TABLES

FIGURES

SECTION 15. SEVERE WINTER WEATHER

15.1 GENERAL BACKGROUND

15.1.1 Snow and Blizzards

Snow is frozen precipitation in the form of a six-sided ice crystal. Snow formation requires temperatures to be below freezing in all or most of the atmosphere from the surface up to cloud level.

Snow can fall when surface temperatures are above freezing in a relatively shallow layer. In situations like this, the snow will not have enough time to melt before reaching the ground - though it will be quite wet with large flakes, the result of wet snowflakes sticking to one another.

Generally, ten inches of snow will melt into one inch of water. Sometimes the snow-liquid ratio may be much higher - on the order of 20:1 or 30:1. This commonly happens when snow falls into a very cold air mass, with temperatures of 20 degrees or less at ground level.

Blowing snow is wind driven snow that reduces visibility to six miles or less causing significant drifting. Blowing snow may be snow that is falling and/or loose snow on the ground picked up by the wind.

A blizzard is a winter snowstorm with sustained or frequent wind gusts to 35 mph or more, accompanied by falling or blowing snow reducing visibility to or below a quarter-mile. These conditions must be the predominant condition over a 3-hour period. Extremely cold temperatures are often associated with blizzard conditions, but are not a formal part of the definition. However, the hazard created by the combination of snow, wind, and low visibility increases significantly with temperatures below 20ºF.

A severe blizzard is categorized as having temperatures near or below 10 °F, winds exceeding 45 mph, and visibility reduced by snow to near zero.

Storm systems powerful enough to cause blizzards usually form when the jet stream dips far to the south, allowing cold air from the north to clash with warm air from the south. Blizzard conditions often develop on the northwest side of an intense storm system. The difference between the lower pressure in the storm and the higher pressure to the west creates a tight pressure gradient, resulting in strong winds and extreme conditions due to the blowing snow.

Regional Snowfall Index (RSI)

NOAA's National Climatic Data Center (NCDC) is currently producing the Regional Snowfall Index (RSI) for significant snowstorms that impact the eastern two-thirds of the U.S. The RSI ranks snowstorm impacts on a scale from one to five, which is similar to the Fujita scale for tornadoes or the Saffir-Simpson scale for hurricanes. The RSI differs from the NESIS because it includes societal impacts. RSI is based on the spatial extent of the storm, the amount of snowfall, and the combination of the extent and snowfall totals with population (based on the 2000 Census) (NOAA-NCDC, 2011). Table 15-1 explains the five categories. The indices for RSI are calculated similar to those for NESIS; however, the new indices require region-specific parameters and thresholds for the calculations. The NCDC has analyzed and assigned RSI values to over 500 storms since 1900 (NOAA-NCDC, 2011).

TABLE 15-1.
RSI RANKING CATEGORIES

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

Source: NOAA-NCDC, 2011 (http://www.ncdc.noaa.gov/snow-and-ice/rsi/)

15.1.2 Ice Storms

Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects creating ice build-ups of 1/4th inch or more that can cause severe damage. An ice storm warning, now included in the criteria for a winter storm warning, is for severe icing. This is issued when 1/2 inch or more of accretion of freezing rain is expected. This may lead to dangerous walking or driving conditions and the pulling down of power lines and trees. A warning is used for winter weather conditions posing a threat to life and property.

Another form of freezing precipitation is ice pellets, which occur when snowflakes melt into raindrops as they pass through a thin layer of warmer air. The raindrops then refreeze into particles of ice when they fall into a layer of sub-freezing air near the surface of the earth.

Sleet occurs when raindrops fall into subfreezing air thick enough that the raindrops refreeze into ice before hitting the ground. Sleet is different from hail. Sleet is a wintertime phenomenon; hail falls from convective clouds (usually thunderstorms) under completely different atmospheric conditions - and often during the warm spring and summer months.

15.2 HAZARD PROFILE

15.2.1 Location

Snow and Blizzards

Figure 15-1 and Figure 15-2 illustrate the normal (30-year average) annual snow totals in New England and in the eastern U.S., respectively. Although the entire Commonwealth may be considered at risk, higher snow accumulations appear to be prevalent at higher elevations in Western and Central Massachusetts, and along the coast where snowfall can be enhanced by additional ocean moisture. The coastline is susceptible to the combination of both snow and coastal flooding during a nor'easter.

Source: Northeast Regional Climate Center

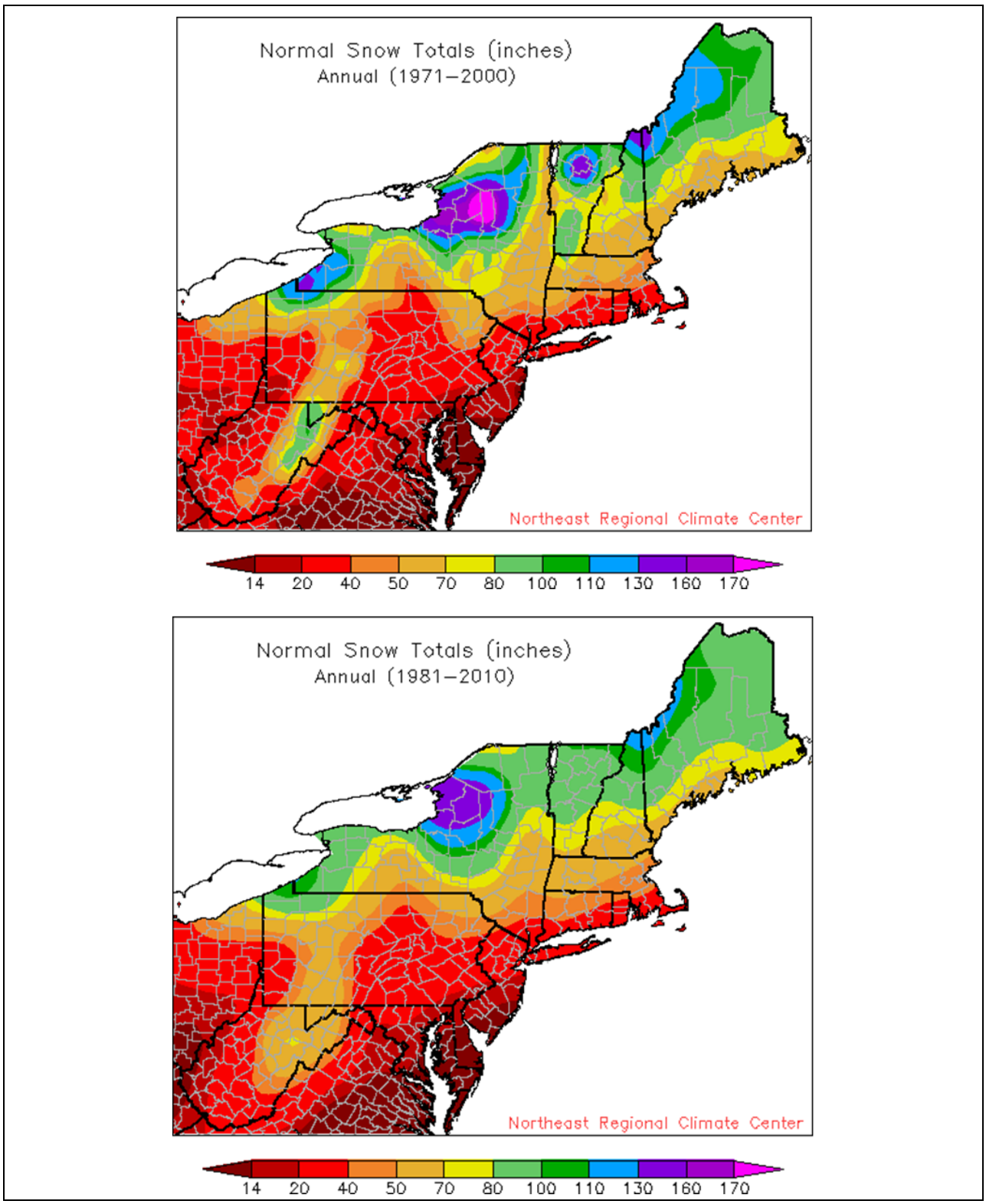

Figure 15-1. Normal Annual Snow Totals from 1971 to 2000 and 1981 to 2010

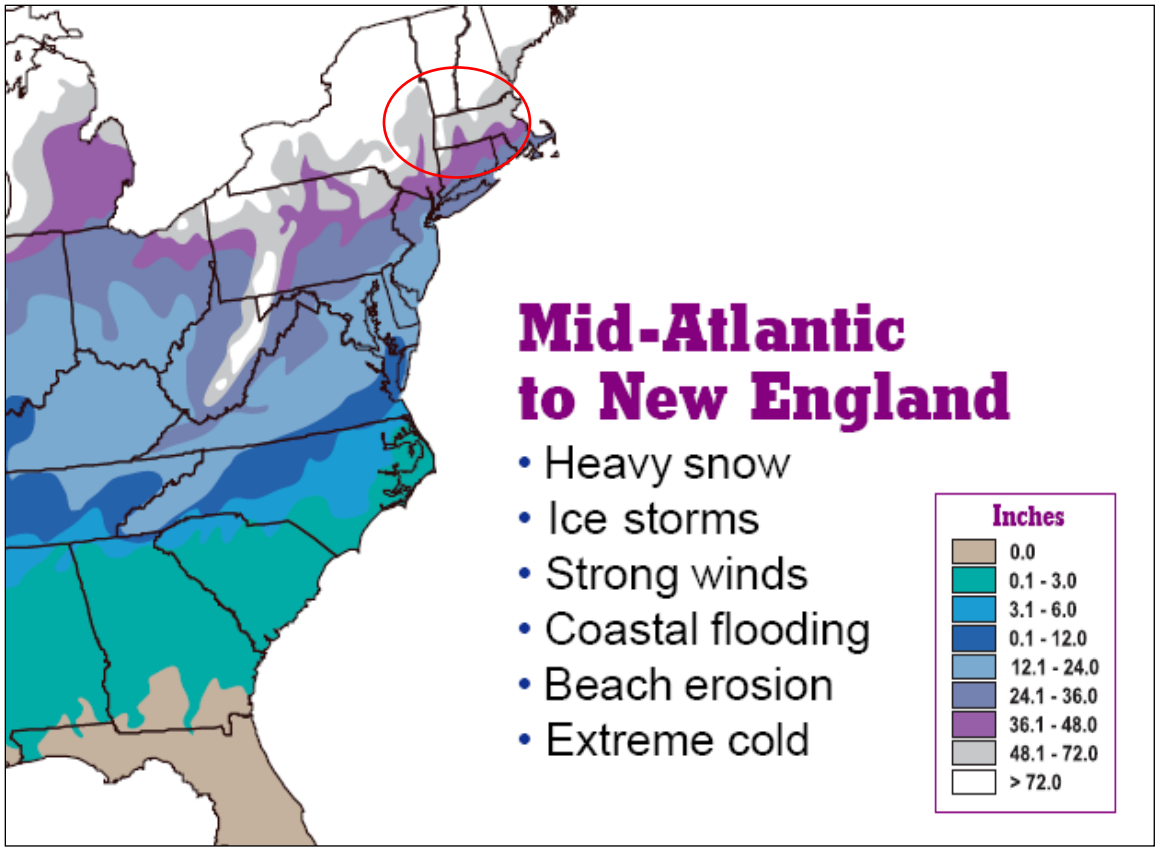

Figure 15-2. Annual Mean Snowfall Within the Eastern U.S.

Ice Storms

Ice storms can arise in any part of the Commonwealth, but they occur most frequently in the higher elevations of Western and Central Massachusetts. Table 15-2 and Figure 15-3 show the number of ice storm events each county has experienced since 1971.

TABLE 15-2.
ICE STORM EVENTS IN MASSACHUSETTS BY COUNTY

County	Number of Ice Events, 1971-2012	County	Number of Ice Events, 1971-2012
Worcester	27	Norfolk	9
Middlesex	22	Bristol	8
Essex	20	Plymouth	8
Hampshire	20	Suffolk	7
Hampden	19	Barnstable	3
Franklin	17	Dukes	0
Berkshire	13	Nantucket	0

Note: Incidents occurring within multiple counties are counted in each affected county.

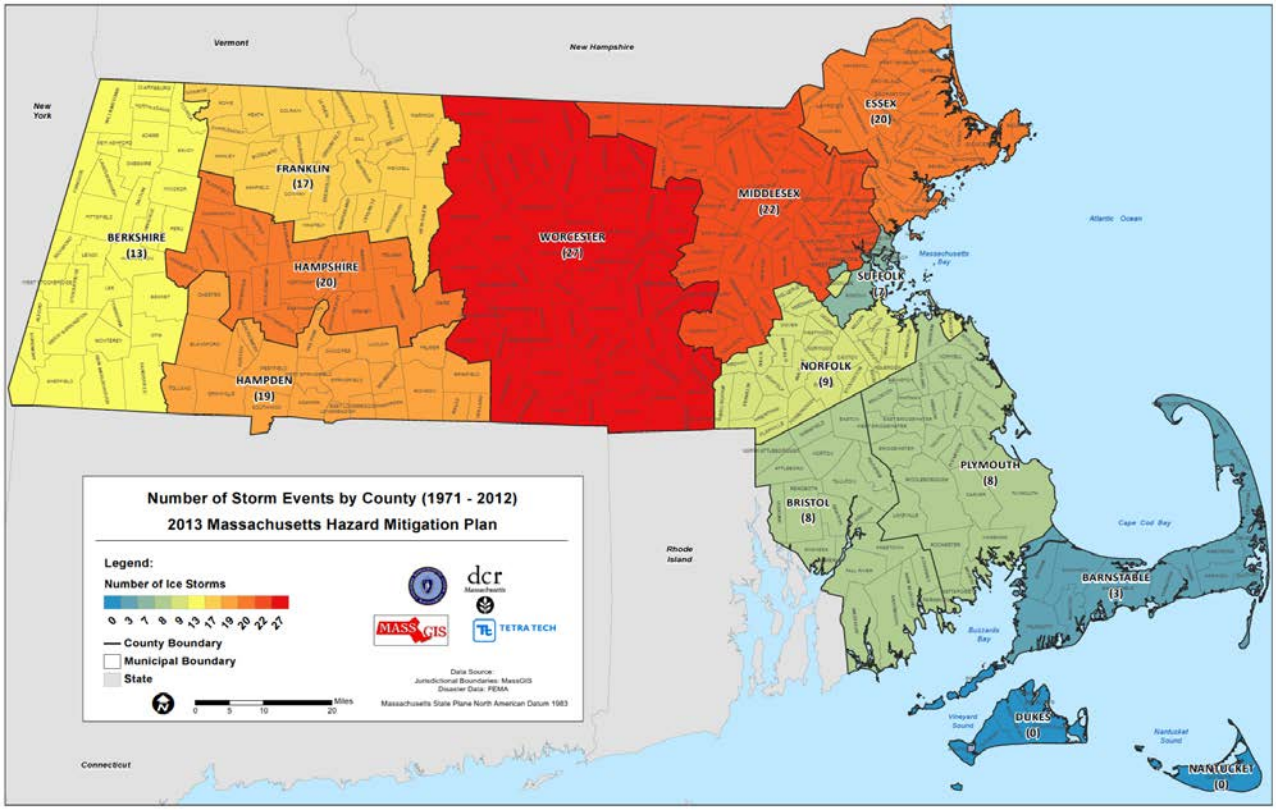

Figure 15-3. Number of Ice Storm Events in Massachusetts by County

15.2.2 Previous Occurrences

Snow and Blizzards

Snow and other winter precipitation occur very frequently across the entire Commonwealth. The total annual snowfall for 2011 is as follows (http://www.ncdc.noaa.gov/land-based-station-data/find-station):

- Blue Hill: 82.5 inches
- Boston: 60 inches
- Worcester: 94.6 inches

Ice Storms

From 1971 to 2012, there have been about 40 ice storm events which impacted at least one or more counties in the Commonwealth. All the storms within that period occurred between November and March, most frequently occurring in late December and early January. Ice storms of lesser magnitudes impact the Commonwealth on at least an annual basis.

Severe Winter Weather Events

Based on all sources researched, known winter weather events that have affected Massachusetts and were declared a FEMA disaster are identified in the following sections.

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

The February 1978 blizzard was a life-threatening nor'easter that crippled most of the Commonwealth with blizzard conditions, extreme snowfall, high winds, and devastating coastal flooding. The storm claimed 73 lives in Massachusetts and 26 in 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.

This blizzard peaked during the Monday evening rush hour and caused over 3,500 vehicles to be stranded on Route 128 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 wind peaked at 93 mph in Chatham. Snowfall generally ranged from 1 to 3 feet with a large swath of the southwest suburbs of Boston receiving over 30 inches. Snowfall reports included 32.5 inches in Rockport, 27.1 inches in Boston and 20.2 inches in Worcester.

Major coastal flooding occurred over multiple high tide cycles and destroyed or severely damaged over 2,000 homes. This storm set a record high water mark of 15.25 feet above mean lower low water at the Boston Harbor National Ocean Service tide gage. Waves in excess of 30 feet were reported just offshore. The storm triggered evacuations and rescues along both the North and South Shores. This event did result in a federal disaster declaration (FEMA DR-546).

Winter Coastal Storm (FEMA DR-975)—December 1992

From December 11 to 13, 1992, a strong nor'easter affected the Commonwealth. Impacts included intense snowfall, freezing rain, heavy rainfall near the coast, coastal flooding, and damaging winds. Storm total snowfall in Massachusetts was as high as 4 feet over the higher elevations of the Berkshires, with 48" reported in Beckett, Savoy, and Peru. Snow drifts as high as 12 feet were created in the Berkshires. Snowfall of 18" to 32" was common over central Massachusetts, with 6 to 20" over interior eastern Massachusetts. Some locations also 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 also 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 from December 11 to 13, the most damaging storm tide occurring early afternoon on December 12. 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 1978. 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. This event resulted in a federal disaster declaration (FEMA DR-975).

Blizzards, High Winds and Record Snowfall (FEMA EM-3103)—March 13-17, 1993

The March 13-17, 1993 storm brought high winds and heavy snow to Massachusetts. Boston's Logan Airport recorded a wind gust to 81 mph, and a gust to 83 mph occurred at the Blue Hill Observatory. Snowfall was generally 10 to 20 inches across the area except 20 to 30 inches over the Berkshires. Snowfall totals included 12.8 inches at Boston, 20.2 inches at Worcester, and 30 inches at both Florida and Peru in the Berkshires. Blizzard conditions existed for a 3 to 6 hour period during the afternoon of March 13. Unlike the December 1992 storm, the snow was a dry enough to minimize accumulation on trees and wires. This precluded widespread power outages. The storm's occurrence on the weekend mitigated traffic issues. The coastal flood potential was not realized, since the strongest onshore winds did not correspond to high tide and the duration was not long enough to produce exceptionally large waves. This storm impacted the entire eastern third of the country and resulted in a federal disaster declaration (FEMA EM-3103).

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 (FEMA DR-1090)—January 7-8, 1996

This storm was one of the most significant winter storms to hit southern New England in the past 20 years. It brought record snowfalls to the mid-Atlantic states to southern New England. Snowfall totals of 13 to 18 inches were reported in Cape Cod. Between 15 and 25 inches fell in Plymouth and Bristol Counties. More than 20 inches were reported in Hampden and Hampshire Counties and more than 30 inches in the Berkshires. Strong to gale-force northeast winds were also associated with this event. Storm surges were between 1.9 and 2.7 feet at the Boston tide gauge. Minor coastal flooding was experienced. On the eastern shore of Nantucket Island, high waves and strong currents eroded sand dunes. The Commonwealth experienced over $350,000 in property damage. MEMA reported damage claims of approximately $32 million from 350 communities, mostly for the cost of snow removal. This event resulted in a FEMA disaster declaration (FEMA DR-1090).

Heavy Snow (EM-3165)—March 5-6, 2001

A major winter storm impacted Massachusetts with near blizzard conditions, high winds, and coastal flooding. It brought over two feet of snow across the interior and caused power outages to approximately 80,000 people. Businesses and schools were closed for several days. There were numerous reports of downed trees and wires during the height of the storm. After the storm, the weight of the snow caused several roof collapses throughout the Commonwealth. The highest snowfall totals were reported from the east slopes of the Berkshires across Worcester County and into northeast Massachusetts. Northeast winds affected much of the east coast and southeast of Massachusetts. Speeds of 50 to 60 mph were observed. High tides during the storm were two to three feet above normal, which resulted in widespread coastal flooding. This event resulted in a FEMA emergency declaration (FEMA EM-3165). Those counties included in the declaration received over $21 million in public assistance grants from FEMA.

Winter Storm (EM-3175)—February 17-18, 2003

A major winter storm struck southern New England, bringing heavy snow and strong winds. This event was the most significant of the 2002-2003 winter, with snowfall totals of one to two feet. The highest totals were around two feet and were reported in two areas: east slopes of the Berkshires into northern Worcester County and over Boston's South Shore communities. This snowstorm ranked in the top 10 for Boston and Worcester. This event resulted in a FEMA emergency declaration (FEMA EM-3175). Those counties included in the declaration received over $28 million in public assistance grants from FEMA.

Winter Storm (EM-3191)—December 6-7, 2003

A major winter storm brought 1 to 3 feet of snow and strong winds to southern New England. In Massachusetts, snowfall amounts averaged between one and two feet across the Commonwealth. Some areas near Cape Cod only received between six and 12 inches. The highest snowfall was reported in Peabody, where 36 inches of snow fell. Minor coastal flooding was reported due to high seas of up to 30 feet off the eastern coast. One fatality was indirectly attributed to the storm. A commuter-rail work was struck by a freight train as they were clearing snow from the tracks near the Wellesley Hills station. This event resulted in a FEMA emergency declaration (FEMA EM-3191). Those counties included in the declaration received over $35 million in public assistance grants from FEMA.

Blizzard (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.

Severe Storms and Flooding (Nor'easter) (FEMA DR-1701)—April 2007

An intense coastal storm (April 15-16, 2007) brought wet snow, sleet and rain to parts of western Massachusetts. Snowmelt and heavy rain between three and six 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. This event resulted in a federal disaster declaration (FEMA DR-1701). Those 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.

Severe Winter Storm and Flooding (FEMA DR-1813)—December 2008

A major ice storm and significant precipitation affected much of New England (December 11 through 12). The ice storm struck across interior Massachusetts, southern New Hampshire, and much of northern New England. The hardest hit areas were the Worcester Hills in central Massachusetts and the east slopes of the Berkshires in western Massachusetts. At least half an ice of ice accreted on many exposed surfaces. The ice downed many trees, branches, and power lines, which resulted in widespread power outages. More than 300,000 people were without power in the Commonwealth. Heavy rain fell in parts of Massachusetts (Berkshire, Worcester, Bristol, and Middlesex Counties), leading to minor to moderate flooding and ponding of water in low-lying, poor drainage areas, streams, creeks, and brooks. Several roadways were closed due to flooding. Rainfall totals ranged between one and four inches. There was one death in Massachusetts associated with this storm. This event resulted in a federal disaster declaration (FEMA DR-1813). Those counties included in the disaster received over $51 million in public assistance from FEMA.

Severe Winter Storm and Snowstorm (FEMA 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.

RSI Events

Table 15-3 lists RSI values of winter storm events for the past 20 years. This table shows the regional RSI values for the Northeast region as well as the area and population of snowfall for those storms.

TABLE 15-3.
RSI AND SOCIETAL IMPACTS FOR THE NORTHEAST

Start Date	End Date	Category	RSI	Area of Snow	Population
2/13/1993	2/17/1993	1	2.223	174,671	57,059,500
2/19/1993	2/23/1993	1	2.291	174,690	57,062,555
3/11/1993	3/14/1993	5	20.465	174,690	57,062,622
12/31/1993	1/4/1994	1	2.911	173,556	56,914,705
1/3/1994	1/8/1994	1	2.62	173,393	56,887,967
1/15/1994	1/17/1994	1	2.995	174,680	57,062,212
2/21/1994	2/24/1994	1	1.917	173,345	56,885,145
2/27/1994	3/3/1994	2	4.448	174,690	57,062,623
2/1/1995	2/5/1995	2	4.535	174,690	57,062,563
12/17/1995	12/21/1995	2	3.551	174,680	57,061,297
1/5/1996	1/8/1996	5	20.281	162,082	56,617,484
1/31/1996	2/3/1996	1	1.349	128,600	52,977,105
3/2/1996	3/8/1996	2	3.259	174,681	57,050,954
4/8/1996	4/10/1996	1	1.726	174,498	57,033,178
1/7/1997	1/11/1997	1	1.597	174,690	57,062,621
3/30/1997	3/31/1997	2	4.666	172,730	57,025,596
1/12/1999	1/15/1999	1	2.554	172,653	56,794,660
3/11/1999	3/15/1999	1	1.913	164,907	54,530,770
1/23/2000	1/26/2000	1	2.567	174,680	57,060,450
1/23/2000	1/31/2000	1	1.469	173,787	56,932,414
2/15/2000	2/19/2000	1	1.395	172,730	57,041,310
12/27/2000	12/31/2000	2	3.369	168,174	52,797,525
12/22/2002	12/25/2002	2	3.75	170,048	56,788,225
2/13/2003	2/17/2003	4	14.452	162,812	56,921,974
12/3/2003	12/7/2003	3	9.024	174,690	57,062,588
2/27/2005	3/1/2005	2	3.159	174,690	57,062,575
2/9/2006	2/13/2006	2	5.128	174,690	57,062,590
2/10/2007	2/15/2007	3	7.316	174,690	57,062,546

TABLE 15-3.
RSI AND SOCIETAL IMPACTS FOR THE NORTHEAST

Start Date	End Date	Category	RSI	Area of Snow	Population
3/15/2007	3/17/2007	2	3.351	173,614	56,930,626
4/2/2007	4/5/2007	1	1.162	161,380	46,978,423
11/29/2007	12/3/2007	1	1.393	169,674	55,864,530
12/13/2007	12/16/2007	1	1.844	166,195	53,716,405
2/20/2008	2/23/2008	1	1.005	174,603	57,061,670
12/17/2008	12/21/2008	1	2.792	174,671	57,060,880
12/20/2008	12/22/2008	2	3.095	174,661	57,059,860
1/8/2009	1/11/2009	1	1.059	168,809	54,332,392
2/21/2009	2/23/2009	1	1.56	169,232	55,409,126
2/25/2009	3/2/2009	1	1.515	170,865	56,437,990
2/28/2009	3/2/2009	1	1.58	174,411	57,038,130
12/6/2009	12/10/2009	1	1.805	169,501	55,845,477
12/17/2009	12/20/2009	1	2.743	130,407	54,528,591
12/27/2009	1/3/2010	2	3.636	174,123	57,008,734
2/2/2010	2/6/2010	3	7.939	86,624	41,413,490
2/3/2010	2/7/2010	3	8.438	90,161	48,490,403
2/4/2010	2/10/2010	2	3.368	147,138	56,328,325
2/7/2010	2/10/2010	2	3.117	146,081	56,302,907
2/11/2010	2/18/2010	1	1.16	174,421	57,029,770
2/20/2010	2/28/2010	4	15.853	174,690	57,062,541
12/23/2010	12/27/2010	2	3.272	174,690	57,062,573
1/8/2011	1/12/2011	2	3.495	174,680	57,057,940
1/25/2011	1/26/2011	1	2.652	174,431	57,059,999
2/23/2011	2/26/2011	1	1.85	155,720	42,991,280
10/24/2011	10/30/2011	1	1.969	157,459	54,140,301
1/11/2012	1/13/2012	1	1.067	167,137	53,414,773
12/25/2012	12/27/2012	1	2.157	176,516	59,057,229
2/6/2013	2/9/2013	3	9.04	174,133	58,806,535

FEMA Declarations

Based on all sources researched, known severe winter weather events that have affected Massachusetts, and were declared a FEMA disaster, are identified in Table 15-4 and displayed on Figure 15-4. This table provides detailed information concerning the FEMA declarations for the Commonwealth.

15.2.3 Frequency

Severe winter weather is a common occurrence each season in Massachusetts. According to NOAA-NCDC storm database, over 200 winter storm events occurred in the Commonwealth between 2000 and 2012. Therefore, winter weather is likely to occur every year.

15.2.4 Severity

The magnitude or severity of a severe winter storm depends on several factors including a region's climatological susceptibility to snowstorms, snowfall amounts, snowfall rates, wind speeds, temperatures, visibility, storm duration, topography, time of occurrence during the day (e.g., weekday versus weekend), and time of season.

TABLE 15-4.
FEMA WINTER STORM-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**
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**
DR-975	Winter Coastal Storm	12/21/92	12/11/92 - 12/13/92	X			X	X				X	X	X	X	X	X	**9**
EM-3103	Blizzards, High Winds and Record Snowfall	03/16/93	3/13/93 - 3/17/93	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
DR-1090	Blizzard	01/24/96	1/7/96 - 1/13/96	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3165	Snowstorm	03/28/01	3/5/01 - 3/7/01		X			X	X		X	X		X			X	**7**
EM-3175	Snowstorm	03/11/03	2/17/03 - 2/18/03	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
EM-3191	Snow	01/15/04	12/6/03 - 12/7/03	X	X	X		X	X	X	X	X		X	X	X	X	**12**
EM-3201	Snow	02/17/05	1/22/05 - 1/23/05	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**14**
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-1813	Severe Winter Storm and Flooding	01/05/09	12/11/08 - 12/18/08		X			X	X	X	X	X					X	**7**
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-4051	Severe Storm	10/01/11	10/29/11 – 10/30/11		X			X	X	X	X	X		X			X	**8**
Total				**8**	**10**	**6**	**7**	**12**	**9**	**9**	**10**	**10**	**6**	**10**	**8**	**8**	**9**	

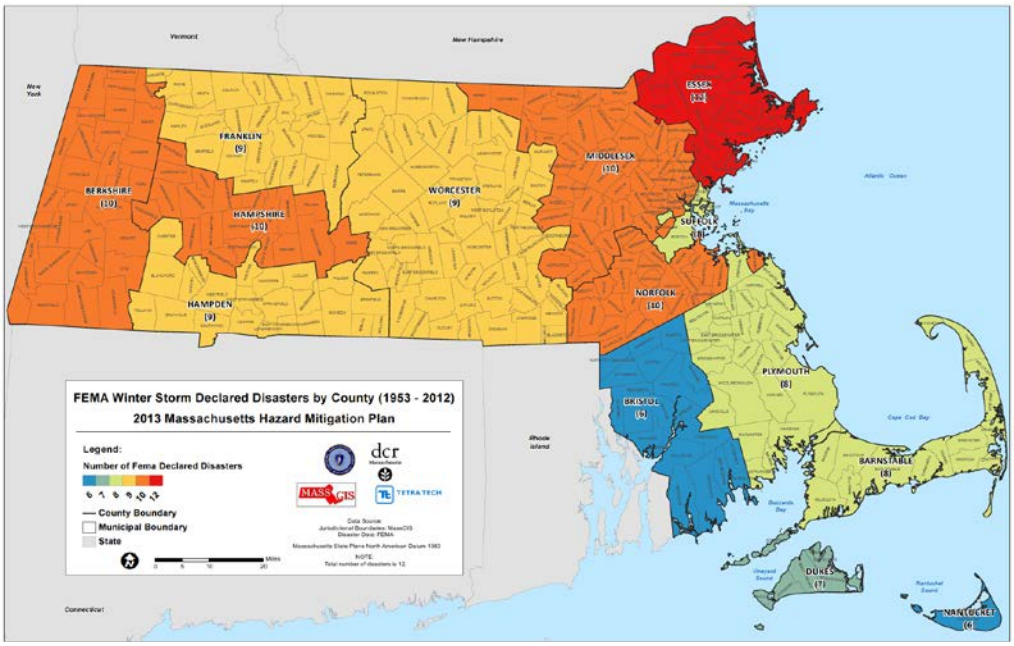

Figure 15-4. FEMA Winter Storm-Related Declared Disasters By County (1953 to 2012)

15.2.5 Warning Time

Meteorologists can often predict the likelihood of a severe storm. This can give several days of warning time. However, meteorologists cannot predict the exact time of onset or severity of the storm. Some storms may come on more quickly and have only a few hours of warning time.

15.3 SECONDARY HAZARDS

Structural damage (snow load); wind damage; impact to life safety; disruption of traffic; loss of productivity; economic impact; loss of ability to evacuate; taxing first responder capabilities; service disruption (power, water, etc.); communication disruption.

15.4 CLIMATE CHANGE IMPACTS

The climate of Massachusetts is changing and will continue to change over the course of this century. Since 1970, ambient air temperatures have increased by 1.8°F and the sea surface temperature by 2.3°F. These warming trends have been associated with other changes, including a 22-centimeter sea level rise between 1921 and 2006, more frequent days with temperatures above 90°F, reduced snowpack, and earlier snow melt and spring peak flows. By the end of the century, under the high emissions scenario of the Intergovernmental Panel on Climate Change, Massachusetts is expected to experience a 5°F to 10°F increase in average ambient temperature with several more days of extreme heat during the summer. Days with temperatures over 90°F are predicted to increase from five to 20 days annually; while up to 28 days annually are predicted to reach above 100°F. Sea surface temperatures are also expected to incase by 8°F (http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf).

Along with rising temperatures, it is expected that annual precipitation will increase by 14%, with a slight decrease in summer totals and a 30% increase in winter totals. Winter precipitation is predicted to be in the form of rain rather than snow. This change in precipitation will have significant effects on the amount of snow cover, winter recreation, spring snowmelt and peak stream flows, water supply, aquifer recharge, and water quality. The Commonwealth is located in an area where thresholds between snow and rain are sensitive and reductions in snow would be the largest. Snow is also predicted to fall later in the winter and cease falling earlier in the spring (http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf).

15.5 EXPOSURE

To understand risk, the assets exposed to the hazard areas are identified. For the severe winter weather hazard, the entire Commonwealth of Massachusetts is exposed. The following discusses the Commonwealth of Massachusetts' exposure to the severe winter weather hazard including:

- Population
- State facilities
- Critical facilities
- Economy

15.5.1 Population

According to the NOAA National Severe Storms Laboratory, every year, winter weather indirectly and deceptively kills hundreds of people in the U.S., primarily from automobile accidents, overexertion, and exposure. Winter storms are often accompanied by strong winds creating blizzard conditions with blinding wind-driven snow, drifting snow, and extreme cold temperatures with dangerous wind chill. They are considered deceptive killers because most deaths and other impacts or losses are indirectly related to the storm. Injuries and fatalities may occur due to traffic accidents on icy roads, heart attacks while shoveling snow, or of hypothermia from prolonged exposure to cold.

Heavy snow can immobilize a region and paralyze a city, shutting down air and rail transportation, stopping the flow of supplies, and disrupting medical and emergency services. Accumulations of snow can collapse buildings and knock down trees and power lines. In rural areas, homes and farms may be isolated for days, and unprotected livestock may be lost. Storms near the coast can cause coastal flooding and beach erosion as well as sink ships at sea. In the mountains, heavy snow can lead to avalanches (NSSL, 2006).

For the purposes of this Plan, the entire population of the Commonwealth of Massachusetts is exposed to severe winter weather events.

15.5.2 State Facilities

As part of a FEMA Hazard Mitigation Grant Program funded study, in 2010 the Northeast States Emergency Consortium developed regional hazard maps for snowfall for the Northeast. Using their GIS data, Figure 15-5 was created to display the number of days with greater than five-inches of snow. Using ArcMap GIS software, these data were overlaid with the DCAMM facility data and the snow data. Table 15-5 summarizes the number of state-owned and leased buildings in each of the four snow bands.

TABLE 15-5.
STATE BUILDINGS VULNERABLE TO SNOW AND BLIZZARD

Number of Days of Storms Totaling More than 5 Inches of Snow	State Structures in each Snow Band
Less than a half day per year	3,236
Half day to 2.4 days per year	2,847
2.5 days to 4.4 days per year	608
4.5 days to 7.4 days per year	74
Total	**6,765**

Source: DCAMM, 2012; NESEC, 2010

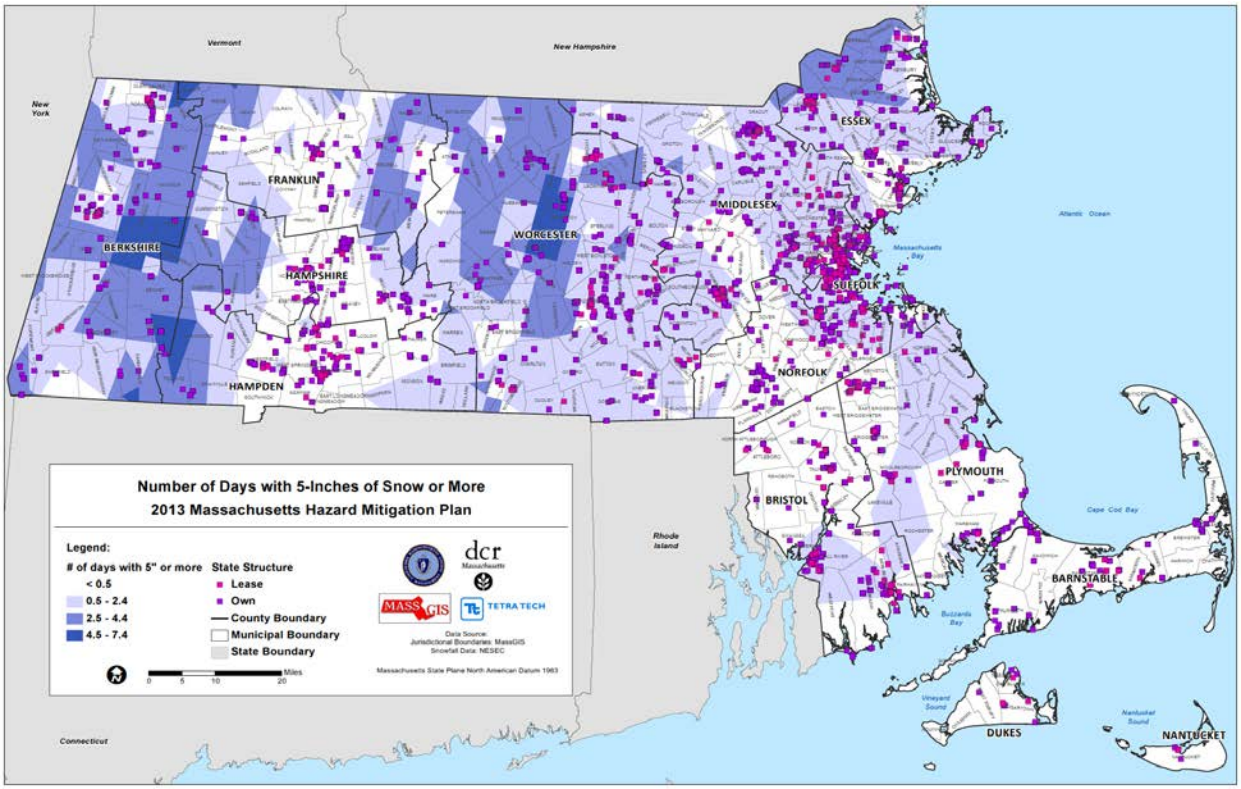

Figure 15-5. Number of Days with 5-inches of Snow or More

15.5.3 Critical Facilities

All critical facilities and infrastructure in the Commonwealth are exposed to the severe winter weather hazard. Table 15-6 summarizes the number of critical facilities in each of the four snow bands described earlier. Full functionality of critical facilities such as police, fire and medical facilities is essential for response during and after a winter storm event. Because power interruption can occur, backup power is recommended for critical facilities and infrastructure. Infrastructure at risk for this hazard includes roadways that could be damaged due to the application of salt and intermittent freezing and warming conditions that can damage roads over time.

TABLE 15-6
NUMBER OF CRITICAL FACILITIES EXPOSED TO THE SEVERE WINTER STORM HAZARD.

	Number of Facilities in each Snow Band					
Number of Days of Storms Totaling More than 5 Inches of Snow	Police	Fire	Emergency Operation Centers	Hospitals	Schools (pre-K-grade 12)	Colleges
Less than a half day per year	203	325	1	35	1,214	95
Half day to 2.4 days per year	181	382	1	42	1,383	106
2.5 days to 4.4 days per year	47	75	0	5	159	4
4.5 days to 7.4 days per year	6	7	0	0	11	0
Total	**437**	**789**	**2**	**82**	**2,767**	**205**

Source: DCAMM, 2012; NESEC, 2010

15.5.4 Economy

The entire general building stock inventory in the Commonwealth is exposed and vulnerable to the severe winter weather hazard. In general, structural impacts include damage to roofs and building frames, rather than building content. Figure 15-6 illustrates the snow loads on the roof for single-family construction. Heavy accumulations of ice can bring down trees, electrical wires, telephone poles and lines, and communication towers. Communications and power can be disrupted for days while utility companies work to repair the extensive damage. Even small accumulations of ice may cause extreme hazards to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces (NSSL, 2006).

15.6 VULNERABILITY

15.6.1 Population

Although the entire population of the Commonwealth is exposed to the severe winter weather hazard, the elderly are considered most susceptible due to their increased risk of injury and death from falls and overexertion and/or hypothermia from attempts to clear snow and ice, or related to power failures. In addition, severe winter weather events can reduce the ability of these populations to access emergency services. Residents with low incomes may not have access to housing or their housing may be less able to withstand cold temperatures (e.g., homes with poor insulation and heating supply). Refer to Section 4 for population statistics summarizing the more vulnerable populations (over the age of 65 and individuals living below the Census poverty threshold).

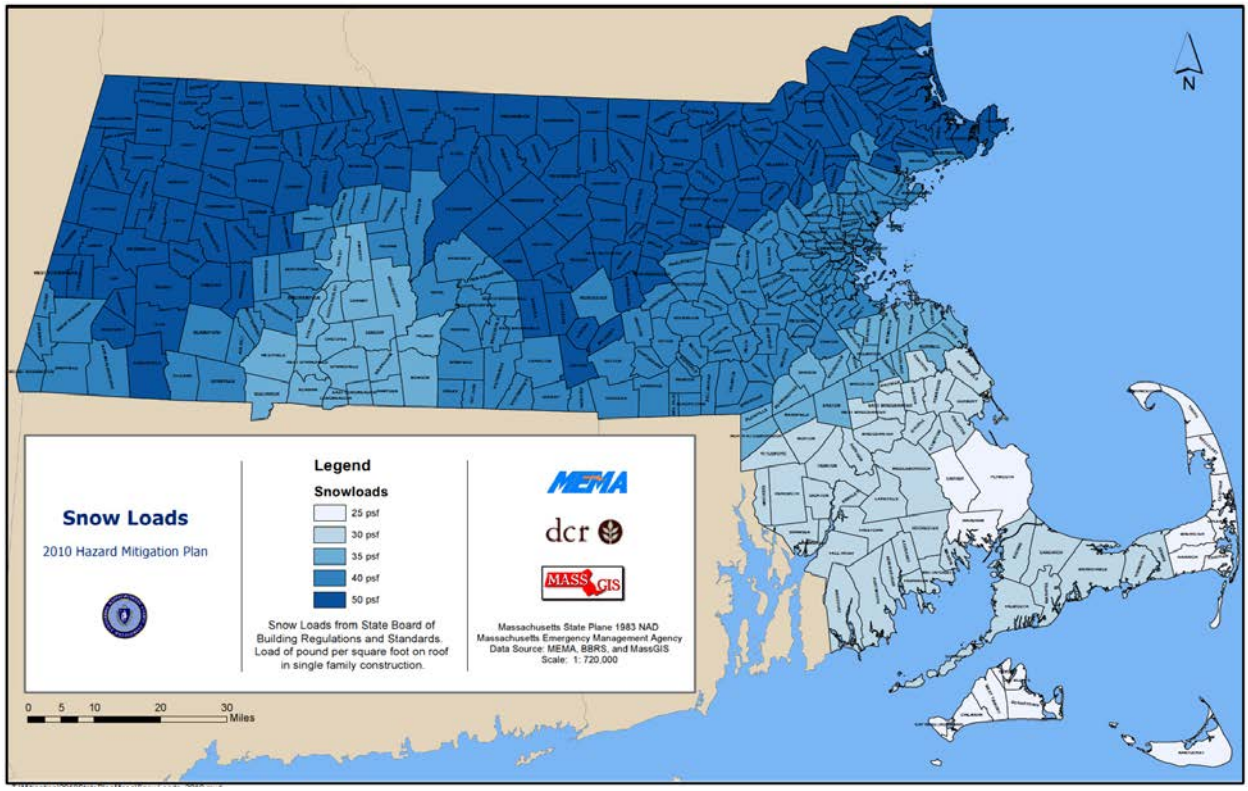

Figure 15-6. Roof Snow Loads for Single-Family Construction (pounds per square foot)

15.6.2 State Facilities

Potential structural damage to buildings may include damage to roofs and building frames. However, state facilities may not be fully operational due to workers' inability to travel to ensure continuity of operations

pre- and post-event. Current modeling tools are not available to estimate specific losses for this hazard. As an alternate approach, for the purposes of this plan, an estimated percent damage (one-percent) to a building's structure that could result from winter storm conditions is considered. Table 15-7 summarizes the Commonwealth's total state buildings (structure only) estimated potential loss replacement cost value. Given professional knowledge and the currently available information, the potential loss for this hazard is often considered to be overestimated due to varying factors (building structure type, age, load distribution, building codes in place, etc.). Therefore, the following information should be used as estimates only for planning purposes with the knowledge that the associated losses for severe winter storm events vary greatly

15.6.3 Critical Facilities

As stated earlier, full functionality of critical facilities is essential for response during and after a winter storm event. Potential structural damage to the facilities themselves may include damage to roofs and building frames. However, these facilities may not be fully operational due to workers unable to travel to ensure continuity of operations pre- and post-event. For future plan updates, the Commonwealth may consider determining which critical facilities have back-up power to enhance their critical facility inventory. The replacement cost values for critical facilities were not available for this planning effort. A total risk exposure would equal to the full replacement value of each critical facility exposed.

TABLE 15-7.
STATE BUILDING ESTIMATED POTENTIAL LOSS DUE TO A SEVERE WINTER STORM EVENT

County	Number of Buildings	Replacement Cost Value (Structure Only)	1% Loss
Barnstable	309	$573,157,181	$5,731,571.81
Berkshire	358	$926,000,416	$9,260,004.16
Bristol	482	$1,506,105,175	$15,061,051.75
Dukes	13	$8,112,024	$81,120.24
Essex	538	$2,236,600,714	$22,366,007.14
Franklin	211	$406,618,464	$4,066,184.64
Hampden	466	$2,525,825,124	$25,258,251.24
Hampshire	562	$2,343,693,926	$23,436,939.26
Middlesex	1,107	$4,940,998,327	$49,409,983.27
Nantucket	5	$15,690,622	$156,906.22
Norfolk	680	$2,570,915,628	$25,709,156.28
Plymouth	542	$1,591,202,077	$15,912,020.77
Suffolk	399	$4,141,536,865	$41,415,368.65
Worcester	1,093	$4,722,349,497	$47,223,494.97
Total	**6,765**	**$28,508,806,041**	**$285,088,060.41**

Source: DCAMM, 2012

15.6.4 Economy

Current modeling tools are not available to estimate specific losses for this hazard. As an alternate approach, this plan considers percentage damage that could result from winter storm conditions. Table 15-8 summarizes percent damage that could result from winter storm conditions on the Commonwealth's total general building stock (structure only).

A specific area that is vulnerable to the winter storm hazard is the floodplain. Snow and ice melt can cause both riverine and urban flooding. At-risk general building stock and infrastructure in floodplains are

presented in the flood hazard profile (Section 10). Estimated losses due to flooding in the Commonwealth are discussed in Sections 10 (Flood) and 11 (Hurricane/Tropical Storms).

The cost of snow and ice removal and repair of roads from the freeze/thaw process can drain local financial resources. The potential secondary impacts from winter storms also impact the local economy including loss of utilities, interruption of transportation corridors, and loss of business function.

TABLE 15-8.
GENERAL BUILDING STOCK ESTIMATED POTENTIAL LOSS DUE TO A WINTER STORM EVENT

County	Replacement Cost Value (Structure Only)	1% Loss
Barnstable	$29,472,545,000	$294,725,450
Berkshire	$12,320,794,000	$123,207,940
Bristol	$44,744,005,000	$447,440,050
Dukes	$3,037,454,000	$30,374,540
Essex	$61,243,002,000	$612,430,020
Franklin	$6,049,044,000	$60,490,440
Hampden	$39,337,031,000	$393,370,310
Hampshire	$12,609,441,000	$126,094,410
Middlesex	$143,825,613,000	$1,438,256,130
Nantucket	$2,225,512,000	$22,255,120
Norfolk	$66,668,319,000	$666,683,190
Plymouth	$42,892,528,000	$428,925,280
Suffolk	$65,816,336,000	$658,163,360
Worcester	$66,832,305,000	$668,323,050
Total	**$597,073,929,000**	**$5,970,739,290**

Source: HAZUS-MH v. 2.1