2.0 Hazards Analysis

2.1 Introduction

2.1.1 Purpose

The purpose of the hazards analysis is to quantify the still-water surge heights for hurricanes that have a reasonable meteorological probability of occurring in the study area. Freshwater flooding from the heavy rainfall frequently accompanying hurricanes, as well as ocean wave action and runup are additional hazards that must be considered separately. The primary objective of the hazards analysis is to determine the probable worst-case storm surge from hurricanes of various intensities that could strike the region. For the purposes of this study, the term “worst-case” is used to describe the peak surges that can be expected at all locations within the study area without regard to hurricane track.

2.1.2 Forecasting Inaccuracies

The worst-case approach is used in the hazards analysis because of inaccuracies in forecasting the precise tracks and other parameters of approaching hurricanes. The National Hurricane Center (NHC) has made an analysis of tropical cyclone forecasts to determine the normal magnitude of error. The current average position error in the official 24-hour track forecasts is about 45 statute miles left or right of the forecast track, and an average error of about 28 miles left or right in the 12-hour forecasts.

The average error in the official 24-hour wind speed (intensity) forecasts is about 9 miles per hour (mph), and the average error in the 12-hour official forecasts is about 6 mph. Hurricane evacuation decision makers should note that an error no greater than average could raise the intensity value of the approaching hurricane one category on the Saffir/Simpson Hurricane Scale, which is discussed in the following paragraph. In addition, other factors may work to increase apparent hurricane surge heights above the values calculated by the SLOSH model (see 2.4.4 Adjustments to SLOSH Model Values / Statistical Analysis). Because of potential forecast and modeling inaccuracies, public officials who are faced with an imminent evacuation should consider preparing for a hurricane one category above the forecast intensity. For more on forecasting inaccuracies, see Table 2-1 and other information on the NHC website.

2.1.3 Saffir/Simpson Hurricane Scale

One of the early guides developed to describe the potential storm surge generated by hurricanes is the Saffir/Simpson Hurricane Scale. Herbert Saffir, Dade County, Florida, Consulting Engineer, and Dr. Robert H. Simpson, former Director of the National Hurricane Center, developed the Saffir/Simpson Scale. The NHC later added a range of central barometric pressures associated with each category of hurricane described by the Saffir/Simpson Scale. The related damage potential of each hurricane category is described in Table 2-2.

Table 2-1: Average NHC 5-Year Average Forecast Errors (2010-2014) / All Tropical Cyclones[1,2,3]

	0 h		12 h		24 h		36 h		48 h		72 h		96 h		120 h	
	Error	N	Error	N	Error	N	Error	N	Error	N	Error	N	Error	N	Error	N
ATL track (n mi)	9.6	1586	28.4	1407	45.0	1235	60.4	1082	77.1	942	113.1	712	157.8	545	210.0	427
ATL intensity (kt)	2.3	1586	6.2	1407	9.4	1235	11.5	1082	13.3	842	14.6	712	14.6	545	14.8	427
EPAC track (n mi)	9.4	1456	23.4	1310	36.1	1163	46.9	1020	59.2	889	89.1	665	124.3	478	160.9	318
EPAC intensity (kt)	1.8	1456	5.9	1310	9.7	1163	12.4	1020	13.9	889	15.3	665	16.1	478	14.7	227

1. Verification based on NHC best track database as of 3/6/15.
2. Verification sample is homogenous with current operational 5-day CLIPER/Decay-SHIFOR (run retrospectively), and includes subtropical cyclones.
3. Source: http://www.nhc.noaa.gov/verification/pdfs/OFCL_5-yr_averages.pdf, (5/26/2015).

Table 2-2: Saffir/Simpson Hurricane Damage Scale

Category	Damage
1	Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage, and mobile homes. No real wind damage to other structures. Some damage to poorly constructed signs. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.
2	Winds of 96 to 110 miles per hour. Considerable damage to shrubbery and tree foliage; some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major wind damage to buildings. Considerable damage could occur to piers. Marinas flooded. Small craft may be torn from moorings.
3	Winds of 111 to 130 miles per hour. Foliage torn from trees; large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some window and door damage. Some structural damage to small buildings. Mobile homes destroyed. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris.
4	Winds of 131 to 155 miles per hour. Many shrubs and trees are blown down and most street signs are damaged. Extensive damage to roofing materials, windows, and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Major erosion of beaches.
5	Winds greater than 155 miles per hour. Shrubs and trees are blown down; considerable damage to roofs of buildings and all signs are damaged or destroyed. There would be very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors would occur. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes.

2.2 Storm Surge

2.2.1 Introduction

Storm surge is the abnormal rise in water level over and above the predicted astronomical tide caused by extreme wind and pressure forces. Various storm events can cause storm surge, but it is generally the result of a very large scale meteorological disturbance. Along the northeastern-Atlantic seaboard, extra-tropical storms known as "nor'easters" have produced some of the highest storm surges and resultant damages in recent history. However, hurricanes, because of their vast energy focused over a more localized area, can have the potential to produce much higher storm surges. Storm surges can affect a shoreline over distances of more than 100 miles; however, there may be significant spatial variations in the magnitude of the surge due to local bathymetric (water depth) and topographic features. Wind is the primary cause of storm surge. Wind blowing over the surface of the water exerts a horizontal force that induces a surface current in the general direction of the wind. The surface current, in turn, forms currents in subsurface water. In the case of a hurricane, the depth affected by this process of current creation depends upon the intensity and forward motion of the storm. For example, a fast-moving hurricane of moderate intensity may only induce currents to a depth of a hundred feet, whereas a slow moving hurricane of the same intensity might induce currents to several hundred feet. As the hurricane approaches the coastline, these horizontal currents are impeded by a sloping continental shelf, thereby causing the water level to rise. The amount of rise increases shoreward to a maximum level that is often inland from the usual coastline.

2.2.2 Factors Affecting Surge Height

The elevation reached by the storm surge depends upon the meteorological parameters of the hurricane and the physical characteristics along the coastline. The meteorological parameters affecting the height of the storm surge include the intensity of the hurricane, measured by the storm-center sea-level pressure, track (path) of the storm, forward speed, and radius of maximum winds. This radius, which is measured from the center of the hurricane eye to the location of the highest wind speeds within the storm, can vary from as little as 4 miles to greater than 50 miles. Due to the complementary effects of forward motion and the counterclockwise rotation of the wind field (in the northern hemisphere), highest surges from a hurricane usually occur on the right side of the storm's track in the region of the radius of maximum winds. Peak storm surge may vary drastically within a relatively short distance along the coastline, depending on the radius of maximum winds and the point of hurricane eye landfall. The geophysical characteristics that influence the surge heights include the basin bathymetry, roughness of the continental shelf, configuration of the coastline, and natural or manmade barriers. A wide, gently sloping continental shelf or a large bay may produce

particularly large storm surges; whereas a steep continental slope will attenuate storm surges in favor of producing large waves.

2.2.3 Total Flood Elevation

Storm surge increases the water level above the normal astronomical tide; the combination of which is referred to as a storm tide. That is why with respect to coastal flooding impacts, a low-tide event is the best possible timing for hurricane landfall, while a high-tide event is the worst. The maximum water elevation calculated by SLOSH is actually the storm tide and not just storm surge. Output for the Providence/Boston 2 SLOSH model was produced for both mean tide and high tide conditions.

Wave action can also increase the potential for coastal flooding, and it is not accounted for in the SLOSH model's calculations of storm tides. One factor that increases the impacts of the storm tide is a phenomenon known as wave setup, where the kinetic energy of the waves breaking near the shore forces water further landward. During severe storms, there is a significant increase in wave height and volume, and water cannot flow back to the sea as rapidly as it comes ashore. This increases the water level along the beachfront. Since waves break and dissipate their energy in shallow water, wave setup allows the waves to move further landward than under normal conditions. Also, a relatively steep offshore beach slope allows large ocean waves to get closer to the shore before breaking, resulting in greater wave setup than on a gradually-sloping beach. Since large waves are generally not transmitted inland of the coastline, even if the beach has been overtopped, wave setup is primarily a concern near the beachfront.

Another contributing factor to coastal flooding is the height of the waves themselves. The SLOSH model does not provide data concerning the additional heights of waves generated on top of the still-water storm surge. Generally, waves do not add significantly to the area flooded and will add little to the number of people that will be required to evacuate. Since near-shore wave phenomena under hurricane conditions are not well understood, it is assumed that for the open coast, maximum theoretical wave heights occur near the time of landfall. Immediately along the coastline or the shorelines of very large sounds and estuaries, wave crests can increase the expected still-water depth above the terrain by one-third, thus greatly increasing the hazard. Due to the presence of barriers such as structures, dunes, or vegetation, the waves break and dissipate a tremendous amount of energy within a few hundred yards of the coastline. Buildings within that zone that are not specifically designed to withstand the forces of wave action are often heavily damaged or destroyed.

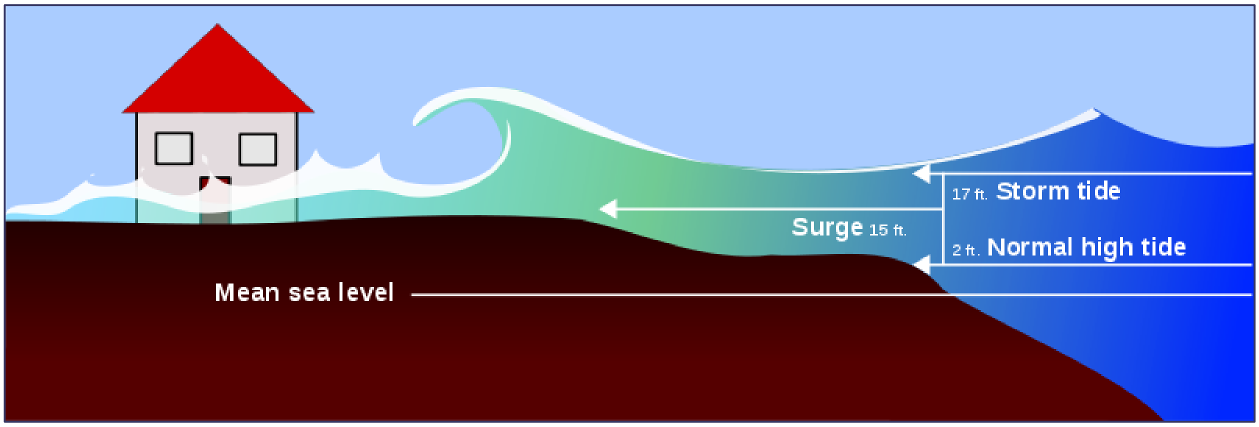

Figure 2-1: Surge Model

2.3 The SLOSH Model

2.3.1 General

The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) numerical storm surge model was developed by the National Weather Service to calculate potential surge heights from hurricanes. To create SLOSH, Jelesnianski and Taylor coupled a hurricane model to a model for storm surge. The SLOSH model was first conceived for real-time forecasting of surges from approaching hurricanes. In addition to computing surge heights for the open coast, the SLOSH model has the added capability to simulate the routing of storm surge into sounds, bays, estuaries, and coastal river basins, as well as calculating surge heights for overland locations.

Geophysical characteristics of an area covered by a SLOSH model are constructed as input data within the model. These characteristics include the topography of inland areas; river basins and waterways; bathymetry of near-shore areas, sounds, bays, and large inland water-bodies; significant natural and manmade barriers such as barrier islands, dunes, roads, levees, etc.; and a segment of the continental shelf. The SLOSH model simulates inland flooding from storm surge and permits flow through barrier gaps and barrier overtopping.

The SLOSH model uses time-dependent meteorological data to determine the driving forces of a simulated storm. These data are as follows:

1. Central barometric pressure at 6-hour intervals.
2. Latitude and longitude of storm positions at 6-hour intervals.
3. The storm size measured by the radius of maximum winds. Wind speed is not an input parameter, since the model calculates a wind-field for the modeled storm based on meteorological input parameters.

The height of the water surface well before the storm directly affects the area of interest and is also required. This initial height is the observed water surface elevation occurring about 2 days before storm arrival.

The SLOSH Basins that were used for the Massachusetts HES were updated as part of a normal update cycle to factor in better computing methodologies, as well as other improvements to hardware and software capabilities. The Providence/Boston 2 (PV2) SLOSH Basin was updated in February 2009. The SLOSH model output provides heights of storm surge for various combinations of hurricane strength, forward speed, and approach direction. Storm strength is modeled using the minimum central pressure and radius of maximum winds for four of the five categories of storm intensity. Because of their extremely low chance of occurrence, Category 5 hurricanes were not modeled for the Providence/Boston 2 SLOSH Basin.

2.3.2 SLOSH Grid Configuration

Figure 2-2 illustrates the area covered by the grid for the Providence/Boston 2 SLOSH model. The area covered by the grid is called a "basin”; in this case Providence/Boston 2 basin.

The Providence/Boston 2 basin covers the western Connecticut, Rhode Island and Massachusetts coastline and extends from New Haven, Connecticut, to Kennebunkport, Maine. Nonetheless the area in the grid with the highest cell resolution is from Westerly, Rhode Island, to Salisbury, Massachusetts and it is therefore used to prepare the inundation maps for both those states. The grid is a telescoping polar coordinate (fan-shaped) grid system with 182 arc lengths and 279 radials. The pole of the grid is located at 41.33100 N and 71.42900 W.

The advantage of this grid system is that it offers good resolution in areas of primary interest, while conserving computer resources by minimizing the number of calculations in areas of secondary interest. Telescoping grids are used to put more grid cells over land for good surge delineation, but they also include a large area offshore for adequate surge calculations. As shown in Figure 2-2, the grid squares constantly expand in size and become progressively larger farther from the coastline. For the Providence/Boston 2 SLOSH Basin, the resolution of the model for locations near the origin is approximately 0.22 square miles per grid square, and increases to approximately 2.9 square miles per grid square at the outer fringe.

2.3.3 Verification of the Model

After a SLOSH model has been constructed for a coastal basin, verification is conducted as real-time operational runs in which available meteorological data from historical storms are input into the model. The computed surge heights are compared with those measured from the historical storms and, if necessary, adjustments are made to the input or basin data. These adjustments are not made to force agreements between computed and measured surge

heights from historical storms but to more accurately represent the basin characteristics or historical storm parameters. In instances where the model has given realistic results in one area of a basin, but not in another, closer examination has often revealed inaccuracies in the representation of barrier heights or missing values in bathymetric or topographic data.

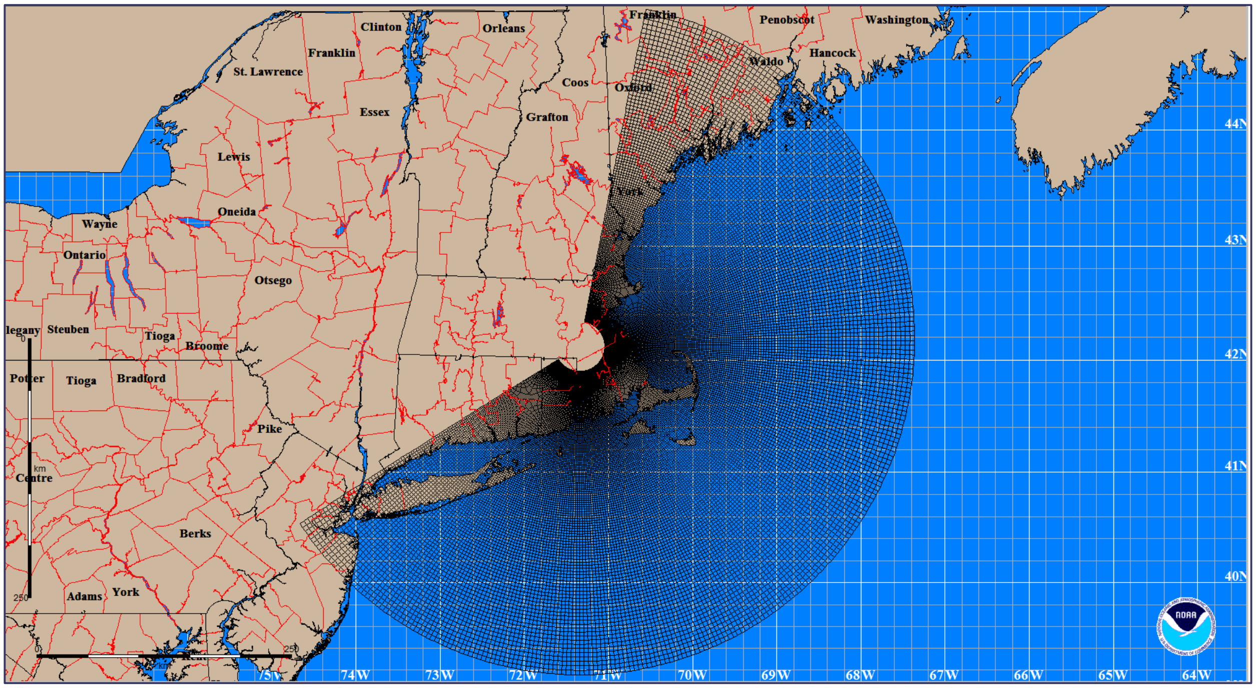

Figure 2-2: Providence/Boston 2 SLOSH Basin Grid Coverage

2.3.4 Model Output

The SLOSH model output for a modeled storm consists of envelopes of high water, and contains the maximum surge height values calculated for each grid point in the model. Maximum surges along the coastline do not necessarily occur at the same time. The time of the maximum surge for one location may differ by several hours from the maximum surge that occurs at another location. Therefore, at each grid point, the water height value shown is the maximum that was computed at that point during the 72 hours of model time, irrespective of the time during the simulation that the maximum surge height occurred. The datum used in the model is the North American Vertical Datum of 1988 (NAVD 88), formerly known as the Mean Sea Level of 1929 (MSL).

2.4 Modeling Process

2.4.1 Simulated Hurricanes

A total of 56,160 hypothetical hurricanes were modeled for the Providence/Boston 2 SLOSH basin, 18,720 at mean tide, 18,720 at with a 2 ft. tide, and 18,720 with a 5 ft. tide. The

characteristics of the simulated hurricanes were determined from an analysis of historical hurricanes that have occurred within the study area. The parameters selected for the modeled storms were the intensities, forward speeds, approach directions, and radii of maximum winds that are considered to have the highest meteorological probability of occurrence within the Providence/Boston 2 basin.

The initial sea surface height set in the Providence/Boston 2 SLOSH model for mean sea level conditions was 0.0 foot above NAVD 88. This initial height, known as tide anomaly, represents the height of the water surface above MSL existing several days in advance of approaching hurricanes. The value for the tide anomaly used in the SLOSH model represents the average sea surface height recorded at tide gauges for historical hurricanes prior to landfall.

2.4.2 Maximum Envelopes of Water (MEOWs)

The highest surges reached at all locations within the affected area of the coastline during the passage of a hurricane are called the maximum surges for those locations; the highest maximum surge in the affected area is called the peak surge. The location of the peak surge depends on where the eye of a hurricane crosses the coastline, hurricane intensity, and basin bathymetry, configuration of the coastline, approach direction, and radius of maximum winds. As discussed previously, the peak surge from a hurricane usually occurs to the right of the storm path and within a few miles of the radius of maximum winds.

Due to the National Hurricane Center's (NHC) inability to precisely forecast the landfall locations of hurricanes, the NHC Storm Surge Group developed the Maximum Envelopes of Water (MEOWs). MEOWs determine the potential peak surge at every location within the SLOSH basin. For example, if there were two storms, identical in every respect and they followed parallel tracks separated by 50 miles, then very likely there would be locations having markedly different surge values resulting from the two storms. This dependency of surge height on storm track can be troublesome in evacuation planning. Accordingly, MEOWs were produced by running the SLOSH model to create a group of storms, all having the same characteristics, but with parallel tracks 10 miles apart. At each grid square, the maximum surge value that was calculated was saved. The result was a "maximum envelope of water." Thus the MEOW is the "worst-case" surge that could be produced at any location by a storm with a particular combination of approach direction, forward speed, and intensity, regardless of where landfall may have occurred. Since the MEOW is the "worst case" at all locations, no one storm can duplicate the flooding depicted by a MEOW. In total, there are 432 MEOWs developed for the Providence/Boston 2 SLOSH Basin used for the Massachusetts HES, 144 are for mean tide conditions, 144 are for a 2 ft. tide and 144 are for a 5 ft tide. These 432 MEOWs are generated for various hurricane tracks and various wind speeds for Category 1 through 4 events. Because

of their extremely low chance of occurrence, Category 5 hurricanes were not modeled for the Providence/Boston 2 basin.

2.4.3 Maximum of the MEOWs (MOMs)

The results of the 432 MEOWs were analyzed to determine which changes in storm parameters (i.e., intensity, approach speed, and approach direction) resulted in the greatest differences in the values of the peak surges for all locations, and those that could reasonably be combined to facilitate evacuation decision-making. Changes in storm category accounted for the greatest change in peak surge heights. Careful consideration was given to the impacts of various combinations of storm parameters on hurricane evacuation planning and decision-making. To simplify these processes, the NHC was asked to compile additional MEOWs.

The NHC subsequently combined MEOWs to create MOMs (Maximums of the MEOWs), eliminating consideration of hurricane approach speed and direction, but maintaining the separation of categories 1, 2, 3, and 4. It was from those MOMs that storm surge inundation maps were developed for high tide conditions in each of the communities within the Massachusetts HES study area. Those storm surge inundation maps depict the limits of inundation from peak storm surge heights that could be generated by the four categories of storm intensity, without regard to approach speed, direction, or track.

2.5 Other Hurricane Hazards

2.5.1 Freshwater Flooding

Predicting the amounts and arrival times of rainfall associated with hurricanes can be subject to the same uncertainty and variability associated with any weather related forecast. For most hurricanes, the heaviest rainfall begins near the time of arrival of sustained tropical storm winds; however, heavy rains in amounts exceeding 20 inches can precede an approaching hurricane by as much as 24 hours. Unrelated weather systems can also contribute significant rainfall amounts within a basin in advance of a hurricane. Therefore, at a minimum, one should assume that locations and facilities which have historically flooded during periods of heavy rainfall are vulnerable to freshwater flooding during hurricane conditions. Nonetheless, other factors such as changes in land use and increased development, especially in urban areas, can also cause flooding in areas not previously known to be susceptible to freshwater inundation or excessive runoff.

Due to the variability of rainfall from hurricanes, no attempt was made to employ sophisticated modeling or analysis in quantifying those effects for the study area. It should be assumed that

locations and facilities which have historically flooded during periods of heavy rainfall are vulnerable to freshwater flooding from hurricane conditions.

Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) are a mapping source to identify properties and facilities that are located in an area prone to both fresh water and coastal flooding. FIRMs are the official map of a community on which FEMA has delineated both the special flood hazard areas and the risk premium flood zones applicable to the community. While FIRMs can be used for emergency management planning, it should be noted that fresh water and coastal flooding from tropical cyclones may exceed the flood hazard areas depicted on the maps.

2.5.2 Hurricane Winds and Vulnerability

In addition to storm surge, extreme winds can be a life-threatening feature of hurricanes. To some degree, all structures exposed to hurricane-force winds are vulnerable to wind-related hazards (see Table 2-2). This is especially true of intense storms, generally considered Category 3 and greater hurricanes. However, high-rise buildings merit special consideration. Wind pressures on upper portions of tall structures can be much greater than those at ground level. These pressures can cause significant problems during even a moderate hurricane. In the study area, complete structural failure of tall buildings due to wind is not a major concern. However, past wind storms in other locations have shown that combinations of wind forces on multi-story buildings can result in window breakage, the destruction of interior partitions, and loss of exterior cladding, creating the potential for high numbers of casualties. Not only could occupants be endangered, but debris falling onto the streets from high above could create an extreme hazard to pedestrians. Within the transportation network, high-rise bridges are particularly vulnerable to the hazards of extreme winds. Although some could experience wind-related structural problems, traffic will probably stop before this becomes a significant factor. Several major high-rise bridges in the study area have been closed during past storms after gale-force winds caused high profile vehicles to overturn.

Destructive hurricane force winds and tornadoes can also affect many inland communities as far as 100 miles from the coast. NOAA’s Hurricane Research Division has developed a model for predicting inland winds associated with landfalling hurricanes. The model accounts for wind speed decay as hurricanes move over land from water. The decay process is due to the interaction with land, where terrain roughness provides the friction needed to slow the wind, and the storm is cut off from the heat and moisture sources that sustain it. Wind gusts, rather than sustained speed, may actually increase because the greater turbulence over land mixes faster air to the surface in short bursts. Studies have shown that the sustained winds in a hurricane will decrease at a relatively constant rate, approximately half the wind speed in the

first 24 hours. The faster the forward speed of a landfalling hurricane, the further the inland penetration of hurricane force winds.

The model applies a simple two parameter decay equation to the hurricane wind field at landfall to estimate the maximum sustained surface wind as a storm moves inland. This model can be used for operational forecasting of the maximum winds of landfalling tropical cyclones. It can also be used to estimate the maximum inland penetration of hurricane force winds (or any wind threshold) for a given initial storm intensity and forward storm motion.

Developed from NOAA's Hurricane Research Division wind speed decay model, wind MEOW (Maximum Envelopes of Wind) maps were prepared for the entire United States based on prevalent wind scenarios specific to each region. These maps depict the most inland penetration of a representative category of wind speed for any storm making landfall from the Atlantic Ocean. Therefore it is important to note that these figures below do not represent the inland extent for any one storm, but a compilation of many events combined together to show the overall effects regardless of where a tropical cyclone makes landfall.

The following figures (Figures 2-3 to 2-22) represent the estimated inland wind extents for sustained wind speeds for a specific hurricane intensity (as measured by the Saffir-Simpson Hurricane Scale) and forward motion of a typical hurricane in statute miles per hour, with sustained wind speeds ranging from 75 mph to 127 mph, and using forward speed intervals of 12, 23, 35, 46 up to 58 miles per hour. Generally, for the color swaths in the figures below:

- Blue roughly equates to the predicted maximum inland extent of tropical storm force winds;
- Yellow roughly equates to the predicted maximum inland extent of gale force winds;
- Pink roughly equates to the predicted maximum inland extent of Category 1 winds;
- Rose roughly equates to the predicted maximum inland extent of Category 2 winds; and
- Coral roughly equates to the predicted maximum inland extent of Category 3 winds.

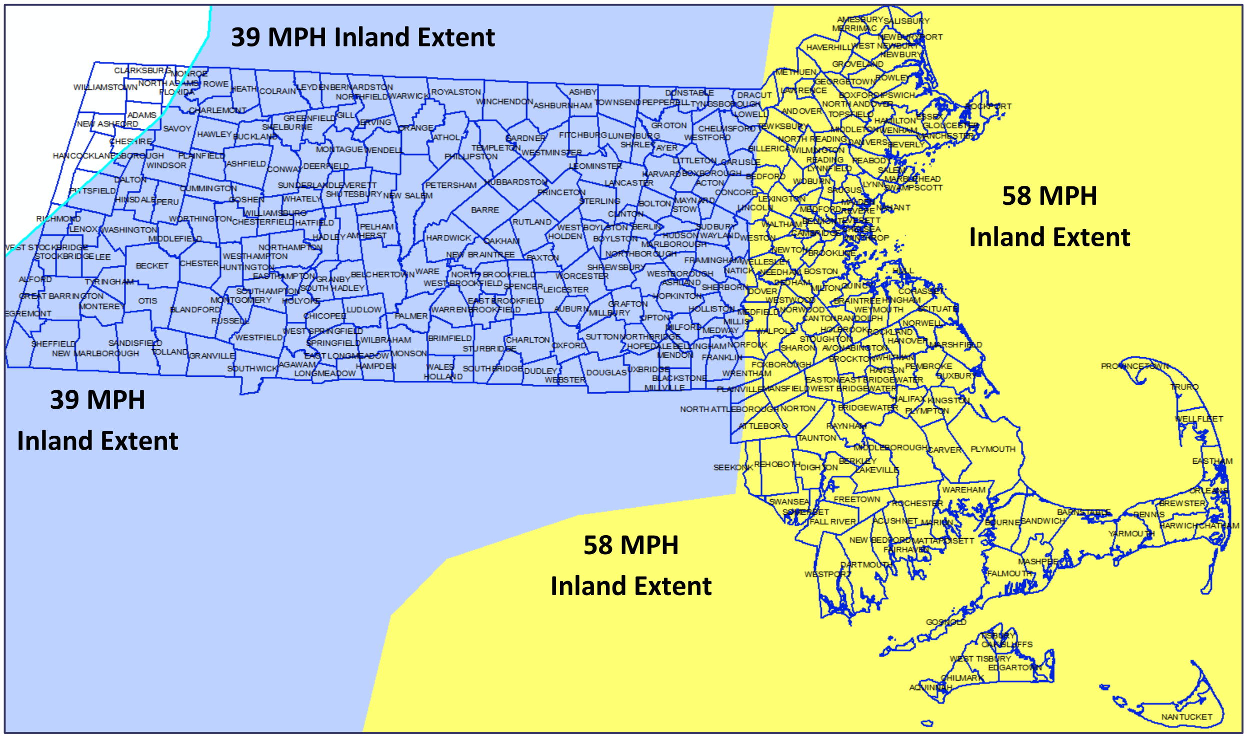

Figure 2-3: Category 1 Tropical Cyclone (75 mph sustained winds) at 12 MPH Forward Speed

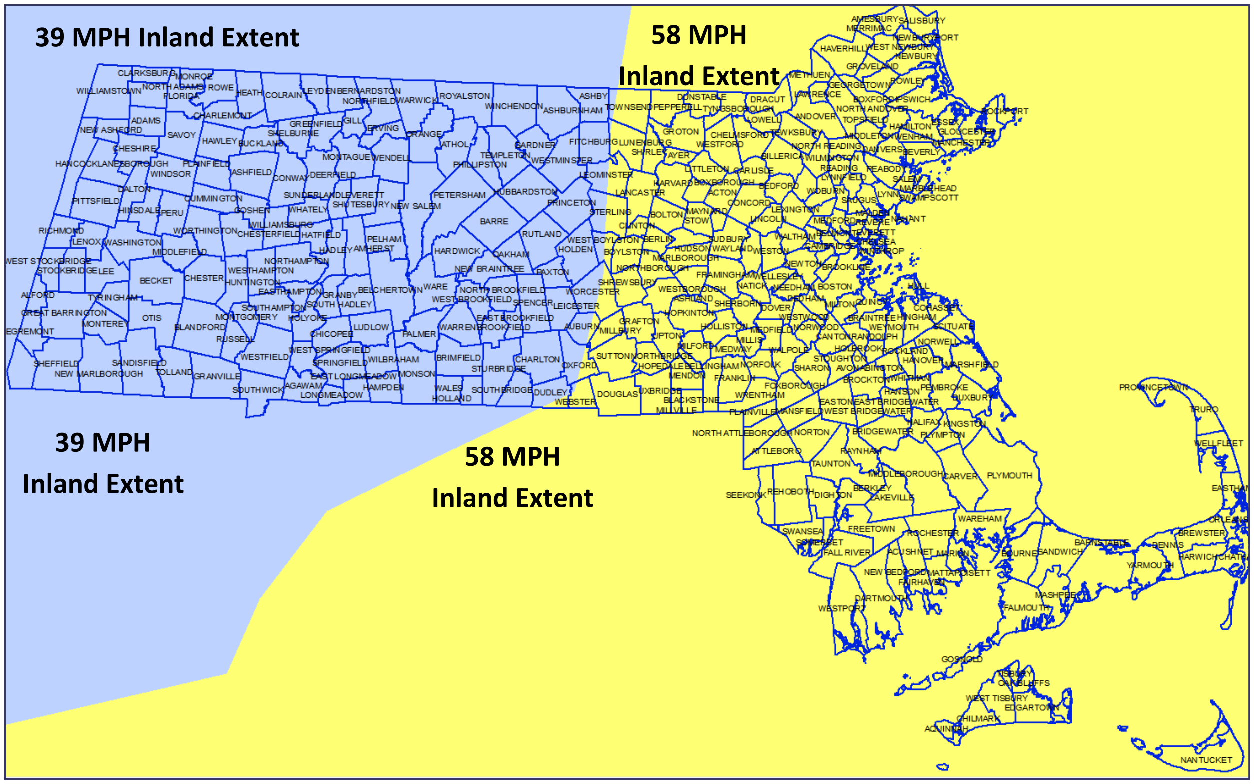

Figure 2-4: Category 1 Tropical Cyclone (75 mph sustained winds) at 23 MPH Forward Speed

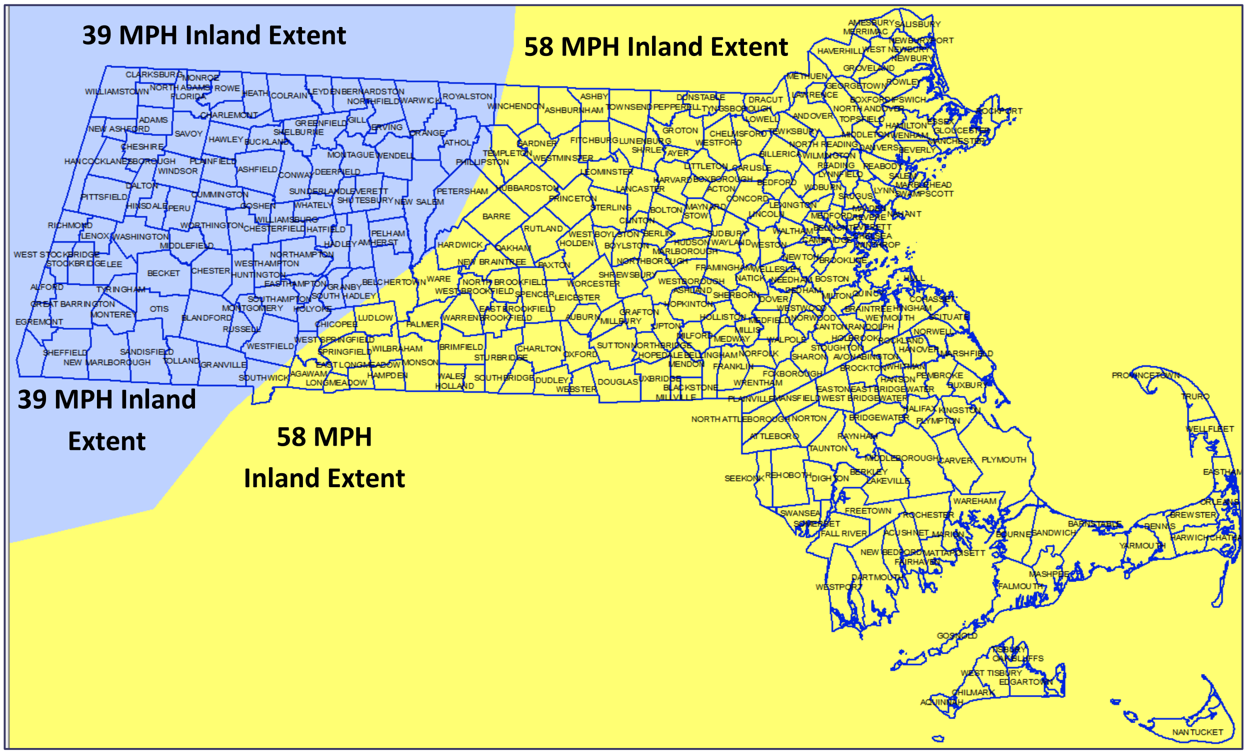

Figure 2-5: Category 1 Tropical Cyclone (75 mph sustained winds) at 35 MPH Forward Speed

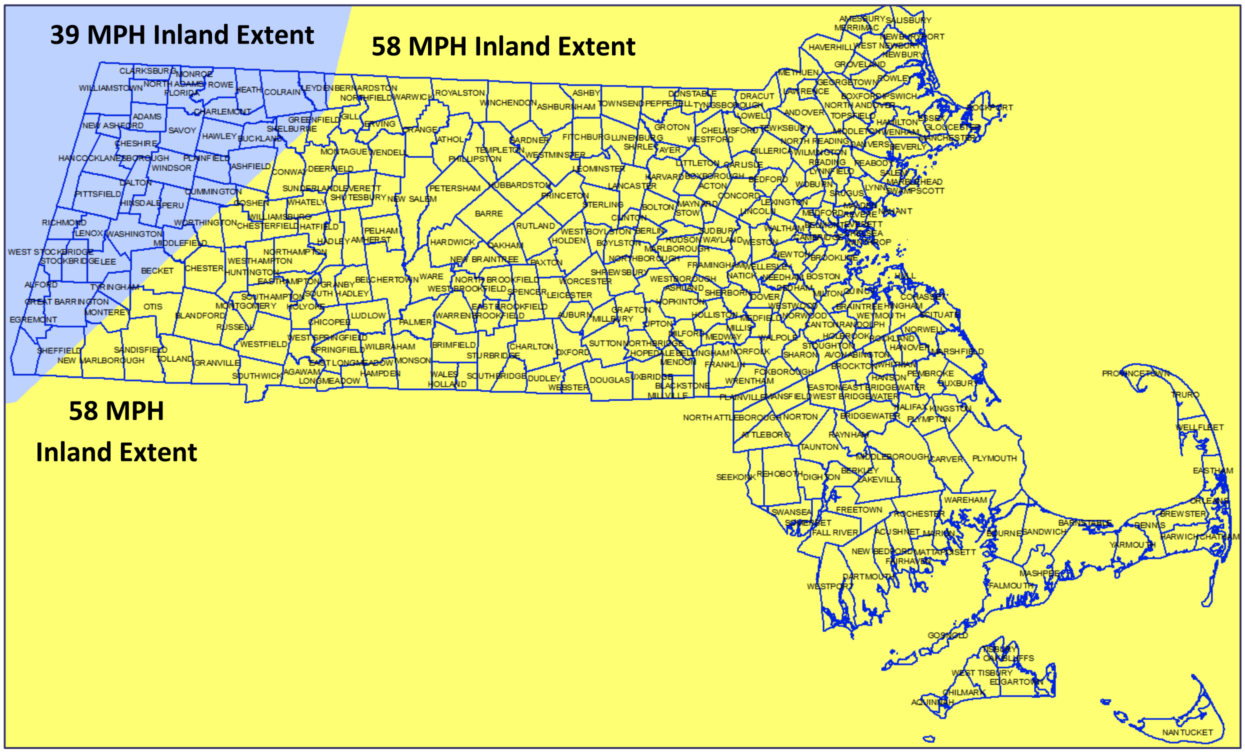

Figure 2-6: Category 1 Tropical Cyclone (75 mph sustained winds) at 46 MPH Forward Speed

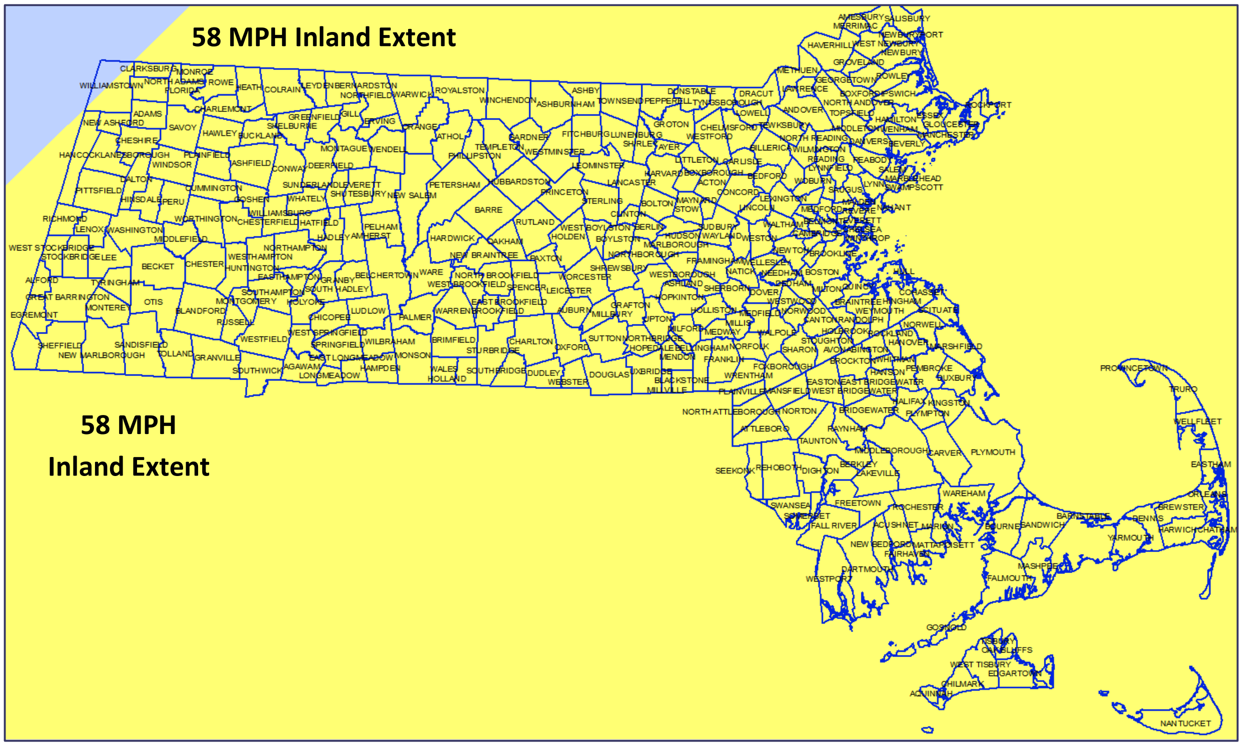

Figure 2-7: Category 1 Tropical Cyclone (75 mph sustained winds) at 58 MPH Forward Speed

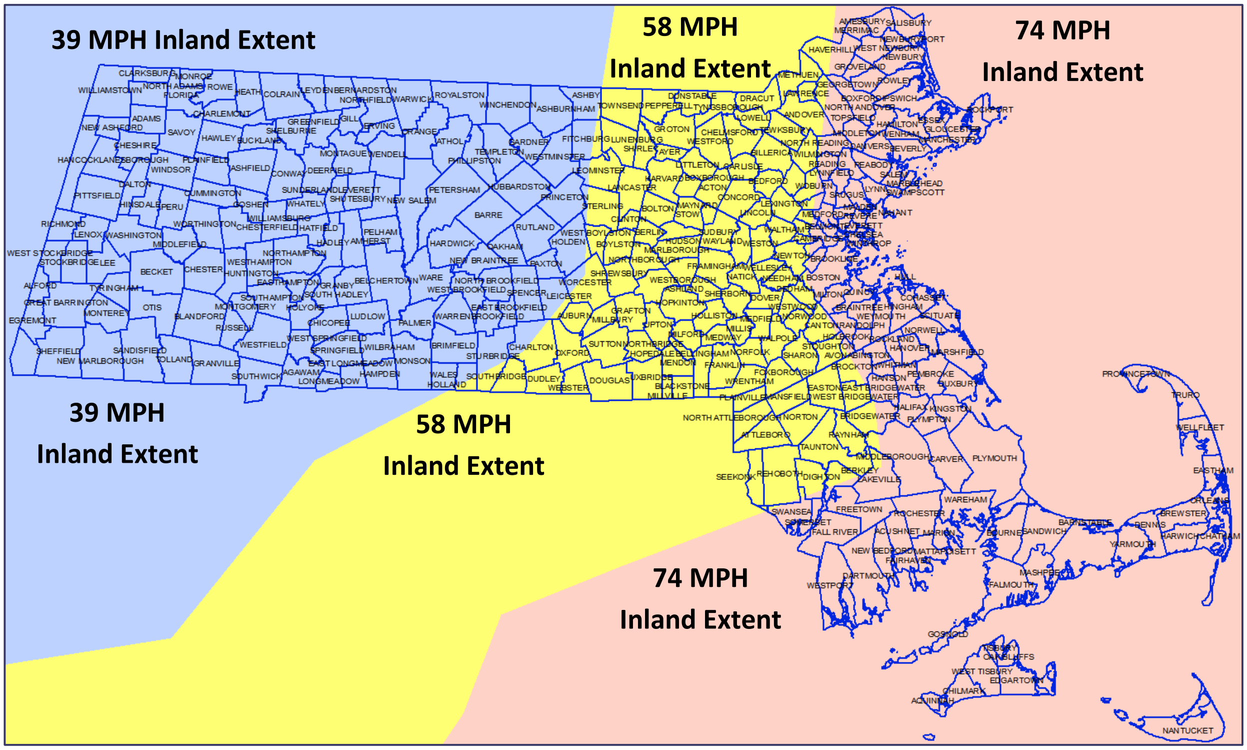

Figure 2-8: Strong Category 1 (92 mph sustained winds) at 12 MPH Forward Speed

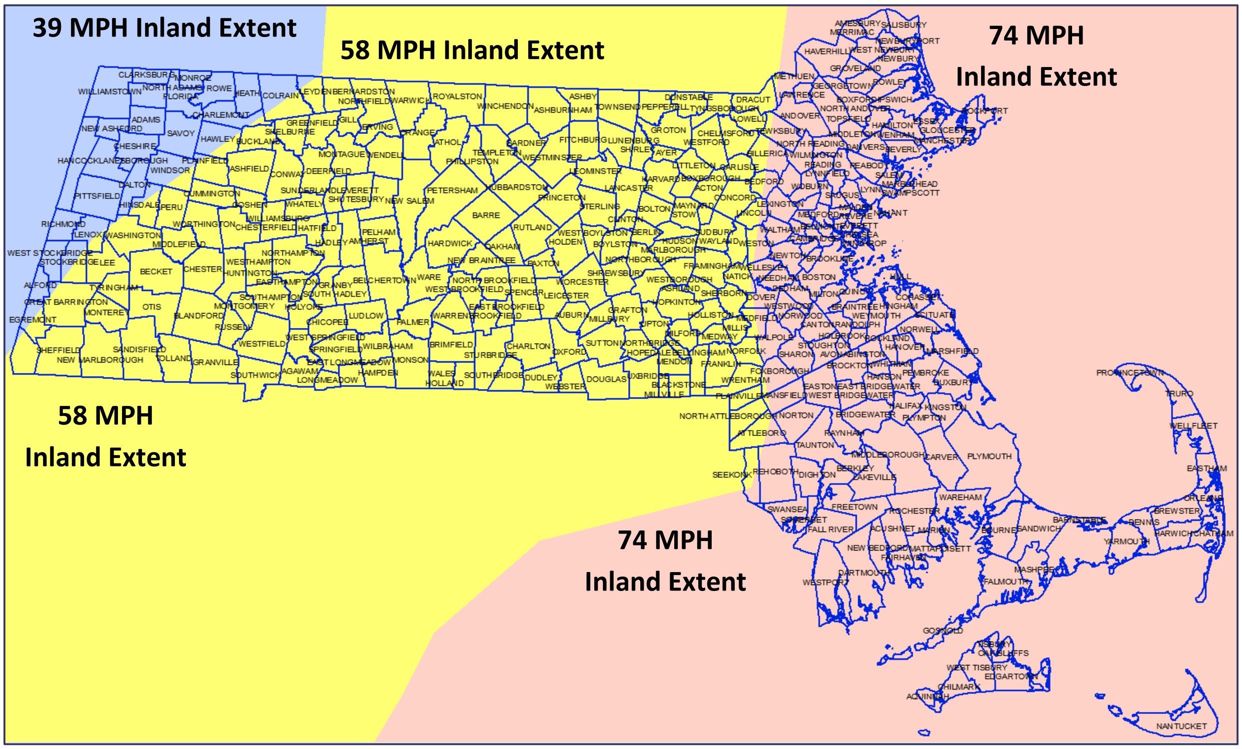

Figure 2-9: Strong Category 1 (92 mph sustained winds) at 23 MPH Forward Speed

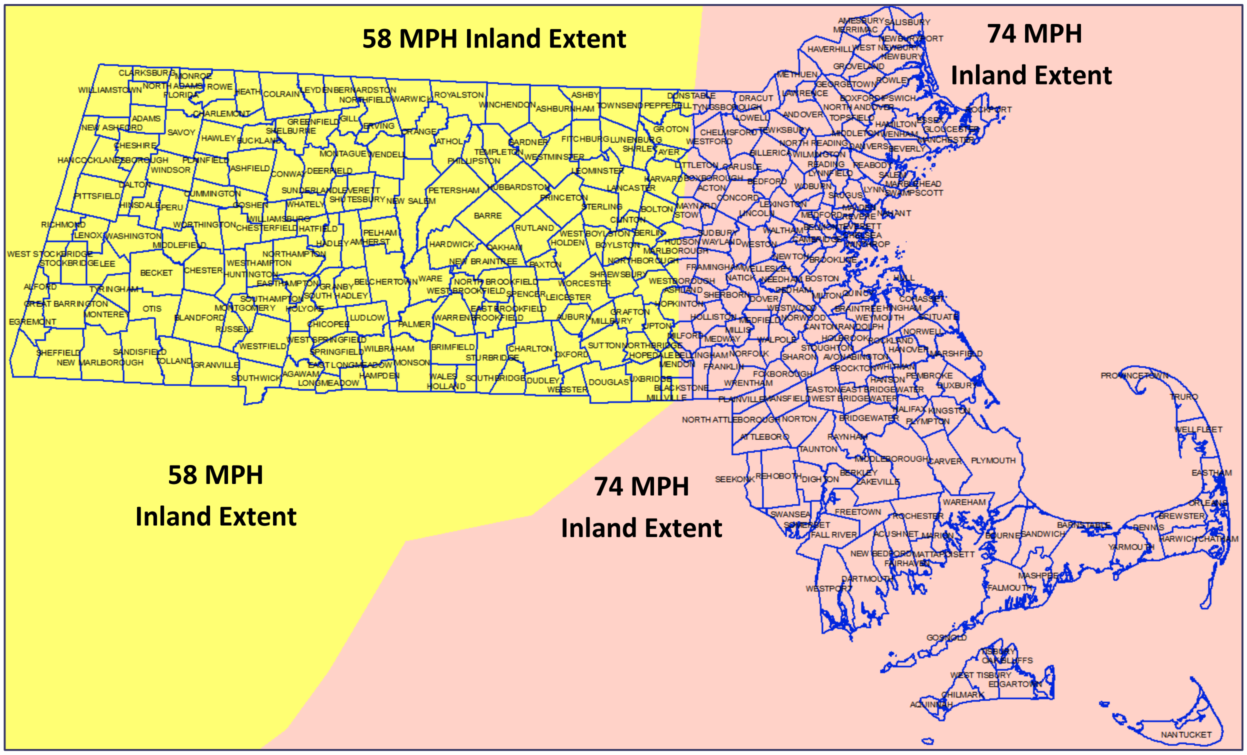

Figure 2-10: Strong Category 1 (92 mph sustained winds) at 35 MPH Forward Speed

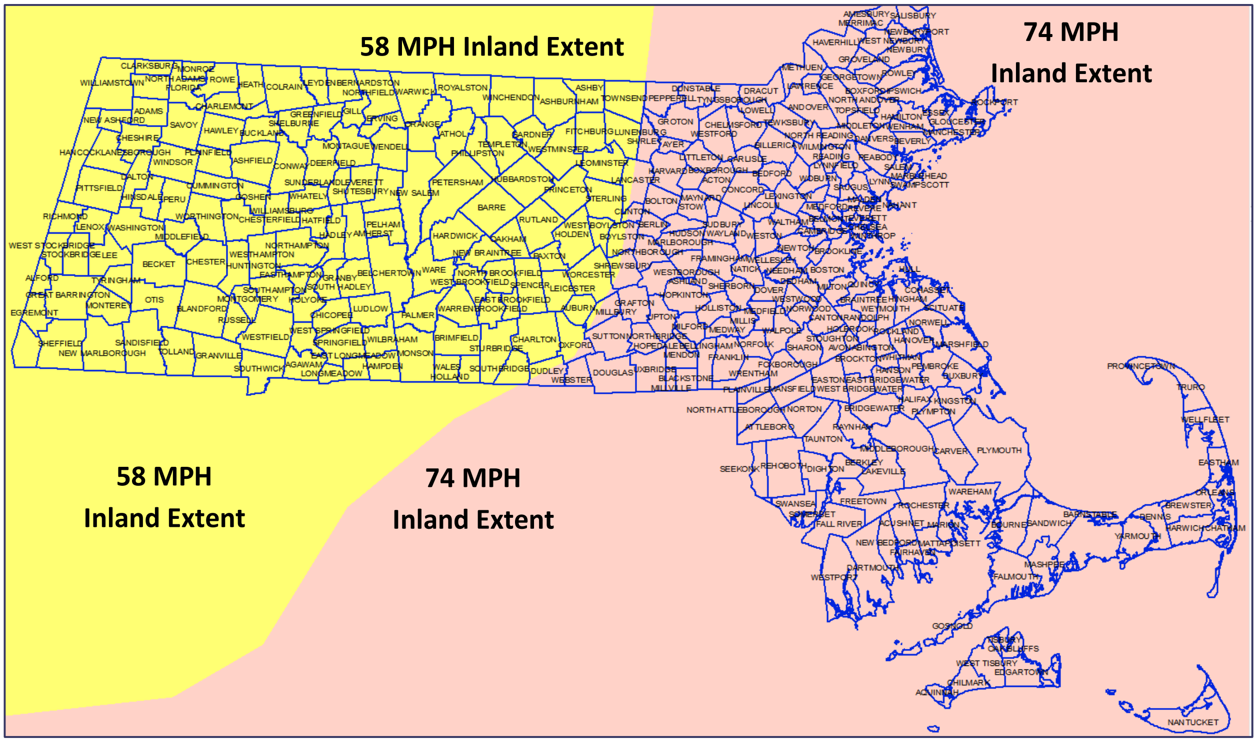

Figure 2-11: Strong Category 1 (92 mph sustained winds) at 46 MPH Forward Speed

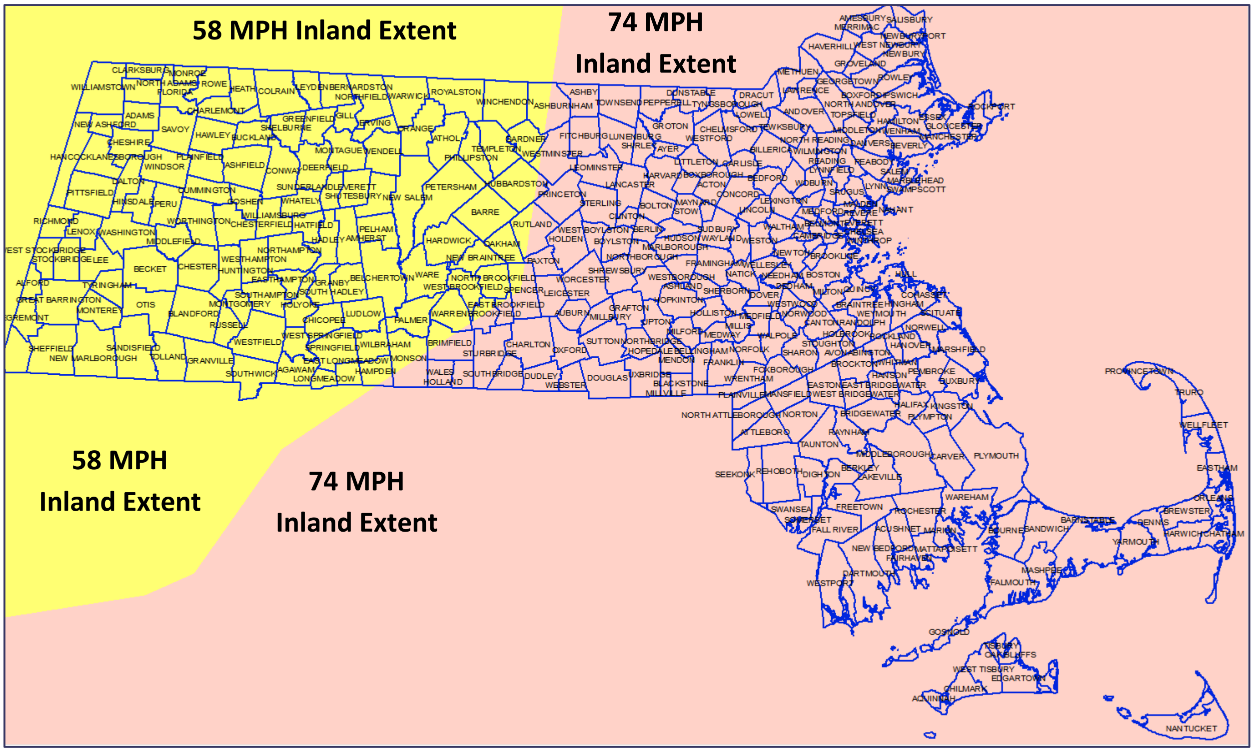

Figure 2-12: Strong Category 1 (92 mph sustained winds) at 58 MPH Forward Speed

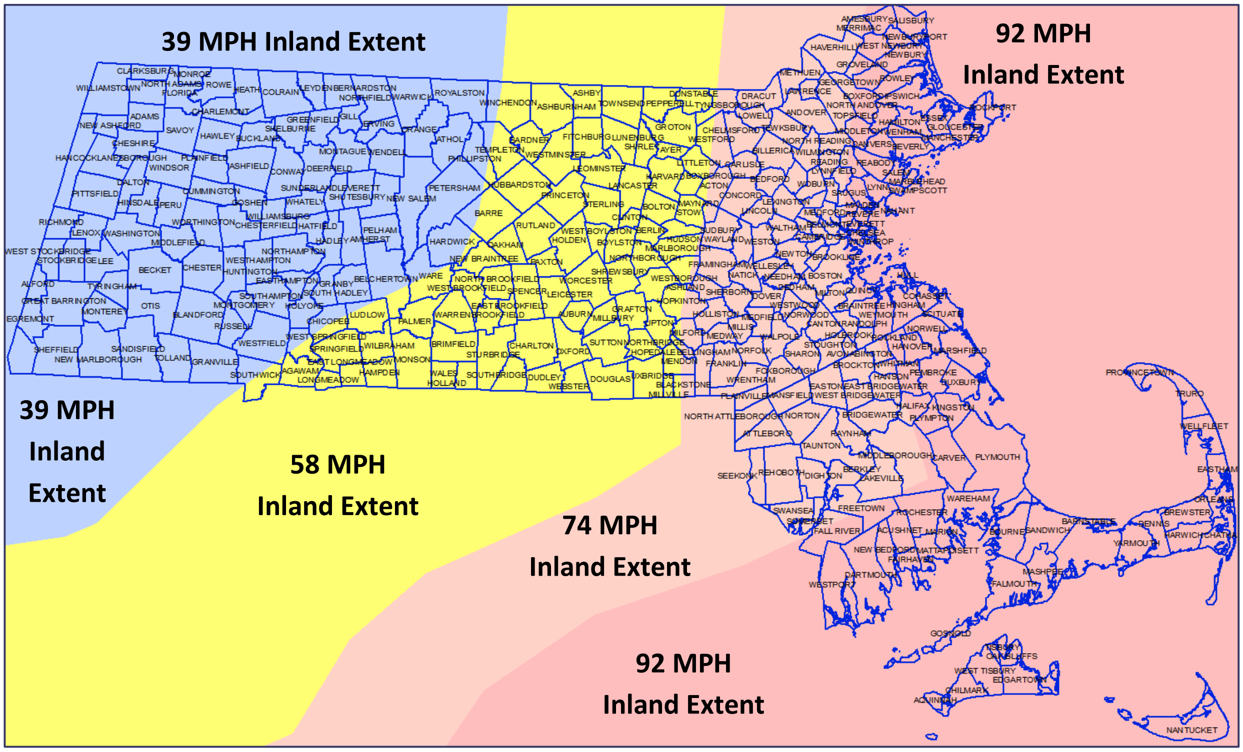

Figure 2-13: Strong Category 2 (109 mph sustained winds) at 12 MPH Forward Speed

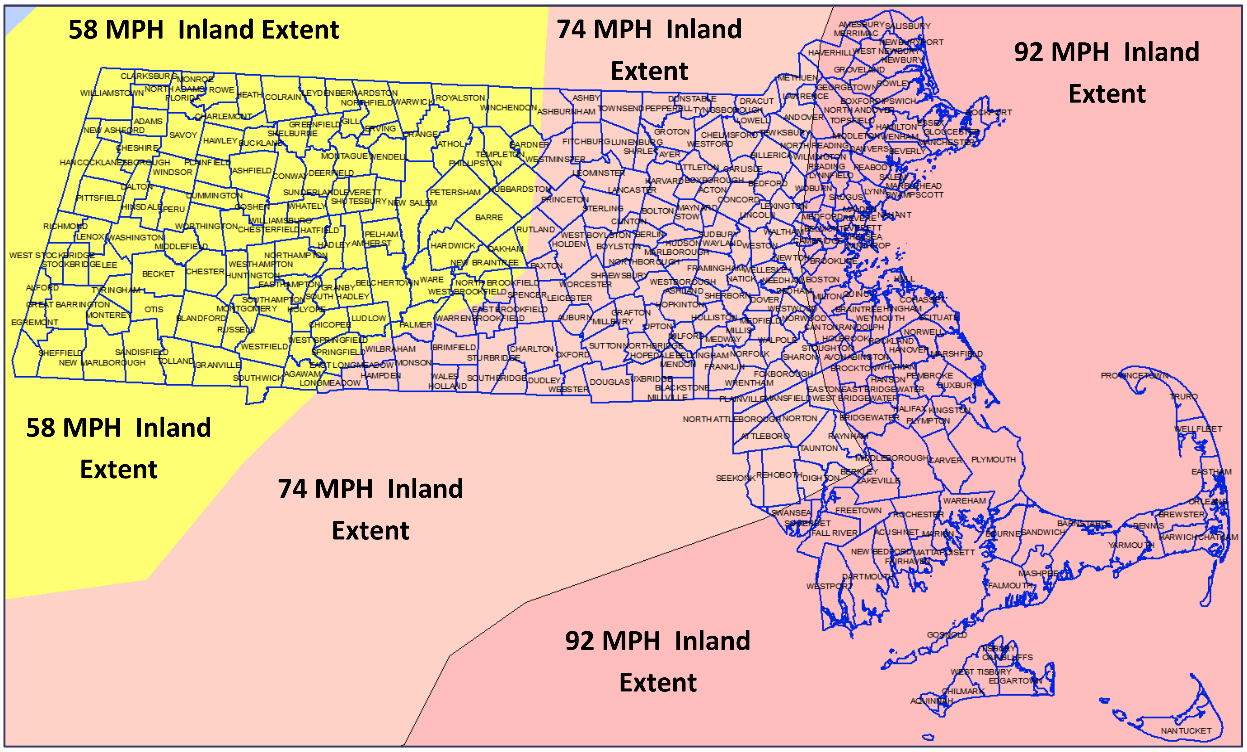

Figure 2-14: Strong Category 2 (109 mph sustained winds) at 23 MPH Forward Speed

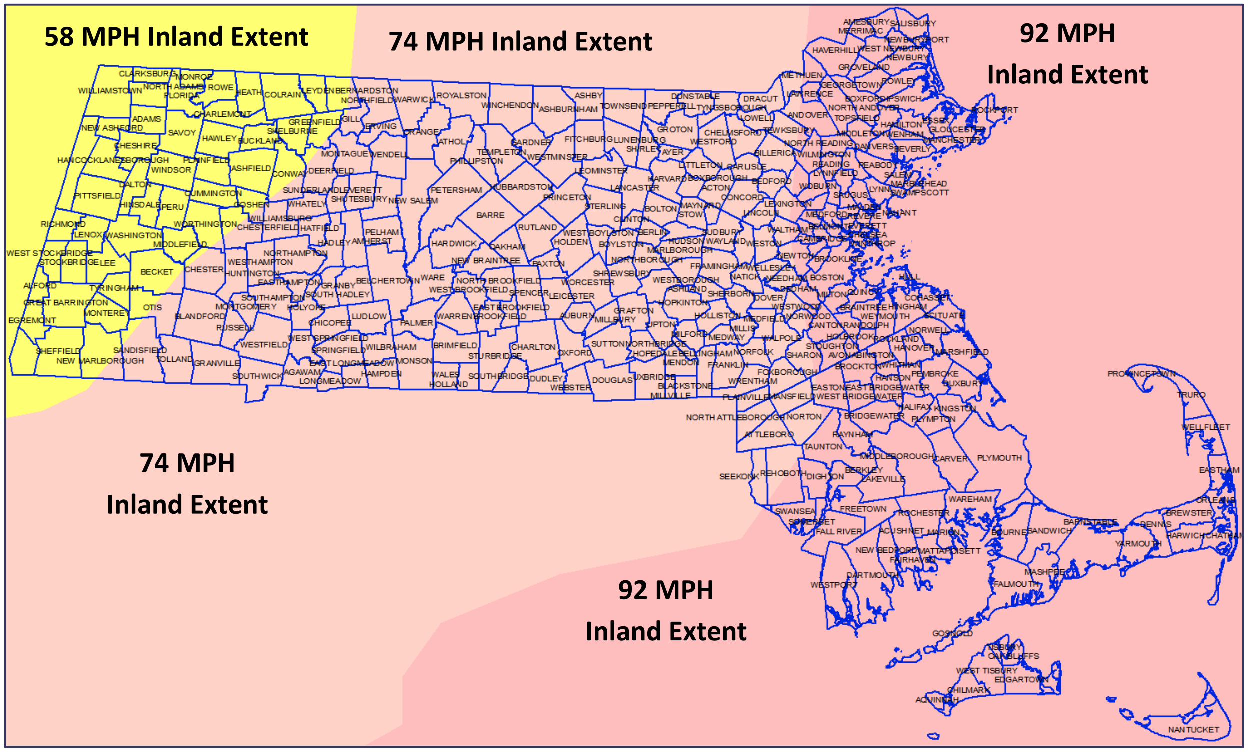

Figure 2-15: Strong Category 2 (109 mph sustained winds) at 35 MPH Forward Speed

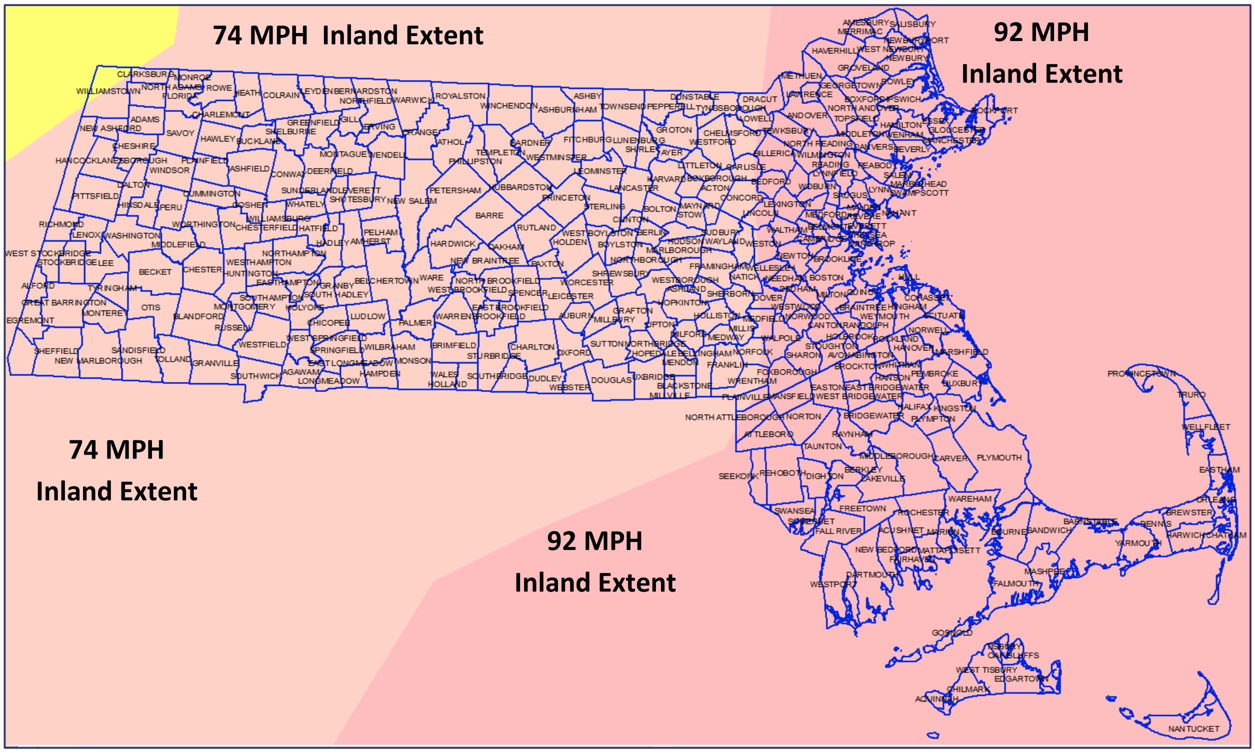

Figure 2-16: Strong Category 2 (92 mph sustained winds) at 46 MPH Forward Speed

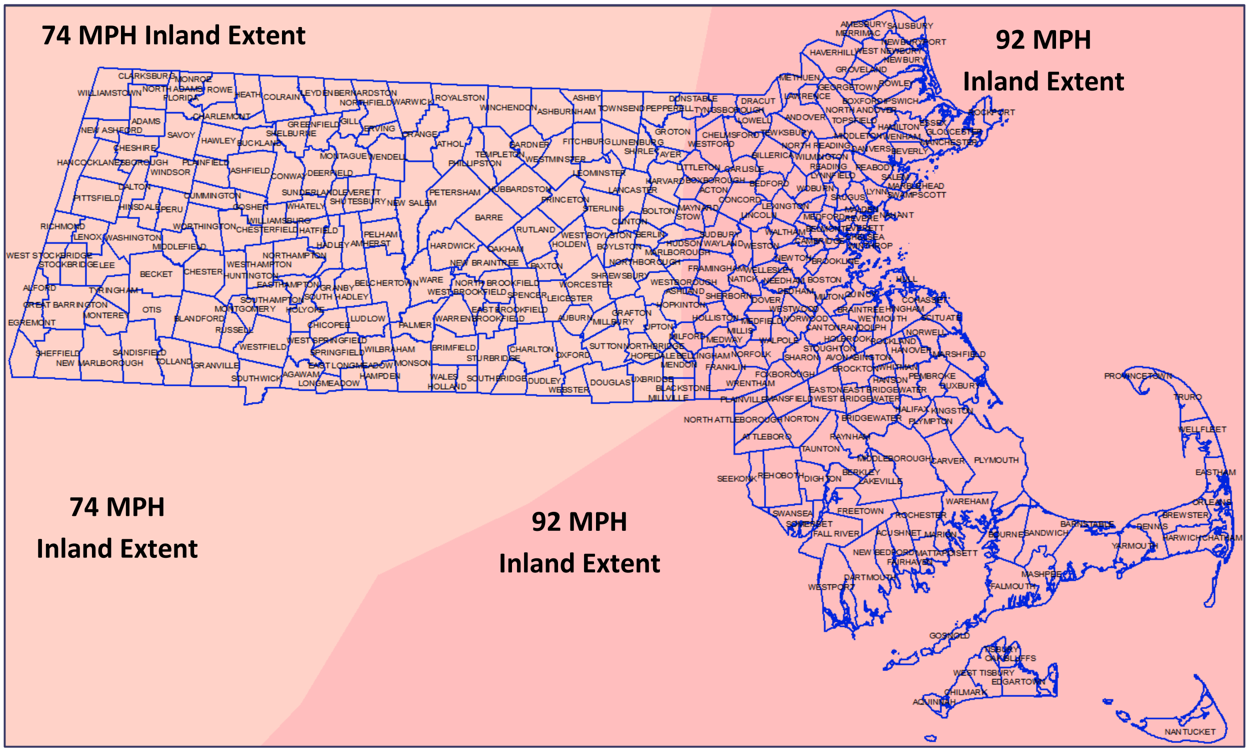

Figure 2-17: Strong Category 2 (109 mph sustained winds) at 58 MPH Forward Speed

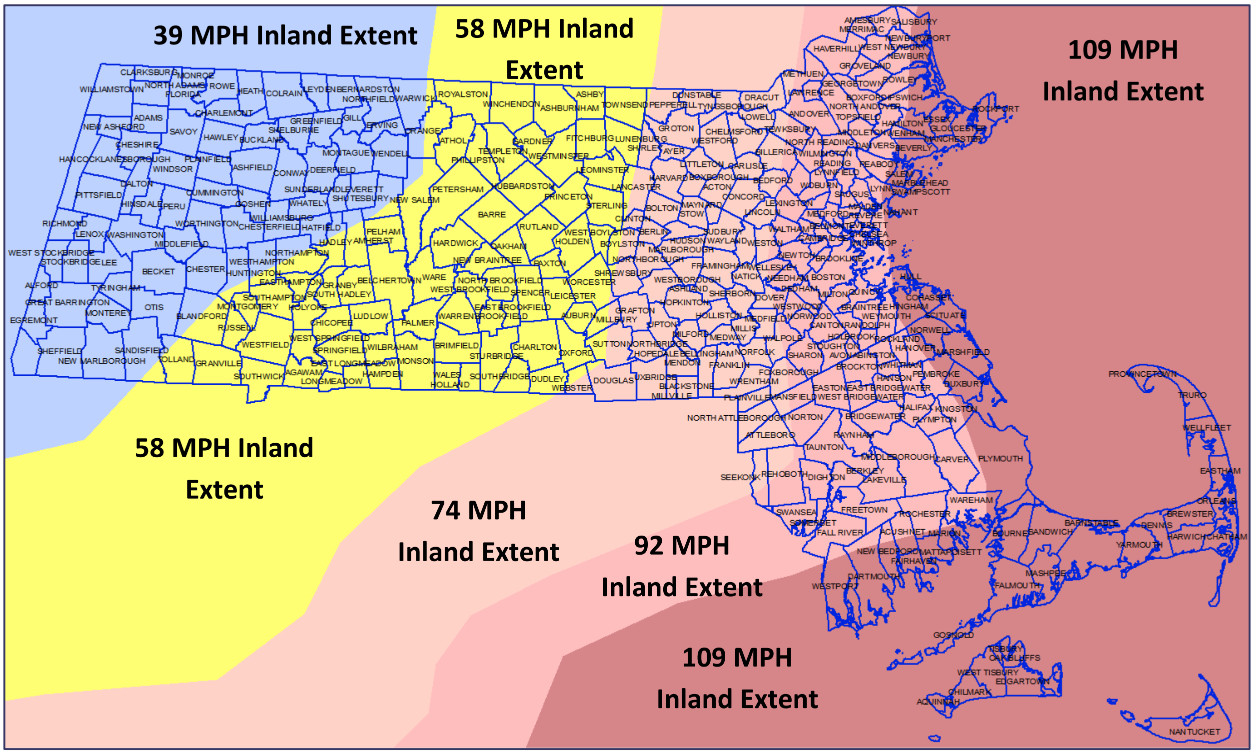

Figure 2-18: Strong Category 3 (127 mph sustained winds) at 12 MPH Forward Speed

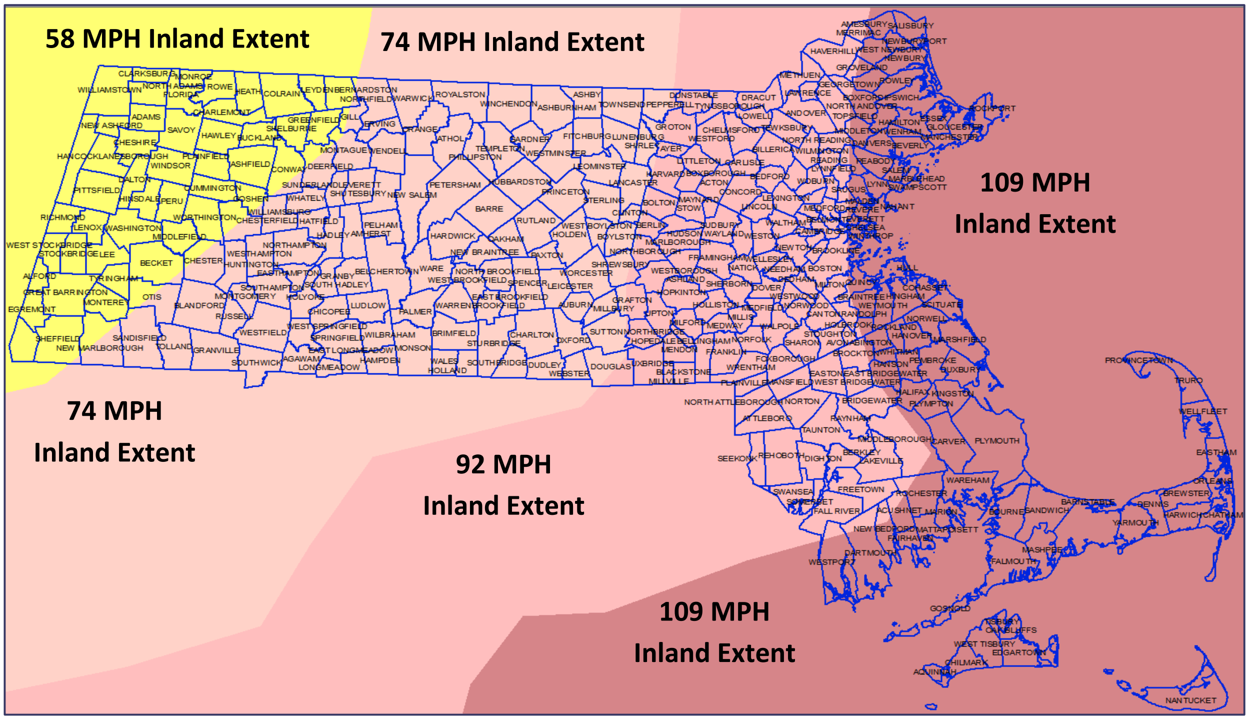

Figure 2-19: Strong Category 3 (127 mph sustained winds) at 23 MPH Forward Speed

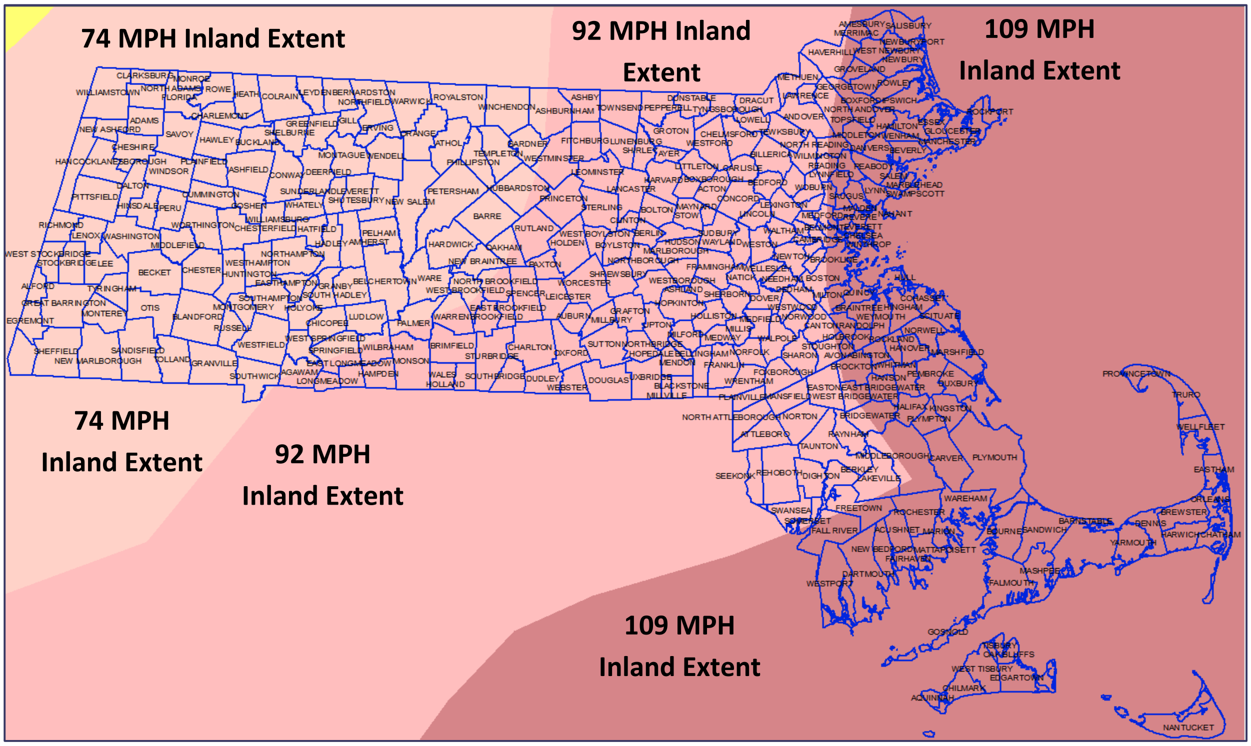

Figure 2-20: Strong Category 3 (127 mph sustained winds) at 35 MPH Forward Speed

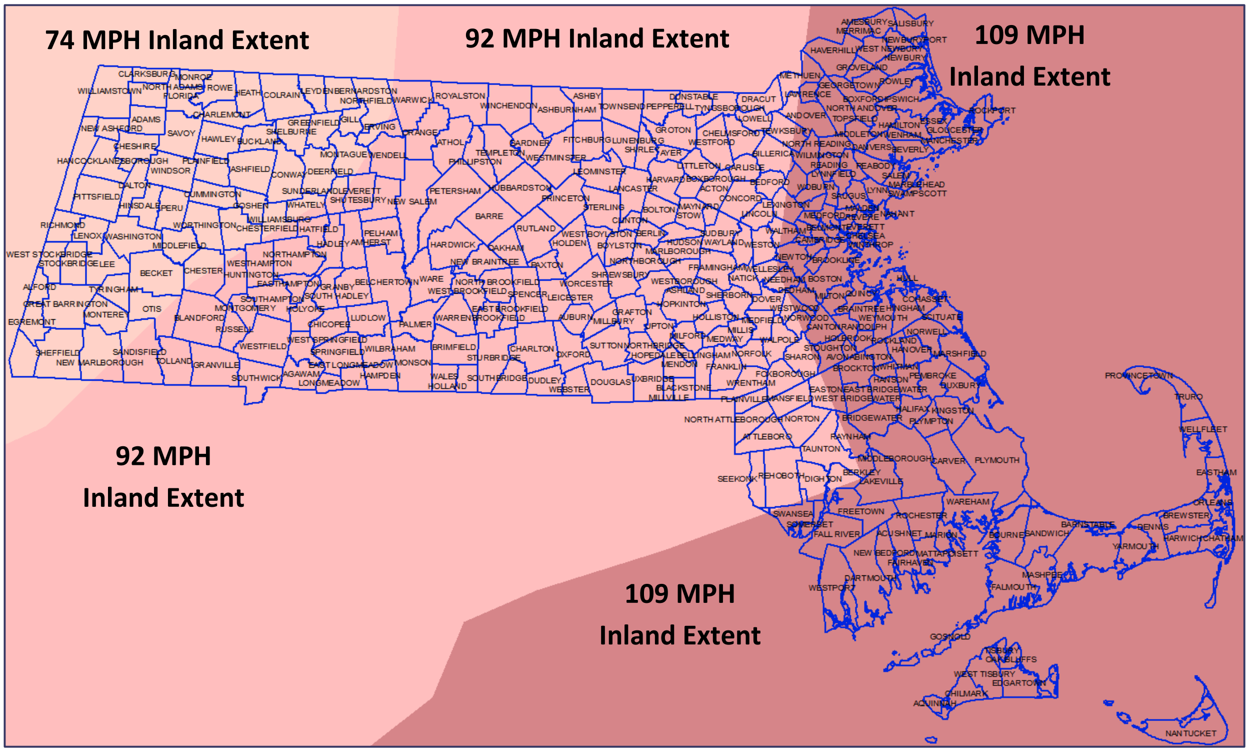

Figure 2-21: Strong Category 3 (127 mph sustained winds) at 46 MPH Forward Speed

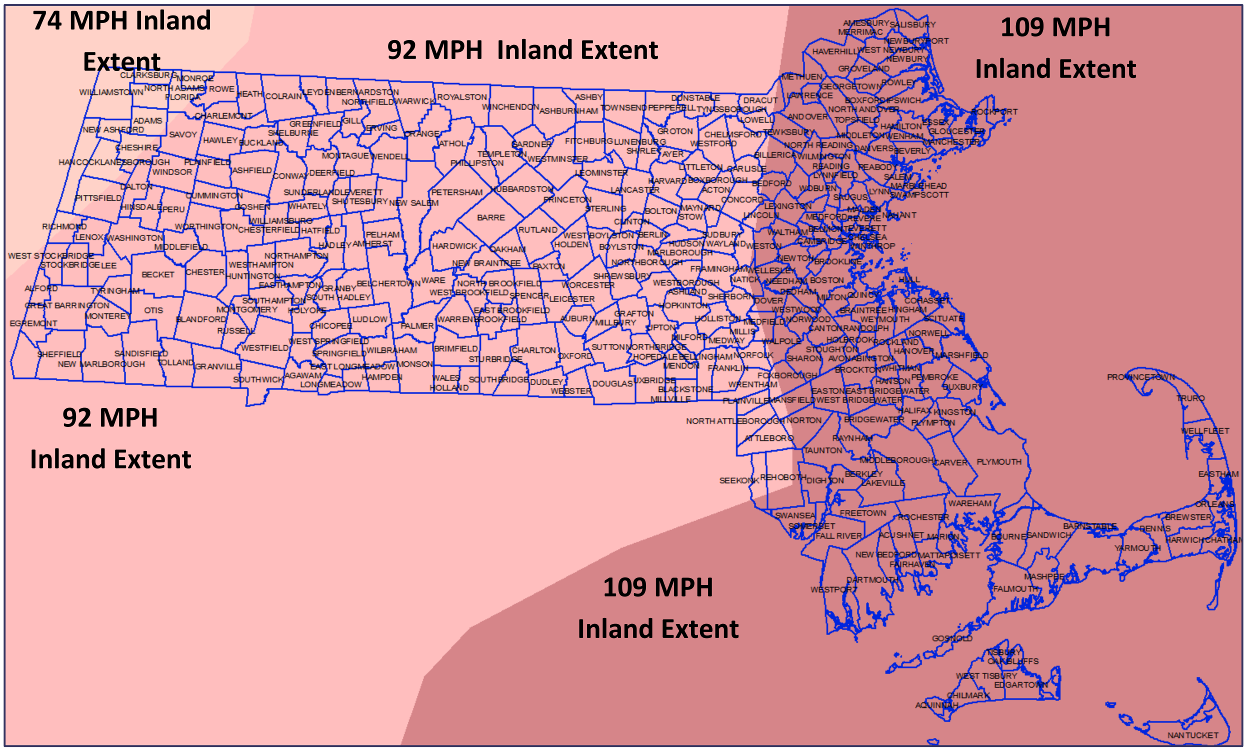

Figure 2-22: Strong Category 3 (127 mph sustained winds) at 58 MPH Forward Speed