drifting snow. Snowfall totals ranged between six and 15 inches from the Boston metro area west and north. Over southeast Massachusetts, between three and six inches of snow fell before it changed to rain. Wind gusts of up to 40 and 60 mph resulted from this event and created snow drifts of up to three feet. Buildings were damaged, businesses and schools were closed, and highway travel was disrupted. The Commonwealth had approximately $5 million in property damage.

Blizzard/Nor'easter (EM-3201)—January 22-23, 2005

A major winter storm brought heavy snow, high winds, and coastal flooding to southern New England. In Massachusetts, blizzard conditions were reported on Nantucket. This was the first blizzard to affect the Commonwealth since the April 1997 storm. Near-blizzard conditions were reported in other areas and brought between one and three feet of snow and produced wind gusts of up to 65 mph.

The highest snowfall totals were reported in eastern Massachusetts (between two and three feet). Minor to moderate coastal flooding was observed around high tide in eastern Massachusetts coast. Coastal flooding was most severe near Hull, Scituate, and Marshfield, where several roads were inundated and evacuations occurred. This event resulted in a FEMA emergency declaration (FEMA EM-3201). Those counties included in the disaster received over $49 million in public assistance from FEMA.

Coastal Storm / Nor'easter—October 2005 (DR-1614)

A strong nor'easter, combined with the remnants of Tropical Storm Wilma, brought heavy rainfall, damaging winds, and coastal flooding to the eastern portion of Massachusetts (see Figure 13-1). Rainfall totals ranged between two and 2.5 inches. The high winds brought down limbs, trees, and wires, resulting in power outages to thousands of people. This event caused approximately $733,000 in property damage.

Severe Storms and Inland and Coastal Flooding (Nor'easter) (DR-1701)—April 2007 (Patriot's Day Event)

An intense coastal storm (April 15-16, 2007) brought wet snow, sleet and rain to parts of western Massachusetts. Snowmelt and heavy rain between 3 and 6 inches led to moderate flooding of small streams and creeks in parts of the Commonwealth, particularly in the lower Merrimack River Basin/mainstream and tributaries. During the peak of the storm, approximately 90,000 customers were without power statewide. This event resulted in a federal disaster declaration (FEMA DR-1701). Counties included in this disaster received over $8 million in public assistance from FEMA. The storm was primarily a rain event due to warmer temperatures; however, higher elevations experienced significant snow and ice accumulations.

> "I have never seen anything like this in 30 years where the entire town is without power."
> *Townsend Board of Selectmen*
> *Quote from Worcester Telegram & Gazette*

Figure 13-1. Coastal Storm Surge During October 2005 Storm

Winter Storm/Nor'easter (DR-1959)—January 11-12, 2011

A developing nor'easter coastal storm brought up to two feet of snow across Massachusetts in a 24-hour period. Strong winds, combined with heavy snow, produced numerous downed trees and wires and resulted in power outages to 100,000 homes statewide. Wind gusts between 49 and 57 mph were recorded in Eastham, Barnstable, Harwich, and Chatham. Between seven and 10 inches of snow was reported in southern Bristol County. The County had approximately $75,000 in property damage. This event resulted in a federal disaster declaration (FEMA DR-1959) for the following counties: Berkshire, Essex, Hampden, Hampshire, Middlesex, Norfolk, and Suffolk. Those counties received over $25 million in public assistance grants.

Severe Storm/Nor'easter (DR-4051)—October 29-30, 2011

A rare October nor'easter brought heavy snow to portions of southern New England on October 29. Snowfall accumulations of one to two feet were common in the Monadnocks, Berkshires, Connecticut Valley, and higher elevations in central Massachusetts. Up to 31 inches of snow was reported in Plainfield, Massachusetts. The accumulation of the heavy, wet snow on trees and power lines resulted in widespread tree damage and power outages across central and western Massachusetts. At the peak, approximately 665,000 customers in Massachusetts were without power. Seventy-seven shelters were opened and housed over 2,000 residents. Governor Patrick declared a state of emergency on October 29. Six fatalities occurred during and in the aftermath of the storm. The Commonwealth had approximately $300,000 in property damage from this nor'easter event. This event resulted in a federal emergency declaration (FEMA EM-3343) for the following counties: Berkshire, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, and Worcester.

13.2.3 Probability of Future Occurrences

Nor'easters may occur at any time of the year; however, they are most common from September through April. Nor'easters are a major concern for Massachusetts' residents not only because of the damage potential in any given storm, but because of their frequent rate of occurrence.

For the purposes of this plan, the probability of future occurrences is defined by the number of events for over a specified period of time. The historical record indicates the Commonwealth has only experienced three nor'easter-related federally declared from 1954 to 2012. This figure greatly underestimates how often nor'easters occur in the Northeast and impact Massachusetts. Based on the historical record of the top 40 events from 1953 to 2011, nor'easters have an average frequency of 1 or 2 per year. While in a typical year it is unlikely to have multiple nor'easter events, some years, such as 2010, experienced four (4) events.

13.2.4 Severity

The magnitude or severity of a nor'easter depends on several factors including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, and time of occurrence during the day (e.g., weekday versus weekend), and time of season. The severity of a nor'easter also depends on the time of occurrence relative to the lunar tide cycles (spring or neap tides) and during what tide stage the maximum storm surge occurs at (high tide or low tide).

13.2.5 Warning Time

Meteorologists can often predict the likelihood of a nor'easter event. NOAA's National Weather Service monitors potential nor'easter events, and provides forecasts and information several days in advance of the storm in order to help prepare for the incident.

Nor'easters are a common winter occurrence in the Commonwealth of Massachusetts and New England and repeatedly result in flooding, various degrees of wave and erosion damage to structures, and erosion of natural resources, such as beaches, dunes, and coastal bluffs. The erosion of coastal features commonly results in greater potential for damage to shoreline development from future storms.

13.3 CLIMATE CHANGE IMPACTS

Climate change refers to unstable weather patterns caused by increases in the average global temperature. Greenhouse gases form a blanket of pollution that stays in the atmosphere and may be the ultimate cause of climate change instability characterized by severe weather events such as storms, droughts, floods, head waves, and sea level rise.

Weather extremes are likely to become more frequent and cause more damage under a changing climate. Although no specific storm is directly linked to climate change, an increasing number of events could become more common. These storms could cause downed power lines, overburdened septic systems, and travel delays.

Climate change may also lead to coastal impacts. Massachusetts may lose beachfront in the coming years as climate change may cause rising sea levels and stronger coastal storms, including nor'easters. In addition, climate change will result in significant impacts on the coast and ocean waters of Massachusetts. On the coast, changes in temperature can have major impacts on sensitive ecosystems.

Sea level rise will exacerbate impacts on development, infrastructure, and natural systems from erosion and storm damage. Impacts may include loss of life; extensive property damage; destruction of public infrastructure; release of sewage, oil, debris, and other contaminants; and loss of commercial and marine-related businesses critical to local, regional, and state economies.

New England is expected to experience changes in the amount, frequency, and timing of precipitation.

13.4 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the nor'easter hazard the entire Commonwealth of Massachusetts is exposed, more specifically the wind and rain/snow associated with these events. However, certain areas, types of building and infrastructure are at greater risk than others due to proximity to the coast and/or their manner of construction. Storm surge from a nor'easter poses one of the greatest risks to residents and property.

The following discusses the Commonwealth of Massachusetts exposure to the nor'easter hazard including:

- Population
- State facilities
- Critical facilities
- Economy

There are similarities and differences between nor'easters and hurricane events, as shown earlier in Table 13-1. Both types of events can bring high winds and surge inundation resulting in similar impacts on the population, structures, and the economy. For the purposes of this plan, the Hazus-MH wind/surge model was used to estimate potential losses to the February 1978 nor'easter with current (2010) population and built environment.

13.4.1 Population

The impact of a nor'easter on life, health, and safety is dependent upon several factors including the severity of the event and whether or not adequate warning time was provided to residents. It is assumed that the entire Commonwealth's population is exposed to this hazard (wind and rain/snow). Figure 13-3 displays the peak gust wind speeds of the 1978 nor'easter modeled in Hazus-MH.

Of the population exposed, the most vulnerable include the economically disadvantaged and population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact on their families. The population over the age of 65 is also more vulnerable because they are more likely to seek or need medical attention which may not be available due to isolation during a flood event, and they may have more difficulty evacuating. Section 4 summarizes the Commonwealth's demographics.

A nor'easter surge inundation zone does not exist to estimate the population exposed. To estimate the population exposed to storm surge, the SLOSH Category 1 through 4 zones were overlaid upon the 2010 Census block population data in GIS (U.S. Census 2010). Census blocks do not follow the boundaries of the floodplain. The Census blocks with their centroid in the SLOSH boundaries were used to calculate the estimated population exposed to the hurricane surge hazard. Table 11-4 summarizes the 2010 Census population in the Category 1 through 4 SLOSH zones by County.

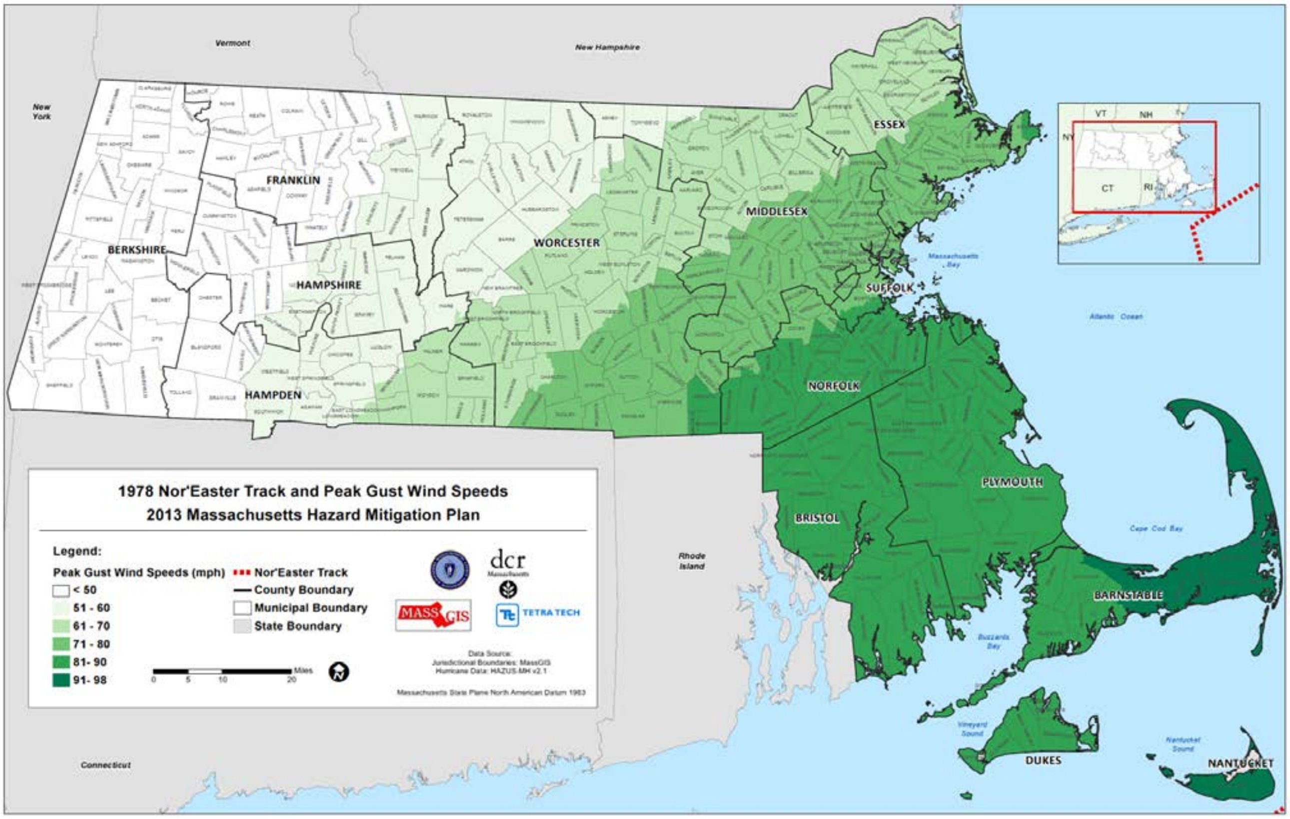

Figure 13-2. Peak Gust Wind Speeds for the 1978 Nor'easter Event in Massachusetts

13.4.2 State Facilities

All Commonwealth state-owned and leased buildings are exposed to the wind and/or rain/snow from the nor'easter hazard. Table 11-5 summarizes the total replacement cost value of all 6,765 state-owned and leased buildings in the Commonwealth. Table 11-6 summarizes the buildings located in the SLOSH zones as a general indication of buildings at risk to storm surge.

13.4.3 Critical Facilities

A nor'easter event may happen and impact anywhere in the Commonwealth; therefore, all critical facilities are exposed to this hazard. Critical facilities and infrastructure at greatest risk are those that may be impacted by storm surge. Tables 11-10 through 11-12 provide a complete listing of the critical facilities, highway bridges, and roadways exposed to the SLOSH model's inundation zones.

13.4.4 Economy

Nor'easter events can greatly impact the economy, including loss of business function, damage to inventory (utility outages), relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. The entire Commonwealth is exposed to a nor'easter event.

Damage to buildings can impact a community's economy and tax base. The area of each County (square miles) exposed to the SLOSH inundation zones is listed by County in Table 11-13. Of the nine Counties with area in the SLOSH inundation zones, four have more than 10 percent of their area in the Category 1 boundary. Suffolk County has the greatest percent of its area in the inundation zones, from 21.5 percent in Category 1 to 42.5 percent in Category 4. The Islands (Dukes and Nantucket Counties) and Barnstable County also have a large percentage of their total area exposed to storm surge inundation.

13.5 VULNERABILITY

To assess the Commonwealth's vulnerability to the nor'easter hazard, potential losses were determined for an historical event selected by the SHMT and the THIRA workgroup: February 1978 nor'easter.

13.5.1 Population

Residents may be displaced or require temporary to long-term sheltering. In addition, downed trees, damaged buildings, and debris carried by high winds can lead to injury or loss of life. Socially vulnerable populations are most susceptible, based on a number of factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing.

The 1978 historical event was run in Hazus-MH to estimate the sheltering needs should this event occur today. The estimated shelter needs due to wind-only impacts are summarized in Table 13-6. All counties, with the exception of Barnstable and Berkshire Counties, have experienced an increase in population growth since the 2000 Census (see Section 4). Therefore, the numbers in Table 13-6 are conservative.

13.5.2 State Facilities

Hazus-MH does not estimate potential dollar losses to critical facilities at this time. When this capability is available, the Commonwealth can enhance this section of the plan. Due to the similarities in impacts from a hurricane and nor'easter, the potential losses to state-owned and leased structures due to storm surge calculated using the SLOSH data can be used. All 6,765 state-owned/leased structures in the Commonwealth are exposed to the nor'easter hazard. Table 11-5 summarizes their total replacement cost value.

TABLE 13-6.
ESTIMATED SHELTER NEEDS FOR 1978 NOR'EASTER;
WIND-ONLY ANALYSIS (U.S. CENSUS 2000)

County	Displaced Households	Short Term Shelter Needs
Barnstable	68	12
Berkshire	0	0
Bristol	107	31
Dukes	1	0
Essex	4	1
Franklin	0	0
Hampden	0	0
Hampshire	0	0
Middlesex	22	1
Nantucket	2	0
Norfolk	65	10
Plymouth	51	11
Suffolk	99	22
Worcester	1	0
Total	**420**	**88**

Source: Hazus-MH v. 2.1

Structures located in the storm surge inundation areas are at greatest risk to surge-related damage. A total risk exposure of nearly $6.2 billion is estimated for state-owned and leased buildings located in the

Category 1 through 4 SLOSH zones. The Hurricane Category 4 SLOSH depth grids provided by FEMA Region IV were imported into the Hazus-MH flood model and the potential losses were estimated for the state-owned and leased facilities. Tables 11-15 and 11-16 summarize the potential losses by County and agency, respectively.

13.5.3 Critical Facilities

Hazus-MH does not estimate potential dollar losses to critical facilities at this time. When this capability is available, the Commonwealth can enhance this section of the plan. For the purposes of this plan update, to estimate potential losses to critical facilities and infrastructure, the exposure analysis methodology was used. As mentioned earlier, all critical facilities and infrastructure are exposed to nor'easter winds and rain/snow (see Tables 11-10 through 11-12); however, those located within the surge inundation zones are at greater risk. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would be equal to the full replacement value of each critical facility exposed.

At this time, Hazus-MH 2.1 does not estimate losses to transportation lifelines and utilities as part of the hurricane model. Transportation lifelines are not considered particularly vulnerable to the wind hazard; they are more vulnerable to cascading effects such as flooding, falling debris etc. Impacts to transportation lifelines affect both short-term (e.g., evacuation activities) and long-term (e.g., day-to-day commuting) transportation needs. In terms of highway bridges, the Hazus-MH v. 2.1 default replacement cost value for the bridges located in the SLOSH Category 1 through 4 hazard areas is $17 billion (of the greater than $68 billion total).

13.5.4 Economy

Nor'easter events, similar to hurricanes and tropical storms, can greatly impact the economy, including loss of business function (e.g., tourism, recreation), damage to inventory, relocation costs, wage loss, and rental loss due to the repair/replacement of buildings. Hazus-MH estimates the total economic loss associated with each storm scenario (direct building losses and business interruption losses). Direct building losses are the estimated costs to repair or replace the damage caused to the building.

A Hazus-MH analysis was conducted to determine the combination wind and surge impacts from the 1978 nor'easter event for the entire Commonwealth building stock. Because of differences in building 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 wind damage than concrete or steel buildings. Table 13-7 summarizes the estimated building loss (structure and contents). Total damage reflects the overall impact at an aggregate level.

TABLE 13-7.
ESTIMATED BUILDING LOSS FROM HAZUS WIND AND STORM SURGE ANALYSIS (STRUCTURE AND CONTENTS REPLACEMENT COST VALUE) 1978 NOR'EASTER

County	Total (Wind and Surge)	Total Wind Only	Total Surge Only
Barnstable	$590,093,258	$194,949,258	$395,144,000
Berkshire	$0	$0	$0
Bristol	$204,625,675	$176,935,675	$27,690,000
Dukes	$53,040,437	$13,157,437	$39,883,000
Essex	$732,222,926	$64,446,927	$667,775,999
Franklin	$484,957	$484,957	$0
Hampden	$5,963,018	$5,963,018	$0
Hampshire	$1,897,908	$1,897,908	$0

TABLE 13-7.
ESTIMATED BUILDING LOSS FROM HAZUS WIND AND STORM SURGE ANALYSIS (STRUCTURE AND CONTENTS REPLACEMENT COST VALUE) 1978 NOR'EASTER

County	Total (Wind and Surge)	Total Wind Only	Total Surge Only
Middlesex	$462,591,150	$221,504,150	$241,087,000
Nantucket	$24,544,131	$17,829,131	$6,715,000
Norfolk	$427,367,579	$231,024,579	$196,343,000
Plymouth	$555,012,866	$242,940,866	$312,072,000
Suffolk	$1,317,085,107	$134,302,106	$1,182,783,001
Worcester	$60,441,016	$60,441,016	$0
Total	**$4,435,370,029**	**$1,365,877,029**	**$3,069,493,001**

Source: Hazus-MH v. 2.1

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. Table 13-8 summarizes the economic losses generated by Hazus-MH's wind model for the 1978 nor'easter event.

TABLE 13-8.
ESTIMATED ECONOMIC LOSS - WIND ONLY HAZUS ANALYSIS HAZUS (U.S. CENSUS 2000)

	1978 Nor'easter				
County	Inventory	Relocation	Income	Rental	Wage
Barnstable	$103,177	$7,139,400	$1,175,329	$4,902,295	$1,481,350
Berkshire	$0	$0	$0	$0	$0
Bristol	$82,310	$5,691,937	$249,251	$5,351,144	$88,553
Dukes	$7,098	$459,138	$69,722	$328,793	$92,091
Essex	$2,463	$1,054,740	$0	$1,136,239	$0
Franklin	$0	$84	$0	$0	$0
Hampden	$0	$3,980	$0	$0	$0
Hampshire	$0	$917	$0	$0	$0
Middlesex	$3,187	$2,017,793	$0	$2,638,504	$0
Nantucket	$10,385	$782,505	$194,022	$486,607	$266,986
Norfolk	$36,595	$4,638,261	$94,102	$3,866,167	$33,432
Plymouth	$52,313	$5,003,665	$235,416	$3,302,624	$201,368
Suffolk	$14,660	$4,656,222	$2,646	$6,328,687	$946
Worcester	$101	$407,748	$0	$562,705	$0
Total	**$312,289**	**$31,856,390**	**$2,020,489**	**$28,903,765**	**$2,164,726**

Source: Hazus-MH v. 2.1

Hazus-MH 2.1 also estimates the amount of debris that may be produced a result of wind events. Table 13-9 summarizes the debris produced from the wind only aspect of the storm hazard. Because the estimated debris production does not include flooding, this is likely a conservative estimate and may be higher if multiple impacts occur. Note the following from the Hazus-MH Hurricane User Manual:

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

TABLE 13-9.
ESTIMATED DEBRIS - 1978 NOR'EASTER WIND ONLY ANALYSIS (U.S. CENSUS 2000)

County	Brick/Wood (tons)	Concrete (tons)	Trees (tons)	Tree Volume (cubic yards)
Barnstable	24,660	9	117,205	1,172,065
Berkshire	0	0	0	0
Bristol	21,168	0	148,211	1,482,129
Dukes	1,501	0	20,208	202,087
Essex	7,521	0	30,721	307,241
Franklin	0	0	7,316	73,159
Hampden	54	0	8,360	83,580
Hampshire	6	0	6,361	63,607
Middlesex	20,497	0	55,718	557,140
Nantucket	2,321	2	5,969	59,686
Norfolk	19,269	0	81,312	813,137
Plymouth	16,779	0	237,870	2,378,770
Suffolk	26,011	0	5,458	54,584
Worcester	5,091	0	62,853	628,508
Total	**144,878**	**11**	**787,562**	**7,875,693**

Source: Hazus-MH v. 2.1