CLIMATE CHANGE VULNERABILITY TRANSPORTATION ASSESSMENT STUDY

October 2021

Contract # 112307

OLD COLONY
PLANNING COUNCIL

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The preparation of this report has been financed in part through grant[s] from the Federal Highway Administration, U.S. Department of Transportation, under the State Planning and Research Program, Section 505 [or Metropolitan Planning Program, Section 104(f)] of Title 23, U.S. Code.

This report was funded in part through grant[s] from the Federal Highway Administration [and Federal Transit Administration], U.S. Department of Transportation. The views and opinions of the Old Colony Planning Council expressed herein do not necessarily state or reflect those of the U. S. Department of Transportation.

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Title VI Specialist
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10 Park Plaza
Boston, MA 02116
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MASSDOT.CivilRights@state.ma.us

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Boston, MA 02109
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Arabic: إذا كانت هناك حاجة هذه المعلومات في لغة أخرى، يرجى الاتصال بات Ciaramella.202 امتداد 1833-583-508 في

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Introduction

Study Purpose

The purpose of the Climate Change Vulnerability Transportation Assessment Study is to identify the impacts of Climate Change on the transportation system in the Old Colony Region (OCPC), to examine those impacts, and to conduct a vulnerability assessment of the transportation system. The study process involves gathering information on transportation assets, identifying stressors due to Climate Change, evaluating the impact of the stresses on the transportation system, developing projects, plans, and policies to manage and adapt to climate change, and integrating projects into transportation programming. The study includes outreach to stakeholders for collaboration and input in identifying local priorities in adapting to the impacts of Climate Change, as well as collaborating and coordinating with federal and state directives, statutes, and initiatives in resilience planning and Climate Change adaptation.

Climate Change has brought about uncertainties into accepted and widely used data regarding historically based floods, precipitation, and natural hazards. The current practice in modeling infrastructure lifecycle, although based on historic meteorological data, does not consider the potential future impacts of Climate Change especially the severity and frequency of flooding on local infrastructure.[1] A better understanding of the potential risks and impacts of Climate Change on the transportation system leads to more informed decision making in the capital investments in infrastructure in the region.

Study Scope

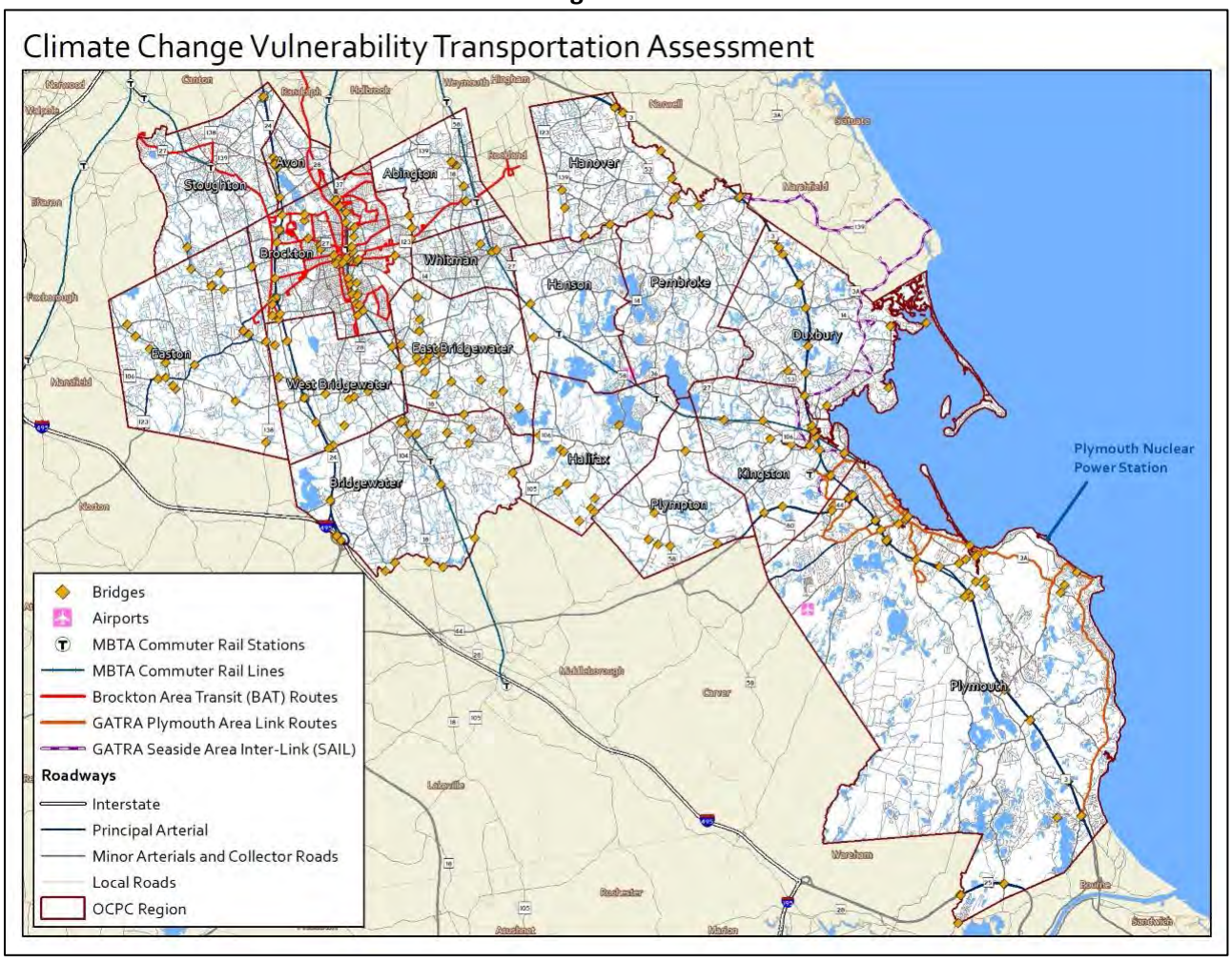
The region consists of seventeen communities that make up the Old Colony Planning Council including the City of Brockton and the towns of Abington, Avon, Bridgewater, Duxbury, East Bridgewater, Easton, Halifax, Hanover, Hanson, Kingston, Pembroke, Plymouth, Plympton, Stoughton, West Bridgewater and Whitman. The region, which is located in Southeastern Massachusetts, is approximately 397 square miles. The region is situated south of the metropolitan concentration of activity and population around Boston and is oriented towards Boston with north-south transportation lines between Greater Boston and the rest of Southeastern Massachusetts. In addition, the OCPC region is drawn to employment concentrations and commercial concentrations associated with the Route 128 area that circumvents to the south, west, and north of the City of Boston. The geographic scope of the study includes all of the seventeen municipalities in the region, although infrastructure as well as watersheds in the region overlap with adjacent regions. The scope of the study includes the transportation infrastructure including the highway and road network, the transit system (bus and passenger rail), harbors and airfields.

Major routes (limited access state highways) in the region include Route 24 running north-south through Avon, Stoughton, Brockton, West Bridgewater, and Bridgewater in the western part of the region. Route 3 runs north-south along the eastern part of the region and along the Atlantic coast through Hanover, Pembroke, Duxbury, Kingston, and Plymouth. Major east-west limited access highways consist of I-495, which is south of Easton and runs through the southeastern portion of Bridgewater, and Route 44, which runs west from Plymouth through Kingston and Plympton. Route 24 and Route 3 provide access to Boston and the Route 128 corridor. Route 44 provides connections to Route I-495 and the Massachusetts Turnpike.

[1] PAS Report 596, Planning for Infrastructure Resilience, American Planning Association, Page 5.

The region is also served by a number of state numbered routes, mostly two lane, undivided facilities providing regional connections including Route 106, which runs east from Easton through West Bridgewater, East Bridgewater, Hanson, Halifax, and Kingston. Route 27 runs southeast from Stoughton through Brockton, Whitman, Hanson, Pembroke, and Kingston. In the north of the region, Route 139 runs east through Stoughton, Abington, Hanover, and Pembroke. State numbered routes that are two lane, undivided facilities running north south through the region include Route 28, which runs north from Bridgewater through West Bridgewater, Brockton, and Avon. Route 18 runs north from Bridgewater through East Bridgewater, Whitman, and Abington. In the eastern portion of the region, Route 53 runs north from Kingston through Duxbury and Pembroke, and Route 3A is a coastal route that runs north along the entire length of Plymouth's coastline and continues north through Kingston and Duxbury. Figure 1 shows the communities in the Old Colony Planning Council Region.

Figure 1



The topography of the region is relatively flat, with the exception of the Pine Hills near the coast in Plymouth. Areas of relatively higher elevation exist in the northern communities of Stoughton, Avon, and Abington, ranging up to approximately 250 feet. The lowest elevations are found where the Taunton River exits the region. Although more than 20 miles from the ocean, the elevation is only 15 feet above sea level. The region's rivers and streams do not experience great or rapid drops in elevation, and generally flow slowly. Many of the rivers are broad and meandering with shallow depths

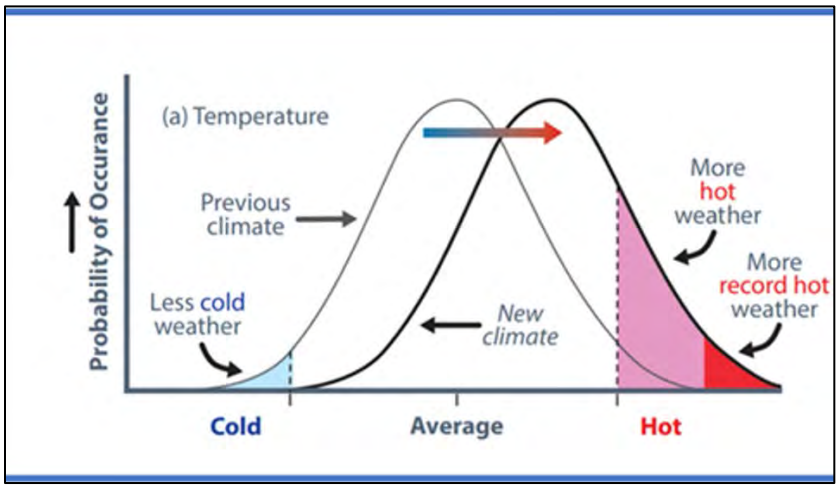
and a wide riparian zone of wetlands along the banks. The Old Colony region's terrain consists of generally low and gently rolling glaciated land with many hills, ridges, and other features created by the late glacial ages, as well as a generally north-south drainage system and extensive wetlands including the Hockomock Swamp in parts of Bridgewater, Easton, and West Bridgewater and the Great Cedar Swamp in Halifax and Hanson. Three of the region's municipalities are coastal communities including Duxbury, Kingston, and Plymouth. Plymouth has the largest land area of any municipality in Massachusetts with 134 square miles and over 20 miles of coastline.

The 2019 population of the OCPC region was 380,509 people, based on estimates derived from the 2010 US Census. According to the *OCPC Comprehensive Economic Development Strategy*, the population of the region is expected to grow to 423,739 by the year 2040. This represents a 9.3 percent growth in population. Most of the growth in the region is expected to occur in Plymouth with a projected increase of 24.5 percent and Abington with a projected increase of 18.9 percent. Communities expected to grow the least include Hanover at 1.5 percent and Halifax at 1.6 percent.

What is Climate Change

Weather is the short-term, day-to-day state of atmospheric changes. The variation in weather occurs in minutes to days, to weeks. Weather is the day-to-day condition of temperature, humidity, precipitation, cloudiness, visibility, and wind. Climate is the weather of a specific place averaged over a period of time, often 30 years. Climate Change occurs as the average temperature of a specific place rises gradually. This gradual rise in temperature is due to the presence of greenhouse gases and atmospheric pollution, (notably carbon) in the Earth's atmosphere, which trap the sun's heat. Climate Change happens due to an increase in global temperatures, which in turn brings extreme weather and extreme weather events as a result of the impact of increased levels of greenhouse gases. Figure 2 shows the shift in the average temperature over time, which results in increases in more hot weather and more extreme weather.

Figure 2



Challenges

According to the *Massachusetts State Hazard Mitigation and Climate Adaptation Plan*, Climate Change in Massachusetts is already exacerbating natural hazards and extreme weather and it is leading to new impacts affecting the state.[2] Massachusetts is expected to experience intensification in four areas, precipitation, sea level rise, rising temperatures, and extreme weather events.

Changes in Precipitation

The changes in precipitation are expected to bring inland flooding as well as drought during the summers. Annual precipitation increases of up to 16 percent or plus 7.3 inches are expected. The days with rainfall accumulation of more than one inch is expected to increase by 57 percent. Conversely, the summers are expected to see a decrease in precipitation with an increase in consecutive dry days leading to more droughts during the summer with an increase in potential for landslides.[3]

Severe and frequent rainfall may exceed the capacity of existing stormwater systems, as Brockton and many of the OCPC communities experienced in March of 2010. Fire stations, police stations, and schools are vulnerable as coastal and riverine flooding may over flood bridges, roads, and public transit infrastructure. Flooding, as well as coastal storm surge, which will be more severe due to sea level rise, can interrupt first responder and emergency operations. Flooded roads or damaged ports could have significant negative impacts on local economies and disrupted transportation networks may impede the mobility of emergency services. In addition, combined sewer overflow events may precipitate public health crises.[4]

Flooding

Inland flooding is the result of moderate precipitation over several days, intense precipitation over a short period, or melting snowpack. In addition, developed areas that have impervious areas can contribute to inland flooding.

Common types of inland flooding include:

- Riverine Flooding - Riverine flooding often occurs after heavy rain. Areas of the state with high slopes and minimal soil cover (such as found in western Massachusetts) are particularly susceptible to flash flooding caused by rapid runoff that occurs in heavy precipitation events and in combination with spring snowmelt, which can contribute to riverine flooding. Frozen ground conditions can also contribute to low rainfall infiltration and high runoff events that may result in riverine flooding. Some of the worst riverine flooding in Massachusetts' history occurred as a result of strong nor'easters and tropical storms in which snowmelt was not a factor. Tropical storms can produce very high rainfall rates and volumes of rain that can generate high runoff when soil infiltration rates are exceeded. Inland flooding in Massachusetts is forecast and classified by the National Weather Service's (NWS) Northeast River Forecast Center as minor, moderate, or severe based upon the types of impacts that occur.

[2] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan | Executive Summary, Page 4.
[3] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan | Executive Summary, Page 4.
[4] PAS Report 596, Planning for Infrastructure Resilience, American Planning Association, Page 6.

- Urban Drainage Flooding - Urban drainage flooding entails floods caused by increased water runoff due to urban development and drainage systems that are not capable of conveying high flows. In urban areas, basement, roadway, and infrastructure flooding can result in significant damage due to poor or insufficient stormwater drainage. Overbank flooding occurs when water in rivers and streams flows into the surrounding floodplain or into any area of land susceptible to being inundated by floodwaters from any source, according to the Federal Emergency Management Administration (FEMA). Flash floods are characterized by rapid and extreme flow of high water into a normally dry area, or a rapid rise in a stream or creek above a predetermined flood level, based on FEMA definitions.
- Flooding and flood-related erosion can result from various types of ground failures, which include mud floods and mudflows, and to a much lesser degree, subsidence, liquefaction, and fluvial erosion.
- Dam Overtopping - A dam is an artificial barrier that has the ability to impound water, wastewater, or any liquid borne material for the purpose of storage or control of water. There are two primary types of dam failure: catastrophic failure, characterized by the sudden, rapid, and uncontrolled release of impounded water, or design failure, which occurs as a result of minor overflow events. Dam overtopping is caused by floods that exceed the capacity of the dam, and it can occur as a result of inadequate spillway design, settlement of the dam crest, blockage of spillways, and other factors.
- Beaver dams or levee failure - Beaver dams obstruct the flow of water and cause water levels to rise. Significant downstream flooding can occur if beaver dams break.
- Floodplains - Floodplains by nature are vulnerable to inland flooding. Floodplains are the low, flat, and periodically flooded lands adjacent to rivers, lakes, and oceans. These areas are subject to geomorphic (land-shaping) and hydrologic (water flow) processes. Floodplains may be broad, as when a river crosses an extensive flat landscape, or narrow, as when a river is confined in a canyon.

The 100-Year Flood

The 100-year flood is the flood that has a one percent chance of being equaled or exceeded each year. The 100-year flood is the standard used by most federal and state agencies. For example, it is used by the National Flood Insurance Program (NFIP) to guide floodplain management and determine the need for flood insurance. The extent of flooding associated with a one percent annual probability of occurrence (the base flood or 100-year flood) is called the 100-year floodplain, which is used as the regulatory boundary by many agencies. Also referred to as the Special Flood Hazard Area (SFHA), this boundary is a convenient tool for assessing vulnerability and risk in flood-prone communities.

The 500-Year Flood

A 500-year flood is an event that has a 1 in 500 chance of occurring in any given year. “For a 500-year flood, there is a 0.2 percent chance of having a flood of that magnitude occurring” in any given year, according to the National Weather Service.

Significant Floods

The Great Flood of 1936

The Great Flood of 1936 brought devastating floods to much of the Bay State, particularly across the Merrimack and Connecticut valleys. This event was created by several key elements. The first was

consistently well below normal temperatures from mid-January through early March. This prolonged cold spell contributed to a buildup of thick ice on many area rivers. The next key element, also helped by the cold temperatures, was the buildup of a sizeable snowpack across much of the region. Finally, mid through late March brought a substantial warm-up accompanied by periods of significant rainfall. The result was a devastating combination of runoff from rain and snowmelt, as well as the breakup of river ice that was destructive in its size and the subsequent creation of ice jams in many rivers.

Record flood crests during March of 1936 occurred over a number of river locations, and these record flood crests stand today: Connecticut River at Montague, Northampton, Holyoke and Springfield, the Merrimack River at Lowell, Lawrence and Haverhill, and the Nashua River at East Pepperell.

Floods of March 2010

Widespread flooding occurred in central and eastern Massachusetts during mid to late March 2010 caused by a series of moderate to heavy rainfall events over a 5-week period starting in late February. The successive and unrelenting nature of these moderate to heavy rainfall events saturated soils and limited opportunities for rivers and streams to recede, making the state vulnerable to flooding. Widespread flooding occurred along the eastern half of Massachusetts in mid-March. An exceptional number of homes, businesses and streets were impacted. Several gages indicated floods of record. These sites included the Concord River at Lowell, the Taunton River at Bridgewater, the Shawsheen River at Wilmington, and the Charles River at Waltham.

Sea Level Rise

Sea level rise projections for the year 2100 are estimated to an average range of one to four feet. The impact of sea level rise can vary because it is dependent on the local ocean current, wind pattern, shoreline contour, land topology, and natural based protection features; however, four feet of water can pose a serious threat to coastal communities and local infrastructure. More extreme average sea level rise scenarios are possible, if greenhouse gas emissions and further destabilization of the Antarctic ice sheet remain unchecked.[5]

Sea level rise is expected to bring on coastal flooding and coastal erosion. There are three towns in the region that will be directly impacted by coastal flooding and erosion, these include Plymouth, Kingston, and Duxbury. Sea level rise poses specific problems for roadways in that it can accelerate roadway deterioration and reduce the life cycle of pavements. In addition, sea level rise can impact ports and harbors as well as coastal development. The impact of sea level rise is dependent on the local ocean current, wind pattern, shoreline contour, land topology, and natural based protection features. It can impact different roads along the coastline more severely in some areas than others.

Rising Temperatures

Massachusetts has a humid continental climate type with warm, humid summers and cold, snowy winters. This type of climate is found over large areas of land masses in the temperate regions of the mid-latitudes where there is a zone of conflict between polar and tropical air masses. The state is prone to extreme weather, with influences from the polar region as well as tropical weather from the south. In addition, the state's proximity to the ocean makes it susceptible to winds and weather from the Atlantic. The hottest month is July, with an average high of 82 °F (28 °C) and average low of 66 °F (18 °C), with conditions usually humid. Periods exceeding 90 °F (32 °C) in summer and below 10 °F (−12 °C)

[5] PAS Report 596, Planning for Infrastructure Resilience, American Planning Association, Page 6.

in winter are not uncommon. The record high temperature is 104 °F (40 °C), recorded July 4, 1911. The record low temperature is -18 °F (-28 °C), recorded on February 9, 1934.

A heat wave is a period of abnormally and uncomfortably hot and usually humid weather. The World Meteorological Organization is specific in its definition by stating that a heat wave is when the daily maximum temperature for more than five consecutive days exceeds the average maximum temperature by 9 degrees. The National Weather Service reported the longest heat wave in Greater Boston lasted 9 days and took place between July 3 and July 11, 1912, a span during which temperatures ranged from daytime lows of 90 degrees to a high of 98 degrees.

According to the *Massachusetts State Hazard Mitigation and Climate Adaptation Plan*, Climate Change is expected to bring average annual temperature increases to 23 percent (plus 10.8 degrees Fahrenheit). It is expected to decrease up to 42 percent the number of days with the minimum temperature below freezing as winter temperatures are expected to increase at a greater rate than spring, summer, or fall. Long-term average minimum winter temperatures are expected to increase up to 66 percent (+11.4 degrees Fahrenheit). The number of days per year with daily maximum temperatures over 90 degrees Fahrenheit is expected to increase to over 64 days per year.

Climate Change is expected to bring, along with the extreme temperatures, more wildfires and invasive species to Massachusetts.

Although New England is generally considered to be a moist region with ample precipitation, droughts are not uncommon. Widespread drought has occurred across New England a number of times since climate records have been kept. More frequent and severe droughts are expected as climate change continues to increase temperatures, raise evaporation rates, and soils dry out, despite heavier rainfall events. Seasonal or short-term droughts that last less than six months are most common in New England. The greatest risk for seasonal drought may be in the summer and early fall as a result of higher temperatures that lead to greater evaporation and earlier snowmelt. The most common index used to define and monitor drought is the Palmer Drought Severity Index (PDSI), which attempts to measure the duration and intensity of long-term, spatially extensive drought, based on precipitation, temperature, and available water content data.

The Palmer Drought Severity Index (PDSI) uses readily available temperature and precipitation data to estimate relative dryness. It is a standardized index that generally spans -10 (dry) to +10 (wet). Table 1 shows the historic droughts in Massachusetts that measured more than – 3.000 on the PDSI.

Table 1

Year	PDSI
1911	- 3.65
1930	- 3.42
1942	- 3.01
1950	- 4.00
1957	- 4.27
1966	- 4.80
1985	- 3.40
2016	- 3.40

Extreme Weather Events

Hurricanes

According to the *Massachusetts State Hazard Mitigation and Climate Adaptation Plan*, the frequency and magnitude of hurricanes are expected to increase in Massachusetts due to Climate Change. The Gulf Stream, which traditionally brings warm water from the Gulf of Mexico and the southern portion of the North Atlantic northward along the eastern seaboard and across the ocean from west to east is disrupted in north due to the melting of the polar ice cap. This in turn stalls warm water in the Gulf of Mexico, the Caribbean, and the southern portion of the North Atlantic Ocean from moving north, making warmer water available with more energy to fuel more frequent and higher intensity storms.

Hurricanes are also known as Tropical Cyclones. Tropical Cyclone is a general term for low pressure systems such as tropical storms and hurricanes, as these systems usually form over the tropics and they have a distinctive rotation. These storms are among the most powerful and destructive meteorological systems on earth. The destruction is mainly caused due to high winds, heavy rain, lightning, tornadoes, and storm surge. As these storms move inland, they can cause severe flooding, downed trees and power lines, and structural damage. The National Hurricane Center (NHC) describes four types classifications for tropical cyclones, including Tropical Depressions, (with maximum sustained winds of 38 mph or less, Tropical Storms, (with maximum sustained winds of 39 to 73 mph), Hurricanes, a tropical cyclone with maximum sustained winds of 74 mph or higher, and Major Hurricanes, a tropical cyclone with maximum sustained winds of 111 mph or higher.

Hurricane intensity is measured according to the Saffir/Simpson scale, which categorizes hurricane intensity linearly based upon maximum sustained winds, barometric pressure, and storm surge potential. These are combined to estimate potential damage. Table 2 gives an overview of the wind speeds, surges, and range of damage caused by different hurricane categories.

Table 2

Scale No. Category	Winds mph	Surge (ft)	Potential Damage
1	74-95	4-5	Minimal
2	96-110	6-8	Moderate
3	111-130	9-12	Extensive
4	131-155	13-18	Extreme
5	>155	>18	Catastrophic

Source: NOAA

Since 1900, 39 tropical storms have impacted New England (NESEC). Table 3 shows the hurricanes and storms that affected Massachusetts since 1938. Massachusetts has experienced two Category 3 Hurricanes since 1938, which include the unnamed Great New England Hurricane of 1938 and Hurricane Carol in 1954.

Table 3 – Hurricanes and Tropical Storms Affecting New England and Massachusetts

Storm Name	Peak Intensity	Intensity at Landfall	Year
Great NE Hurricane	Category 5	Category 3	1938
Great Atlantic	Category 4	Category 1	1944
Carol	Category 3	Category 3	1954
Edna	Category 3	Category 2	1954
Connie and Diane	Tropical Storm	Tropical Storm	1955
Cindy	Category 1	Tropical Storm	1959
Brenda	Tropical Storm	Tropical Storm	1960
Donna	Category 4	Category 1	1960
Unnamed	Tropical Storm	Tropical Storm	1961
Esther	Category 5	Tropical Storm	1961
Gerda	Category 3	Category 2	1969
Heidi	Tropical Storm	Tropical Storm	1971
Belle	Category 3	Tropical Storm	1976
Gloria	Category 4	Category 1	1985
Bob	Category 3	Category 2	1991
Bertha	Category 3	Tropical Storm	1996
Floyd	Category 4	Tropical Storm	1999
Hermine	Tropical Storm	Tropical Storm	2004
Beryl	Tropical Storm	Tropical Storm	2006
Hanna	Category 1	Tropical Storm	2008

The Great New England Hurricane of 1938

The Great New England Hurricane of 1938 came ashore on September 21 as a Category 3 Hurricane at Suffolk County Long Island, then into Milford, CT. The center made landfall at the time of astronomical high tide, moving north at 60 mph. The hurricane produced destructive storm surge over south coastal Massachusetts and Cape Cod. Sections of Falmouth and New Bedford were submerged under as much as 8 feet of water, in concert with sustained winds of 121 mph and a peak gust of 186 mph.

Rainfall from this hurricane resulted in severe river flooding, especially across portions of western Massachusetts, where 3 to 6 inches of rain fell. The rainfall from the hurricane added to the amounts that had occurred with a frontal system several days before the hurricane struck. The combined effects from the frontal system and the hurricane produced rainfall of 10 to 17 inches across most of the Connecticut River Valley. This resulted in some of the worst flooding ever recorded in this area. Along the Connecticut River in the vicinity of Springfield, the river rose to 6 to 10 feet above flood stage, causing extensive damage. While less rains fell across eastern Massachusetts, substantial freshwater flooding still occurred at some locations. This included the lower Merrimack River, which from Lowell to Haverhill achieved one of its top 3 flood crests on record.

Throughout southern New England, a total of 8,900 homes, cottages and buildings were destroyed, and over 15,000 were damaged by the hurricane. The marine community was devastated. Across all of southern New England, over 2,600 boats were destroyed, and over 3,300 damaged. The hurricane was responsible for 564 deaths and at least 1,700 injuries in Southern New England. Damage to the fishing

fleets in Southern New England was catastrophic. A total of 2,605 vessels were destroyed, with 3,369 damaged.[6]

Hurricane Carol

Hurricane Carol made landfall on eastern Long Island, New York, and then over eastern Connecticut on August 31, 1954 with sustained winds estimated at 110-mph. It later transitioned into an extratropical cyclone over New Hampshire, on August 31, 1954. Hurricane Carol brought strong winds and rough seas to coastal Connecticut, Rhode Island, and southeastern Massachusetts. Throughout the region, about 150,000 people were left without electricity and telephone service, 1,545 houses were destroyed and another 9,720 were damaged, and approximately 3,500 cars and 3,000 boats were destroyed. There were 65 deaths and 1,000 injuries in New England. In Massachusetts, the hurricane produced winds between 80 and 110 mph (130 to 180 km/h) across much of the eastern part of the state. Gusts reached 80 mph (130 km/h) at Blue Hill Meteorological Observatory, and the highest gusts in the state were around 125 mph (201 km/h). The winds downed about 50 million board feet of trees in the state, many of which fell onto power lines as much of eastern Massachusetts lost power during the storm. Carol left about $15 million in crop damage in the state. In Wareham, MA, about 1,500 people were left homeless

1955 Floods from Connie and Diane

Two named tropical systems in August 1955, producing significant flooding over much of Massachusetts. Connie produced generally 4 to 6 inches of rainfall over Massachusetts on August 11 and 12. The result of this was to saturate the ground and bring river and reservoir levels to above normal levels. Diane came a week later with rainfall totals ranging up to nearly 20 inches over a to- day period. This exceeded records for New England.

With the strong intensity rainfall on saturated soil, the rise of the rivers was rapid. Even rivers along the coastal region of eastern Massachusetts, including the Charles, Taunton, and Neponset, experienced dramatic and rapid rises. On the Blackstone and Thames River headwaters south of Worcester, many dam breaks occurred, producing significant flooding and destruction downstream. In the Connecticut River Valley, the most significant floods were experienced on the Chicopee and Westfield Rivers; however, since the heaviest rains did not reach into northern New England, the mainstem Connecticut River did not flood to the degree seen on the Chicopee and Westfield Rivers.

Tornados

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud. These events are spawned by thunderstorms and occasionally by hurricanes and may occur singularly or in multiples. They develop when cool air overrides a layer of warm air, causing the warm air to rise rapidly. Most vortices remain suspended in the atmosphere. Should they touch down, they become a force of destruction. Some ingredients for tornado formation include:

- Very strong winds in the mid and upper levels of the atmosphere
- Clockwise turning of the wind with height (from southeast at the surface to west aloft)
- Increasing wind speed with altitude in the lowest 10,000 feet of the atmosphere (i.e., 20 mph at the surface and 50 mph at 7,000 feet)
- Very warm, moist air near the ground with unusually cooler air aloft

[6] This information was taken from "Southern New England Tropical Storms and Hurricanes, A Ninety-eight Year Summary 1909-1997", by David R. Vallee and Michael R. Dion, National Weather Service, Taunton, MA.

- A forcing mechanism such as a cold front or leftover weather boundary from previous shower or thunderstorm activity.

Tornado damage severity is measured by the Fujita Tornado Scale, is which wind speed is not measured directly but rather estimated from the amount of damage. As of February 1, 2007, the National Weather Service began rating tornados using the Enhanced Fujita-scale, which allows surveyors to create more precise assessment of tornado severity.

Table 4 – Enhanced Fujita Scale

EF 0	65-85 mph	Light damage
EF 1	86-110 mph	Moderate damage
EF 2	111-135 mph	Considerable damage
EF 3	136-165 mph	Severe damage
EF 4	166-200 mph	Devastating damage
EF 5	>200 mph	Incredible damage

On average there are six tornados that touchdown somewhere in the Northeast region every year. On average, (between 1950 and 2008), more than two tornadoes per year strike the state of Massachusetts alone, with New England as a whole recording more than 8. Most tornadoes reported in the region are "weak", rated EF0 or EF1 on the Enhanced Fujita Scale. Around 30 percent are "significant" tornadoes (rated EF2 or greater), and only one percent are violent (rated EF4 or EF5, the highest damage rating). Weak tornadoes occur in all areas of New England, but EF3 or greater tornadoes have been reported. There have been 34 killer tornadoes in New England's recorded history.

Nor'easter

A nor'easter is an extratropical cyclone in the western North Atlantic Ocean. The name derives from the direction of the winds that blow from the northeast. The original use of the term in North America is associated with storms that impact the upper north Atlantic coast of the United States and the Atlantic Provinces of Canada.

These storms originate as a low-pressure area that forms within 100 miles from the shore between North Carolina and Massachusetts. The precipitation pattern is similar to that of other extratropical storms. Nor'easters are usually accompanied by very heavy rain or snow, and can cause severe coastal flooding, coastal erosion, hurricane-force winds, (more than 74 miles per hour) or blizzard conditions. Nor'easters are usually most intense during winter in New England and Atlantic Canada. They are fueled by converging air masses that include the cold polar air mass and the warmer air over the water. They can be more severe in the winter when the difference in temperature between air masses is greater.

Nor'easters tend to develop most often and most powerfully between the months of October and April, although they can (much less commonly) develop during other parts of the year as well. Table 5 shows major Nor'easter events in Massachusetts.

Table 5

Nor'easter Event	Date
Blizzard of 1978	February 1978
Coastal Storm ("Perfect Storm")	October 1991
Great Nor'easter of 1992	December 1992
Nor'easter/Blizzard	January 2005
Coastal Storm/Nor'easter	October 2005
Inland and Coastal flooding/Nor'easter	April 2007
Winter Storm/Nor'easter	January 2011
Blizzard of 2013	February 2013
Blizzard of 2015	January 2015
March 2015 Nor'easter	March 2015

Blizzard of '78

Although the Blizzard of '78 (February 6-8) is known for the incapacitating snowfall, snow drifts and wind gusts it brought to Massachusetts, it is also known for the devastating coastal flooding that it brought to Massachusetts. Astronomical high tides occurred during the timeframe of the blizzard. Major coastal flooding severely damaged over 2,000 homes, displacing some of the 10,000 people who required shelter. Damage from the storm is estimated at more than $2.3 billion (in 1998 dollars). The storm resulted in 73 deaths in Massachusetts.

Public Outreach

OCPC contacted key stakeholders to garner input regarding community efforts to identify and mitigate the impacts of Climate Change on the transportation infrastructure at the local level. Much of the effort by communities has been completed through the Municipal Vulnerability Preparedness Program, although only 15 of the 17 OCPC communities have participated in this statewide effort. Stakeholder identification and involved outreach local officials, watershed associations, local agencies, and interested groups. Stakeholder outreach included regular updates to the Old Colony Metropolitan Planning Organization (MPO) and Joint Transportation Committee (JTC).

OCPC staff contacted interviewed local elected officials and representatives of agencies to help discern the impacts and priorities in dealing with the effects of Climate Change.

Federal and State Directives and Policies

Federal Response to Climate Change

Executive Order

The federal government issued a number of executive orders in response to Climate Change. Executive Order 13653, "Preparing the US for the Impacts of Climate Change", was issued in 2013. It built on a previous 2009 executive order, which supported scientific research, observational capabilities, and assessments to improve understanding and response to climate change and its impacts on the country. The 2013 executive order promoted federal agencies to engage in strong partnerships and information sharing at all levels of government, utilize risk-informed decision making and the tools to facilitate it, utilize adaptive learning, in which experiences serve as opportunities to inform and adjust future actions, and promote preparedness planning.

In 2014, the Federal Highway Administration (FHWA) created policy in response to executive Order 13653 via directive. The FHWA stated that it will, "Integrate consideration of the risks of climate change and extreme weather event impacts and adaptation responses, into the delivery and stewardship of the Federal-aid and Federal Lands Highway programs, including encouraging State DOTs, MPOs, tribal governments, and others to develop cost-effective strategies to minimize climate and extreme weather risks." Specifically, the FHWA developed the *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance,* for in response to the need for action due to Climate Change.

The FHWA guide focuses on two transportation functions, transportation systems management and operations and maintenance of transportation infrastructure. Both of these involve the day-to-day activities that maximize the use of transportation infrastructure. The FHWA anticipates a number of operational impacts due to Climate Change including:

- Increase in traffic incident management activities.
- Road and lane closures.
- Reduced (and variable) speed limits.
- Disruption of transit service.
- Road and transit diversions.
- Truck restrictions.
- Work zone management (to accommodate additional lane closures).

In order to ensure that infrastructure is resilient against Climate Change, maintenance practices have to be pro-active to anticipate changes to the system (e.g., inspection, frequency of repairs, need for "quick maintenance" patrols).

Transportation systems management and operations include; Traffic Management, Freight Management, Work Zone Management, Traffic Incident Management, Planned Special Event management, Traveler Information Services, Road Weather Management, Traffic Signal Coordination, Active Transportation & Demand Management, and Transit Priority and Integration. Maintenance includes; Pavement Management, Shoulder Maintenance, Bridge Inspection, Vegetation Management, Road Weather Management, and Asset Management.

State Response to Climate Change

Global Warming Solutions Act

Massachusetts approved the Global Warming Solutions Act (GWSA) on August 7, 2008, as a comprehensive response to the impacts of global climate change. The GWSA requires the Executive Office of Energy and Environmental Affairs (EOEEA), in consultation with other state agencies, as well as the public, to set economy-wide greenhouse gas (GHG) emission reduction goals for the state. The GWSA approved (in consultation with the state executive office of administration and finance), the use of market-based compliance mechanisms to address climate change concerns and for setting and reaching reduction goals. In addition, it allowed the state to work with other states to develop a plan to expand market-based compliance mechanisms such as the regional greenhouse gas initiative to other sources and sectors necessary or desirable to facilitate the achievement of the greenhouse gas emission. This includes those states who have in the past participated in the regional greenhouse gas initiative and includes other interested states and Canadian Provinces.

The GWSA set the following priorities:

- Establish 1990 as a baseline assessment of statewide GHG emissions used to measure goal progress (1990 is the base year of the Kyoto Protocol).
- Establish target emission reductions for 2020, and a plan for achieving them.
- Analyze strategies via advisory committee and make recommendations for adapting to climate change, the committee reports to the Legislature by December 31, 2009.
- Reduce between 10 percent and 25 percent below statewide 1990 GHG emission levels in the state by 2020.
- Reduce to at least 80 percent below statewide 1990 GHG emission levels by 2050.
- Establish regulations requiring reporting of GHG emissions by the Commonwealth's largest sources by January 1, 2009 providing data about the types and levels of GHG.
- Develop a projection of the statewide GHG emissions for 2020 (a "business as usual" scenario as if no government action is implemented for reductions).
- EOEEA established two advisory committees to provide input on the implementation of the GWSA 1.) The Climate Protection and Green Economy Advisory Committee to advise the Executive Office of Energy and Environmental Affairs on measures to reduce greenhouse gas emissions in accordance with the GWSA, 2.) The Climate Change Adaptation Advisory Committee to study and make recommendations on strategies for adapting to climate change.

<u>The Transportation Climate Initiative</u>

According to the Massachusetts Department of Environmental Protection, the Transportation Climate Initiative (TCI) is a regional collaboration of Northeast and Mid-Atlantic jurisdictions, working together since 2010 to improve transportation, develop the clean energy economy, and reduce emissions from vehicles and fuels. Twelve northeast and mid-Atlantic states plus Washington, D.C., are involved in the discussions to join the TCI, these include: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and Virginia.

TCI is a “Cap-and-Trade” system, whereby a cap is set on the total amount of carbon dioxide that can be released from vehicles using transportation fuels (lowered as time goes on) in each jurisdiction. Transportation fuel suppliers must then buy allowances for every ton of carbon dioxide their fuel will produce, the total number of allowances is limited, based on the cap. An auction is held in which fuel suppliers can bid to buy fuel allowances in which the price of those allowances depends on the market, as allowances can be traded.

The states and jurisdictions get money from the sale of the allowances and would be required to invest that money into projects that reduce carbon emissions from transportation. This system is expected to incentivize development of fuel-efficient technologies and incentivize people to use less pollution emitting fuel. It is also expected that the system will raise money for state investments in new technologies, such as electric vehicles.

According to the Transportation Climate Initiative, the Memorandum of Understanding was signed in December of 2020 by Massachusetts, Connecticut, Rhode Island, and the District of Columbia and includes a commitment to dedicate a minimum of 35 percent of each jurisdiction’s proceeds, (which can amount to nearly $100 million each year in the inaugural jurisdictions combined), to ensure that communities underserved by the transportation system and overburdened by pollution will benefit

equitably from clean transportation projects and programs. Each jurisdiction will designate an advisory body to identify underserved and overburdened communities, provide guidance for investments, and define goals and metrics for measuring progress. A majority of the members of each advisory body will be people from or representing underserved and overburdened communities.

It was expected that each signatory jurisdiction will work with communities and with its Equity Advisory Body to assess the equity impacts of the program on an ongoing basis, including by monitoring air quality in communities overburdened by air pollution to ensure the effectiveness of policies and investments, and will ensure transparency by annually reviewing and reporting on program progress. The Signatory Jurisdictions agreed to work together to encourage other jurisdictions to participate in TCI to expand the program. Any jurisdiction may withdraw at any time; however, they must not interfere with the integrity of the program. The jurisdictions also commit to continue to work individually and together on additional policies that reduce pollution from transportation and advance shared goals of equity and environmental justice.

On Nov. 15, 2021, Connecticut and Massachusetts pulled out of the 12-state TCI Agreement. The governor of Massachusetts cited a lack of support of TCI from the other partners as a reason to pull out of the agreement. The governor's spokesperson cited that the administration maintained that Massachusetts would only move forward with TCI if multiple states committed and if that was not possible, then TCI would no longer be the best solution for the Commonwealth's transportation and environmental needs.

State Hazard Mitigation and Climate Adaptation Plan

The *Massachusetts 2018 State Hazard Mitigation and Climate Adaptation Plan* integrated the traditional hazard mitigation plan with a climate change adaptation plan. It is an update of the state's *2013 State Hazard Mitigation Plan* and the *2011 Massachusetts Climate Change Adaptation* and is also intended to fulfill the requirements for the Executive Order 569 climate adaptation plan.

The plan aims to provide a better understanding of transportation infrastructure asset risk due to future inland flooding. According to the Massachusetts Department of Transportation (MassDOT), the plan objective is to utilize the latest climate model results, suitable hydrologic and hydraulic tools, geospatial analysis, and scenario planning methods to achieve the study goals. The potential impact of extreme heat on transportation assets and operations is also investigated qualitatively. The study is meant to coordinate and integrate with the MassDOT Highway Division and the MBTA's efforts related to climate change and resiliency.

The study results are expected to include:

- A prototype methodology for estimating future climate-related inland flooding risks and asset vulnerability at the state level.
- Downscaled climate projections for three emission scenarios (Representative Concentration Pathway 4.5, 6.0 and 8.5) for four future periods (2030, 2050, 2070 and 2100).
- Projected percent change of 1% annual exceedance probability (AEP) 24-hour precipitation.
- Projected 1% AEP 24-hour precipitation depth.
- Projected annual maximum number of consecutive days less than 95°F.
- Projected number of days greater than 95°F in summer months.
- Future 1% AEP floodplain maps for selected climate scenarios and future periods.

- Risk analysis of MassDOT assets' potential exposure to future inland flooding.
- High-level synthesis of extreme heat impact on transportation assets and operations.
- A prioritized list of MassDOT assets that are most vulnerable to climate risks for different future time periods.
- A final report describing the study methods, findings, constraints and recommended next steps.

MassDOT intends to release project products that may be of interest and benefit to other state agencies, public organizations and stakeholders, as these products become available and approved. The down-scaled climate projection maps for the whole state and the report, Assessment of Extreme Temperature Impacts on MassDOT Assets are the first set of completed products.

Massachusetts 2050 Decarbonization Roadmap

The *Massachusetts 2050 Decarbonization Roadmap* report was released in January of 2021 by the Executive Office of Energy and Environmental Affairs. The main goal of the report was to identify and document cost-effective and equitable strategies for achieving net zero greenhouse gas (GHG) emissions by the year 2050. The study created a planning process that included stakeholder engagement, science-based analysis, and the inclusion of the business community to maintain the economy while addressing the impacts of Climate Change and reducing greenhouse gas emissions improving air quality and public health.

The approach toward achieving decarbonization goals explores what the report calls "multiple pathways". These include policies that reduce carbon but also support maintaining equity and a thriving economy. According to the Executive Office of Energy and Environmental Affairs, the study seeks to understand interdependencies in the current system and from there create actions and policies that transition energy use to the goal of net zero carbon emissions in Massachusetts. The study process involves modeling future scenarios as well as producing data that can guide the policy and program design.

The policies to achieve the study's 2050 net zero goals include:

Transportation – Emissions free cars, trucks, and buses by utilizing zero carbon fuels, which will include electric and hydrogen powered vehicles. In addition, create a healthy public transit system in concert with transit-oriented development, bike lanes, and sidewalks.

Buildings – Build structures with higher performing heat pumps that can provide energy saving heat and air conditioning as more energy efficient buildings and electric appliances help reduce energy bills for families and small businesses.

Energy Supply – Widely utilize wind and solar power to decarbonize the grid and meet growing demand for clean electricity, but also employ a diverse mix of energy resources for year-round reliability. Make improvements to the transmission and distribution systems to increase access to diverse low-cost energy resources and allow offshore wind to power New England.

Non-Energy – Increase composting and recycling of plastics to minimize waste generation. Manage and reduce emissions in agriculture and industry.

The Clean Energy and Climate Plan for 2030 (2030 CECP)

The Executive Office of Energy and Environmental Affairs (EOEEA) developed the Clean Energy and Climate Plan for 2030 (2030 CECP) to ensure that the 2030 emissions limits that have been set for Massachusetts will be met. This plan provides details on the actions Massachusetts will undertake through the 2020s to ensure the emissions limit is met. The 2030 CECP was prepared in coordination with the development of the 2050 Decarbonization Roadmap in order that the strategies, policies, and actions in the 2030 CECP align with the goal to achieve net zero greenhouse gas emissions by 2050.

The CECP for 2030 outlines a plan to achieve emissions reductions of at least 45% below the 1990 level for 2030. The plan outlined a number of priorities for the EOEEA:

Protect Natural and Working Lands - Create programs with incentives to achieve no net-loss in forest or farmland. Protect and restore inland and coastal wetlands.
Manage for Ecosystem Health and Enhanced Carbon Sequestration - Implement best management practices identified in the Healthy Soils Action Plan and the Resilient Lands Initiative. Commission additional forest carbon sequestration research, building upon the land use analysis in the 2050 Roadmap, to assess the long-term impacts of sustainable forest management practices.
Incentivize Regional Manufacture and Use of Durable Wood Products - Explore opportunities to incentivize the regional use of harvested wood in long-lived products, such as cross laminated timber and wood-based building insulation.
Develop Sequestration Accounting and Market Frameworks - Work with states and stakeholders in the Northeast to develop the measurement, accounting, and market frameworks necessary to support development of a regional carbon sequestration offset market by the end of 2025 (Transportation Climate Initiative, TCI). Convene an inter-agency Carbon Sequestration Task Force beginning in 2021. MassDEP will update the statewide biogenic emissions inventory as needed to support and track verified carbon sequestration.

In April of 2021, Governor Baker signed comprehensive climate change legislation (*Senate Bill 9 - An Act Creating a Next Generation Roadmap for Massachusetts Climate Policy*) codifying Massachusetts' commitment to achieve Net Zero emissions by 2050. This new law establishes new interim goals for emissions reductions, significantly increases protections for Environmental Justice communities across Massachusetts, authorizes the implementation of a new, voluntary energy efficient building code for municipalities, and allows the Commonwealth to procure an additional 2,400 Megawatts (MW) of clean, reliable offshore wind energy by 2027. This legislation updates the greenhouse gas emissions limits related to the 2008 Global Warming Solutions Act, commits Massachusetts to achieve Net Zero emissions in 2050, and authorizes the Secretary of Energy and Environmental Affairs (EEA) to establish an emissions limit of no less than 50% for 2030, and no less than 75% for 2040. The legislation also authorizes EEA to establish emissions limits every five years and sub-limits for at least six sectors of the Massachusetts economy - electric power; transportation; commercial and industrial heating and cooling; residential heating and cooling; industrial processes; and natural gas distribution and service.

Previous OCPC Study

OCPC 2010 Climate Change Transportation Impact Study

The *OCPC 2010 Climate Change Transportation Impact Study* analyzed the impacts of climate change on the Old Colony Region's transportation infrastructure. The study made recommendations for the planning, design, and maintenance of the system. A series of maps that highlighted flood prone areas along and on federal-aid roads, and other transportation facilities for each of the OCPC communities

was developed. The flood maps provided an inventory and starting point to document and address potential issues.

The study documented impacts due to precipitation, extreme weather events, and coastal sea rise and flooding on the transportation system including airports and transit as well as impacts on roadways and bridges. The flooding impacts from precipitation in the study included flooding on the coastline (resulting from precipitation and high tides) and flooding in non-coastline areas for 100-year and 500-year flooding events. The study specifically cited the storms of March 2010, which caused extensive flooding on numerous streets and bridges in the OCPC Region causing travel delays as many roads and bridges were closed. OCPC staff canvassed the DPW's and public works department in an effort to determine the locations affected by the March 2010 flooding. The March 2010 storms created flooding in almost all the OCPC region communities except for Avon and Abington.

The study also discussed Dam Infrastructure as well as Sea Level Rise at specific locations, including White Horse Beach, Plymouth, impacts to coastal landowners and the tourism industry, air quality and health impacts, and increase ground-level ozone and air quality alerts creating health issues among the elderly and young children.

The *OCPC 2010 Climate Change Transportation Impact Study* cited a number of short-term and long-term infrastructure needs. The short-term needs assessment in the study included regulatory and educational recommendations and some of the short-term recommendations were very specific for certain communities while other recommendations applied to the region as a whole.

Short-term infrastructure recommendations included:

- Improve local storm drainage in urban areas, such as in Brockton's Belmont Avenue/Sycamore Avenue neighborhood and Ames Street/Spark Street neighborhood, which flood during times of heavy rainfall.
- Repair and upgrade dams suitable for safe flood storage and storm flow management as needed.
- Reduce fallen tree risk with selective trimming and infill planting by private firms and community tree departments.
- Continue creating and expanding fire breaks upwind of critical facilities and other developments, particularly via controlled burns along roads and power lines; expand efforts to key out-of-forest locations.
- Inspect, maintain, and upgrade older dams for present functions and stormwater management potential, particularly reduction of Sea, Lake, Overland Surge from Hurricane (SLOSH) damage by repairing and modifying seawalls for minimum erosion.
- Reduction of SLOSH damage and personal injury by elevating structures at risk before they are damaged.
- Sweep streets to remove trash, debris, and sediments from the roadside that may impede water flow.
- Remove or modify obstacles to flow in confined streams, e.g., bridges with inadequate clearance.
- Maintain clear spillways and operable boards or sluices to allow purposeful dam operation.
- Directly reduce streamside risks, e.g., by removing selected structures from floodway and reconfiguring banks for flood storage and safe dry weather open space / habitat use.

- Identify opportunities to increase safe flood storage by improving potential multi-use detention and retention basins.

Regulatory recommendations included:

- Flood control though repair and operation of local dams.
- Acquiring homes and properties in areas that flood consistently during storms.
- Enforcing current flood hazard zoning.
- Adopting storm water treatment and retention provisions (maximizing recharge and allowing no increase in runoff) where missing in the local subdivision regulations.
- Encouraging communities to record information about potential damages made by climate change effects.
- Developing and updating local stormwater and floodplain management plans.

Opportunities for utilizing increased public awareness and education include:

- Increase public awareness of flood hazards (e.g., posting signs showing past high water lines).
- Publicize continuing long-term beach loss, potential storm surges, and the function of and need for sand dunes.
- Inform home-owners, residents, and agencies / firms of defensive space principals.

Opportunities for policy improvements include:

- Improve national and international warning systems.
- Promote Transit Oriented Development and Smart Growth principals.
- Revise zoning accordingly – promote compatible, mixed-use development that is
- compact, conserves land, protects historic resources and integrates uses.
- Eliminate the negative impacts of transportation infrastructures on low-income and
- minority neighborhoods.

The *OCPC 2010 Climate Change Transportation Impact Study* cited a number of long-term infrastructure recommendations. The long-term needs require forward-looking suggestions that can support and sustain renewed economic growth and accommodate the growing population for climate change impacts over the next 40 years. Similar to the short-term infrastructure needs, the long-term infrastructure needs also include regulatory recommendations. In addition, the long-term recommendations also suggest preventative methods for future climate change effects in the Old Colony communities and transportation system.

These long-term infrastructure needs include the following:

- Create drainage channels connected to detention ponds on roadways located in high risk
- flooding zones.
- Dredge shallow streams and rivers to increase water flow.
- Consider rail track elevation in potentially flooded or low-lying inland areas.
- Use porous asphalt when replacing paved roads to assist in managing stormwater.
- Integrate transit, bicycle, and pedestrian infrastructure amenities into residential and
- commercial/industrial developments.
- Increase usage and capacity for public transit services.
- Increase connectivity of neighborhoods, enrich urban design, especially as it relates to
- transportation options.

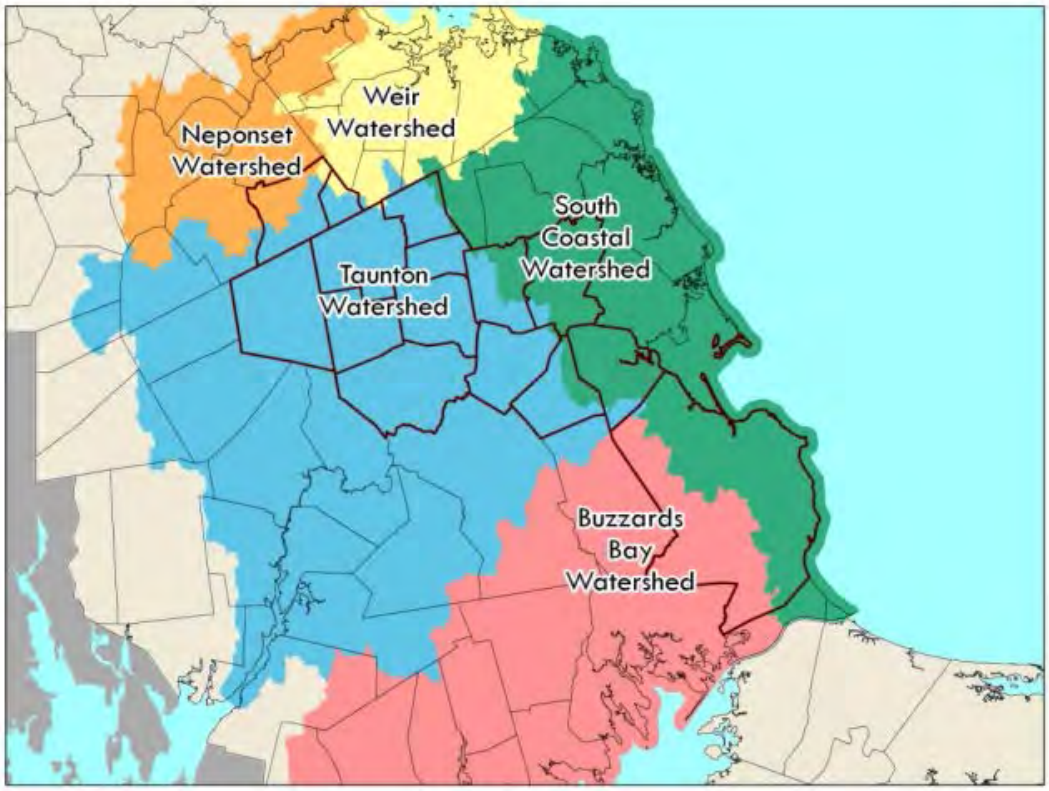
OCPC Climate Change Roadway Drainage and Runoff Study 2011

The purpose of the *OCPC Climate Change Roadway Drainage and Runoff Study (2011)* was to explore the potential effects that climate change-related events could have on the transportation network and on the natural environment, and to explore the condition of the storm water drainage network in problem areas within the OCPC region. The study made connections between the potential impacts discussed in the *OCPC 2010 Climate Change Transportation Impact Study* with potential adaptation measures designed to keep the transportation infrastructure functioning properly.

The study reviewed and outlined the physical geology, watersheds, and impervious areas in the OCPC region. Sandy and loamy soils predominate in the OCPC area, the large grain sizes of these soils providing good natural drainage, as a result of glacial action during the latest glacial age crushing and grinding rock and depositing newer layers of soil.

According to the study, the headwaters of several major watersheds of Southeastern Massachusetts originate in the Old Colony region. The Taunton River flows south, draining much of the region's western half. The northern extremes of the region flow into the Weir and Neponset Rivers. The eastern half of the region drains primarily to Massachusetts Bay, by a number of streams, most notably the Jones River and the North River. The western half of Plymouth, mostly covered by the Myles Standish State Forest, drains into the Buzzards Bay Watershed. Figure 3 shows the watersheds in the OCPC region.

Figure 3



The study documented and discussed the impact of impervious surfaces on the stormwater run-off and stormwater mapping was completed for each of the OCPC communities (with the exception of Duxbury

and Hanover as these towns were not members of OCPC at the time). In addition, the impacts of the March 2010 storm event were documented with flooding in almost all of the OCPC communities. Regional drainage analysis and areas of concern were highlighted in the stormwater mapping. Stormwater regulation was reviewed and strategies to mitigate stormwater impacts, such as Low Impact Development (LID) practices were discussed.

Climate Change and Impact in the OCPC Region

Vulnerability can be defined as the potential or possible exposure to harm a community may have due to a number of hazards or risks. Resilience is the ability of a community to adapt to or to endure those hazards. The Municipal Vulnerability Preparedness Program (MVP) is a planning process designed for climate change resiliency that identifies specific climate related hazards in a community. The MVP process helps communities identify existing and future climate vulnerabilities and strengths and identify opportunities for action to reduce risk and build resilience. The MVP process focuses around three key categories, infrastructure, societal, and environmental.

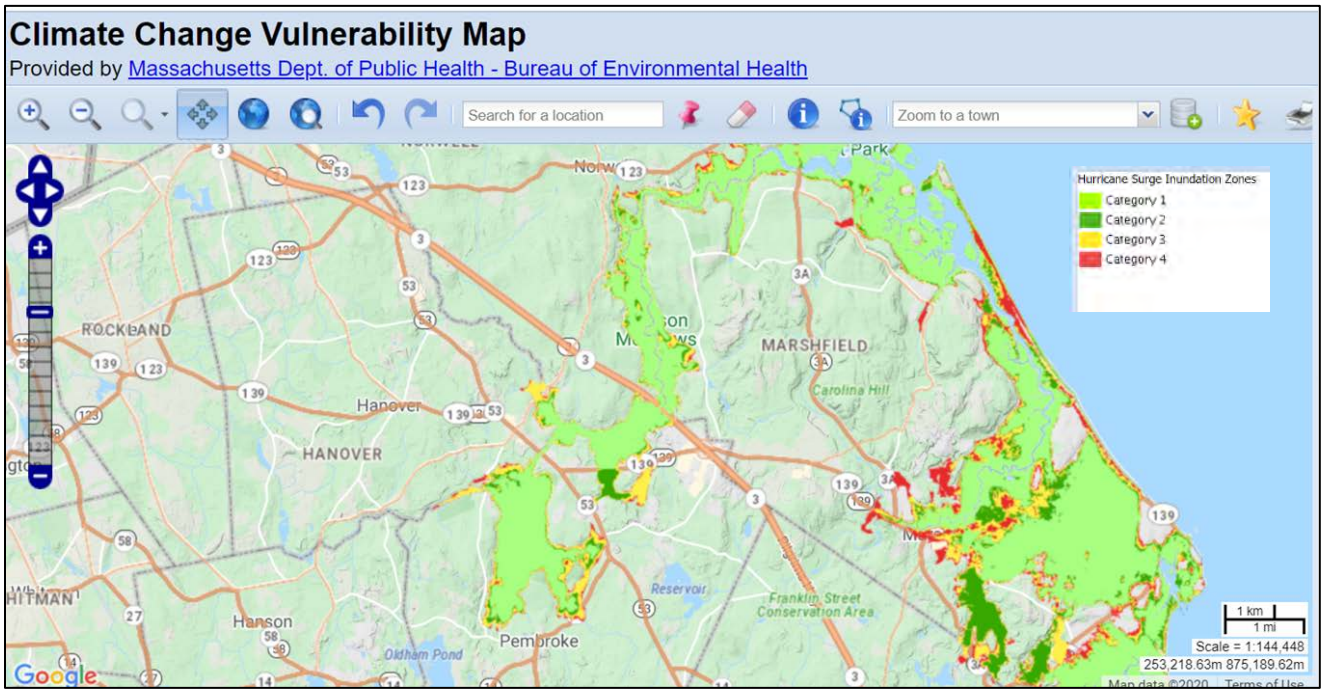
Resiliency planning for transportation is also concerned around the same key categories; however, in keeping in conformance with the FHWA directives, this study focuses on the need for Transportation Systems Management and Operations and Maintenance Programs (TSMO) to adapt to Climate Change. This means assessing the vulnerability of the transportation system in terms of the loss of alternative routes, the loss of situational awareness (due to power/communication), the inability to evacuate/shelter-in-place, the loss of service life (due to faster deterioration, etc.), increased safety risks, and the loss of economic productivity and reduced mobility.

The OCPC Transportation System and Potential Risk

Hurricane Surge Zones

Maps from the Massachusetts Department of Public Health show the impact of the Hurricane surge zone on several OCPC coastal communities including Duxbury, Kingston, and Plymouth as well as those communities of Hanover and Pembroke in close proximity to the coast, (including the non-OCPC communities just north and east, Marshfield and Norwell). The following figures, Figure 4 to Figure 6 show the inundation zones from Hurricane surges from Category 1 through 4 Hurricanes and how they impact the OCPC transportation system.

Figure 4



Based on this data, Figure 4 shows that a Category 1 Hurricane is expected to cause a storm surge that will impact the North River causing flooding inland through Marshfield, Norwell, Hanover and Pembroke. A Category One hurricane has the potential to flood out Route 3 at the Pembroke/Norwell Town Line as well as other arterials important to travel on the road network in Hanover and Pembroke including Route 139, Route 53, and Route 14, as well as Elm Street and West Elm Street in Pembroke. This map also shows significant flooding impacts to Route 3A in the northern part of Duxbury at the Marshfield line with flood inundation from a Category 2 and 3 Hurricane.

Figure 5

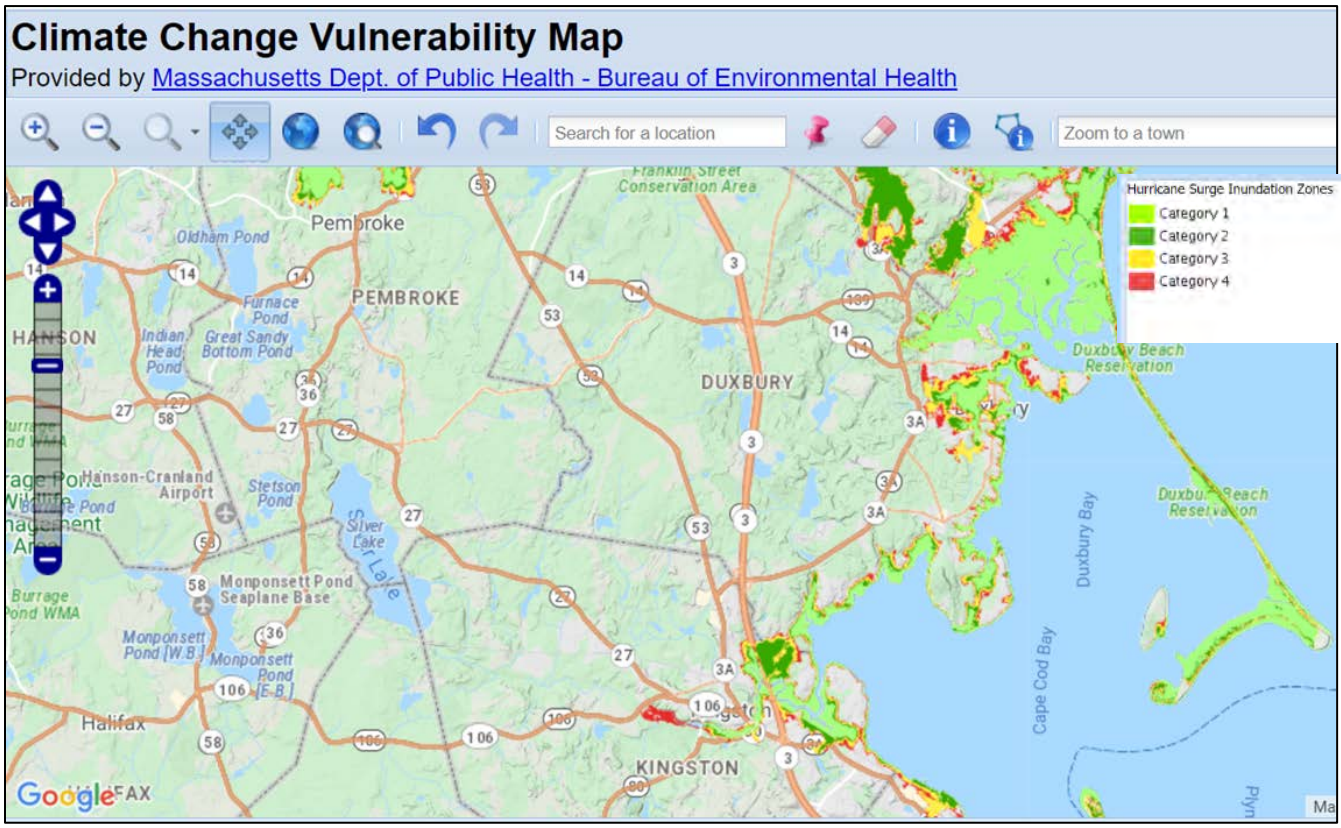


Figure 5 shows that a potential storm surge from a Category 1 and 2 Hurricane will impact Route 3A in Duxbury as well as Route 139 in Marshfield just north of the Duxbury line, and St. George Street and Washington Street. A storm surge from a Category 1 or 2 Hurricane is expected to impact Kingston significantly with flood impacts to Route 3 and Main Street (Route 3A). The Hurricane storm surge is also expected to flood the passenger rail lane to North Plymouth, which runs parallel to Main Street (Route 3A) in Kingston, to Kingston center where it then crosses Main Street and runs west at Evergreen Street.

Figure 6

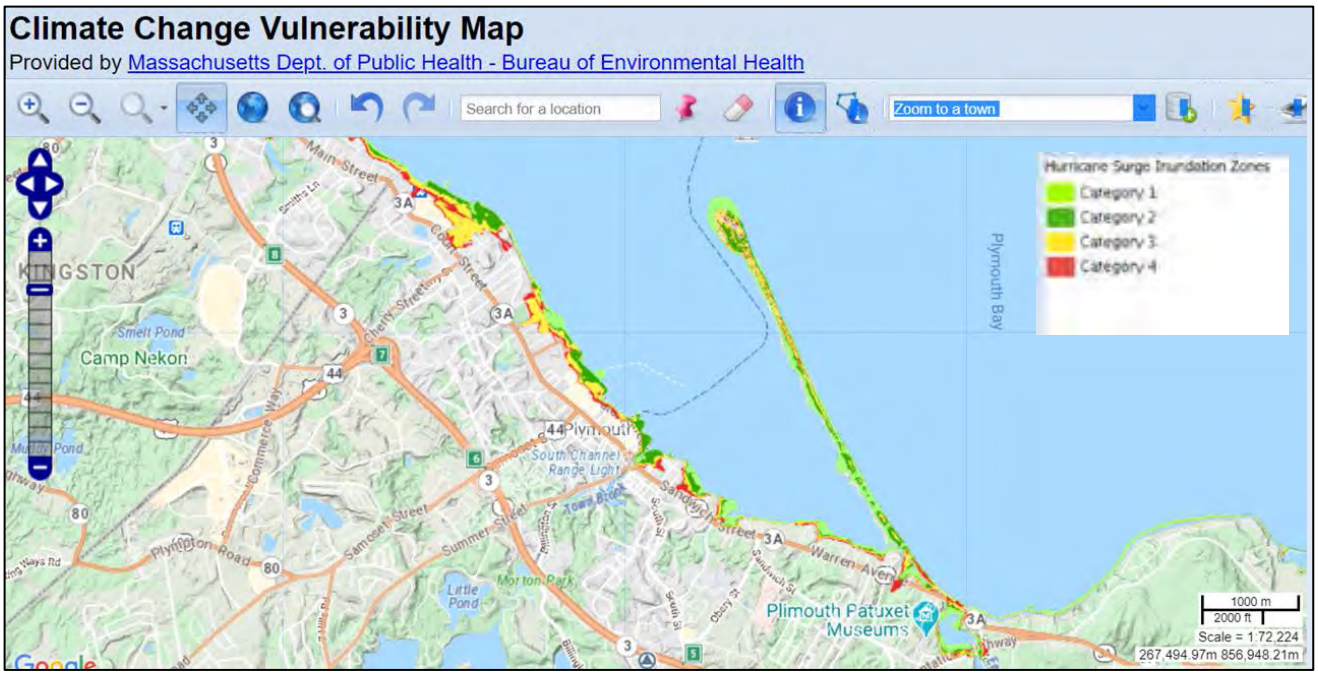


Figure 6 shows that Cordage Park, Route 3A at Cordage Park, and the MBTA T Cordage Passenger Rail Station in Plymouth are expected to be flooded during the storm surge from a Category 3 or higher Hurricane. Much of the coastline from Eel Brook north through the Plymouth Center to the Holmes Reservation in the north is expected to be impacted by a Category 1 and higher Hurricane in Plymouth. The most significant impacts to the transportation network in Plymouth occur on Route 3A over the Eel River and also at the Town Brook at Summer Street and Route 3A, where Route 3A in Plymouth is likely to be flooded from a Category 1 or higher Hurricane.

National Flood Insurance Program (NFIP)

According to the Federal Emergency Management Administration (FEMA), the National Flood Insurance Program (NFIP) is a federal program that aims to reduce the impact of flooding on private and public structures. It provides affordable insurance to property owners, renters and businesses and encourages communities to adopt and enforce floodplain management regulations. The program is intended to reduce the socio-economic impacts of disasters by promoting the purchase and retention of general risk insurance, and specifically, flood insurance.

FEMA has defined flood zones within are geographic areas according to varying levels of flood risk. These zones are shown on a community's official Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area. According to FEMA, The Flood Insurance Rate Map (FIRM) is the official map of a community on which FEMA has delineated Special Flood Hazard Areas (SFHA) for floods and the risk premium zones applicable to parcels in a specific community.

Special Flood Hazard Areas (SFHA) identified on the Flood Insurance Rate Map are defined as the area that will be inundated by the flood event having a one percent chance of being equaled or exceeded in any given year. The one percent annual chance flood is also referred to as the base flood or 100-year flood. The FEMA flood zones are defined as follows (a more detailed description is included in the appendix to this report):

Zone A
The flood insurance rate zone that corresponds to the 100-year floodplains no Base Flood Elevations or depths are shown within this zone.

Zones AE and A1-A30
The flood insurance rate zones that correspond to the 100-year floodplains determined by detailed methods. Base Flood Elevations are shown at selected intervals within this zone.

Zone AH
The flood insurance rate zone that corresponds to the areas of 100-year shallow flooding with a constant water-surface elevation (usually areas of ponding) where average depths are between 1 and 3 feet.

Zone AO
The flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average flood depths derived from the detailed hydraulic analyses are shown within this zone.

Zone D
The designation on NFIP maps is used for areas where there are possible but undetermined flood hazards. In areas designated as Zone D, no analysis of flood hazards has been conducted.

Zone V and VE
The flood insurance rate zone that corresponds to the 100-year coastal flood plains that have additional hazards associated with storm waves.

Zones B, C, and X
The flood insurance rate zones that correspond to areas outside the 100-year floodplains, areas of 100-year sheet flow flooding where average depths are less than 1 foot, areas of 100-year stream flooding where the contributing drainage area is less than 1 square mile, or areas protected from the 100-year flood by levees.

Figures 7 through 9 show a series of maps that show the FEMA flood zones in the OCPC region and their impact on the transportation infrastructure. Figure 7 shows the Plymouth/Kingston passenger rail line is impacted by Zone A through Kingston center as well as in Plymouth at Cordage Park. The Marlborough passenger rail line impacted by Zone A in Bridgewater and East Bridgewater. Figure 7 also shows the Zone A flood impacts on Route 3A in Kingston Center and Route 106 in Kingston as well as Route 3A in Duxbury. In addition, the Kingston-Plymouth passenger rail is expected to be impacted in Whitman.

Figure 7

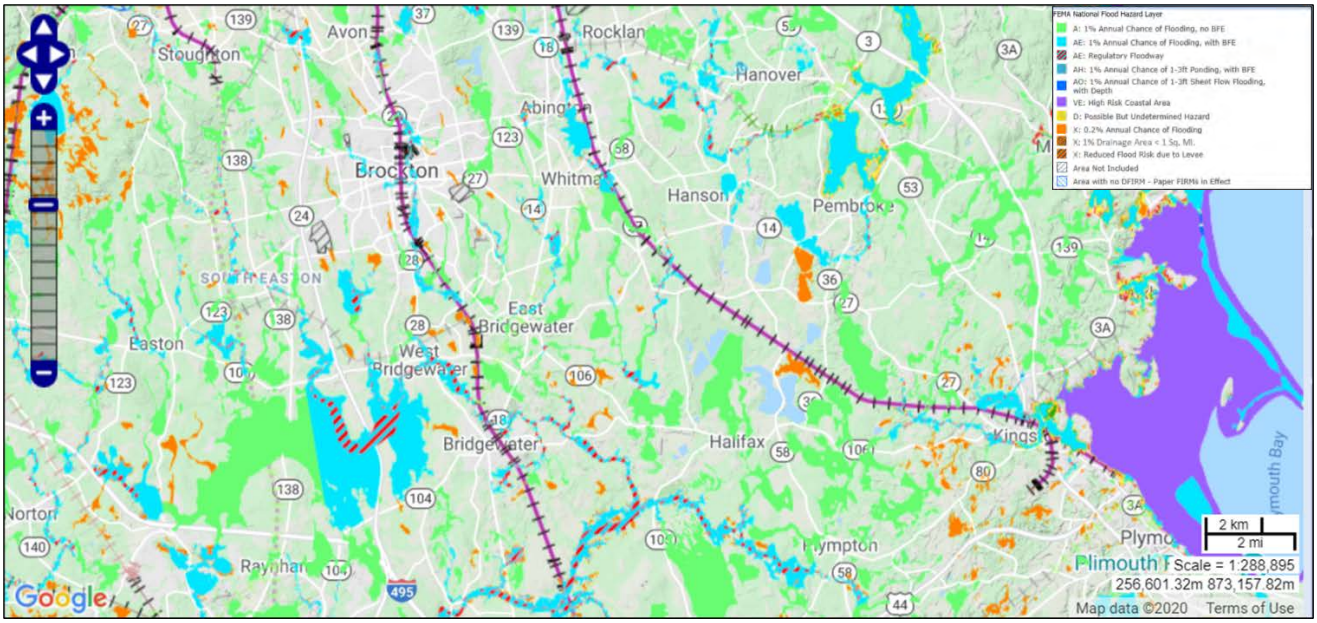


Figure 8

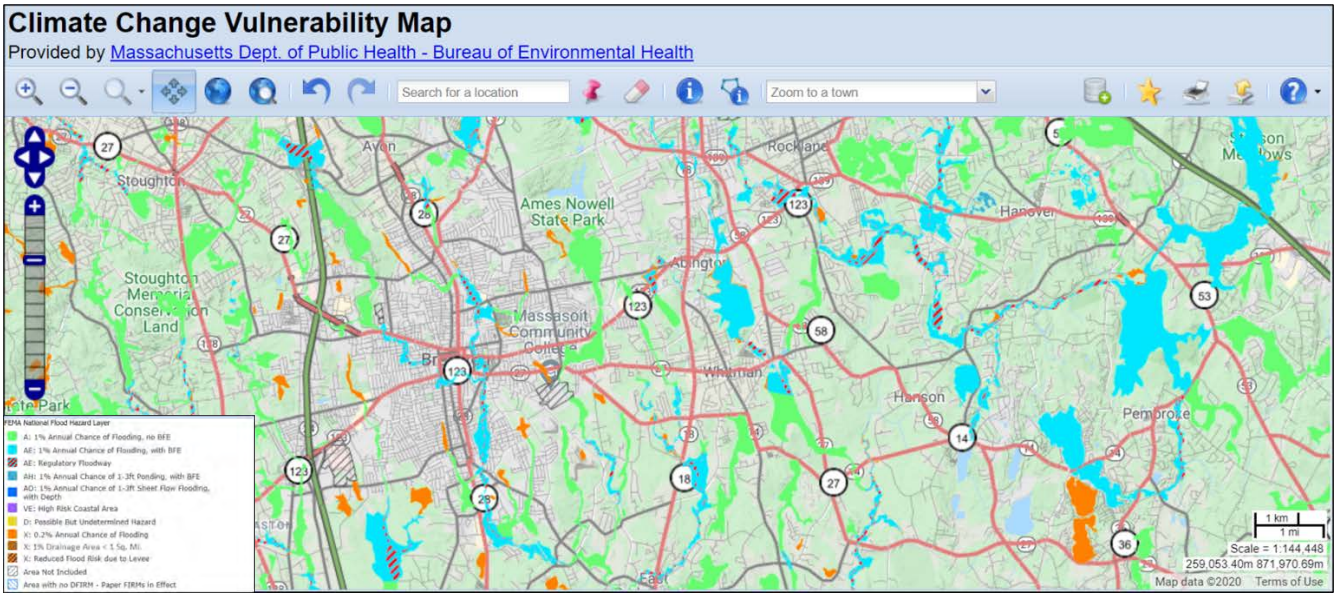


Figure 8 shows the impact of the FEMA flood zones on the regional highway network with impact flooding (Zone A) on Route 53 and Route 139 in Hanover, Route 14 in Pembroke, Route 14 in Hanson and Halifax, Route 123 and Route 139 in Abington, Route 18/28 in Bridgewater, Route 18 and Route 28 in West Bridgewater, and Route 28 in the south of Brockton. In addition, Figure 8 shows potential Zone A flooding impacts to the two limited access highways in the region, Route 24 in the north at the Avon/Stoughton line, and Route 3 in Pembroke.

Figure 9

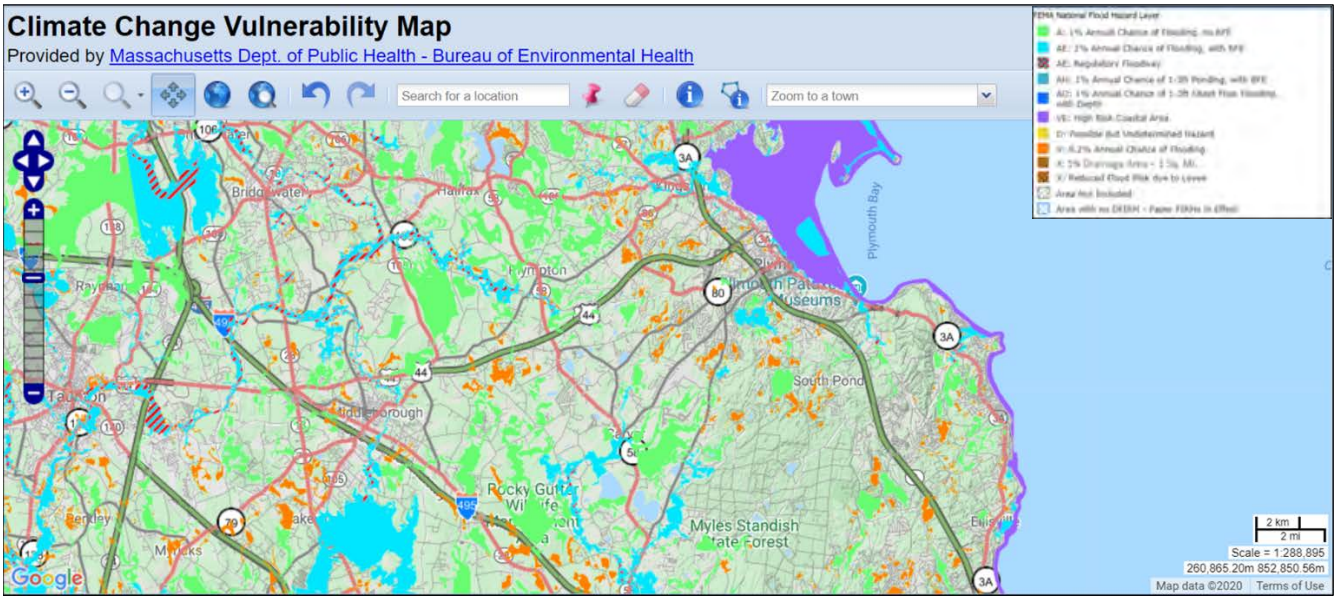


Figure 9 shows the flood zone map impacts on Route 138 in Easton, just north of Raynham, as well as the impacts to Route 24 in Bridgewater, Route I-495, just south of the OCPC region, and Route 44. Figure 9 also shows flood zone map impacts on Route 105 in Bridgewater and Halifax, Route 36 in Halifax, Route 106 in Halifax and Kingston, as well as the impacts to Route 3A in Kingston center and along the coast in Duxbury and Plymouth.

Municipal Vulnerability Preparedness Program

In 2016, the Massachusetts governor issued Executive Order 569. This established a comprehensive statewide approach to reducing greenhouse gas emissions and the impacts of climate change. As part of the initiative, the Municipal Vulnerability Preparedness (MVP) Program was established, which is administered by the Massachusetts Executive Office of Energy and Environmental Affairs. The MVP Program provides communities with funding to identify vulnerabilities and develop plans to increase climate change resilience. In 2018, a $2.4 billion Environmental Bond Bill authorized over $200 million to fund climate change adaptation, including both planning and implementation aspects of the MVP Program. Approximately eighty-one percent of the municipalities in Massachusetts have participated in the MVP Program. Fifteen of OCPC's 17 communities have applied for or are receiving MVP grants for completing the MVP planning process. Three OCPC communities have received MVP action grants to implement the recommendations of their MVP plan including Easton, Duxbury, and Brockton.

Projects funded through Action Grants vary and include a number of priority project categories:

- More detailed vulnerability and risk assessments
- Community outreach and education projects
- Local bylaw updates
- Redesign and retrofits of infrastructure
- Nature-based solutions for flood protection, drought mitigation, and water quality improvements
- Nature-based infrastructure and technology solutions for extreme heat and poor air quality

Abington

The Town of Abington conducted a Community Resiliency Building (CRB) workshop in 2020, which was funded through an MVP grant. The goal of the workshop was to complete a climate change and natural hazard vulnerability assessment through the collaborative efforts of community stakeholders. The goals of the workshop included the development of prioritized actions to address vulnerabilities and improve strengths. Abington is now eligible to apply for state MVP Action Grant funding as it has completed the MVP plan process.

The "core team", consisted of an interdisciplinary team including town staff. The team worked to implement the CRB process with consultant support and state and regional partners. The major areas of concern for Abington cited in the MVP included flooding (multiple areas in locations of historical flooding), strong storms and extreme weather events (winter storms, heavy rainfall, high winds, and ice storms), and drought and extreme temperatures.

Priorities for infrastructure improvement included:

- Town-wide stormwater management system, dam maintenance and repairs Hunts Brook, Beaver Brook, and Island Grove Pond Dam
- Bridge repairs (e.g., Central Street Bridge)
- Maintenance and security of the public water supply
- Senior Housing Centers (install back-up generators)
- Schools
- Critical facilities with only one egress
- Island Grove area (erosion and tree loss)
- Carista property (potential for wildfires)
- Loss of tree canopy (town-wide)
- Water quality concerns (e.g., algae blooms)
- Strawberry Valley Golf Course (loss of pond)

<u>Abington Improvement Recommendations:</u>

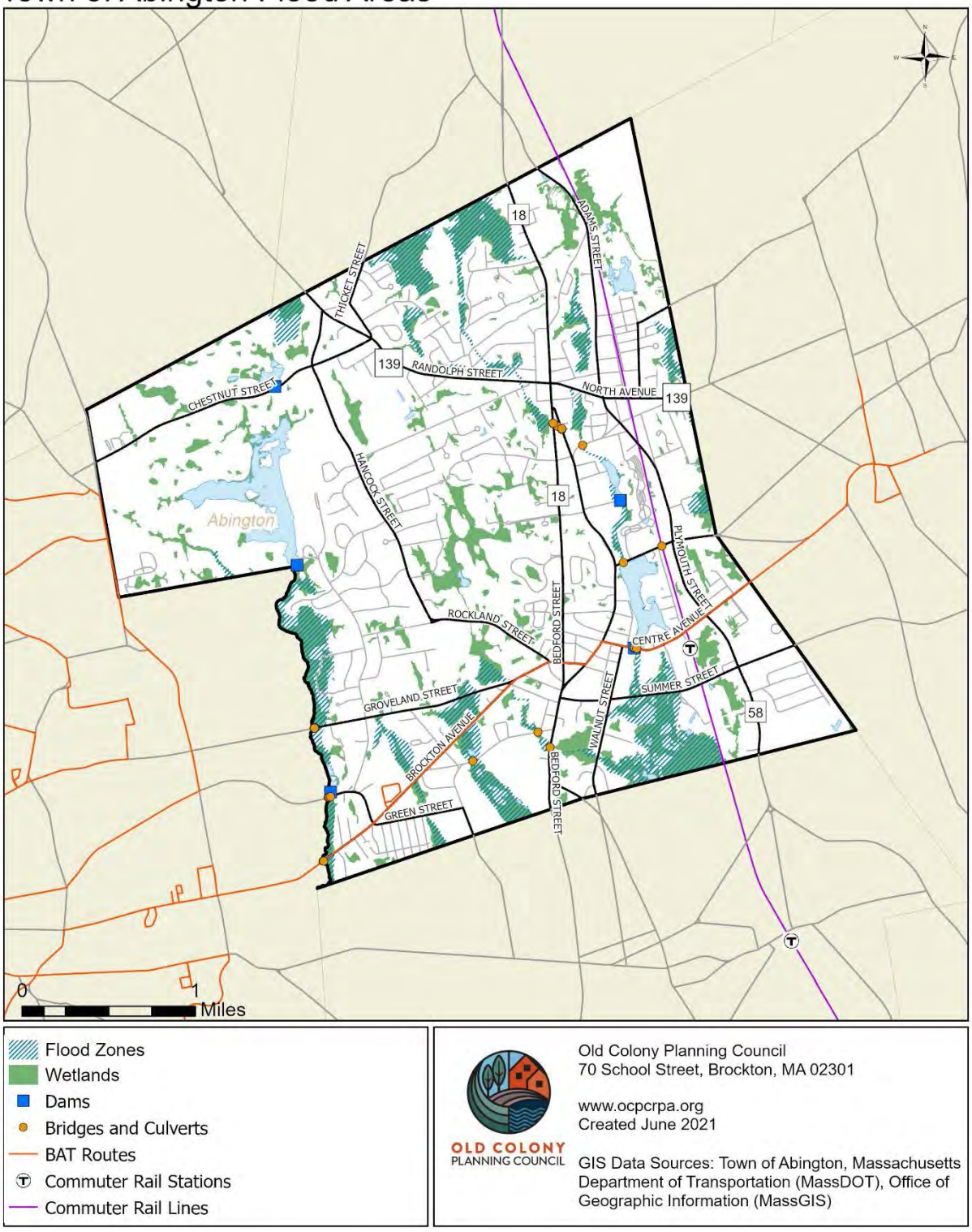
Recommended infrastructure improvements (based on the Abington MVP) include improvements to the Central Street Bridge, which is extremely vulnerable to potential devastating flooding from Island Grove. The bridge has been deemed a significant hazard by the state's bridge inspectors and the town is expected to begin the design process upon Town Meeting approval. Figure 10 shows the location of the Central Street Bridge and the Island Grove Dam, which is adjacent to Route 123. Figure 11 shows the potential flood risk and its potential impact on the road, transit (BAT Routes), and passenger rail infrastructure in Abington. Figure 11 also shows the locations of dams, bridges and culverts.

Figure 10


Abington Police Station
Central Street Bridge
Grove Pond Dam
Gliniewicz Way
Giardino's
Early Childhood Center
Lowe's Home Improvement
Bedford St
18
Central St
Island Grove Pond
Island Grove Park
Park Ave
Washington
Colonel Hunt Dr
Thayer St
Stewart Dr
Chapel St
Everett St
Cliff St
Lake St
Pond St
Plymouth St
Pilgrim St
58
123
Bradford St
The UPS St
Stop & Shop
Orange St
Centre Ave
Abington
Block St
Brothers Roast Beef & Pizza
Spencer's Pizza
Mo'Rockin Fusion
Elm St
Thaxter Ave
Niles St
Progress St
Summer St

Figure 11

Town of Abington Flood Areas



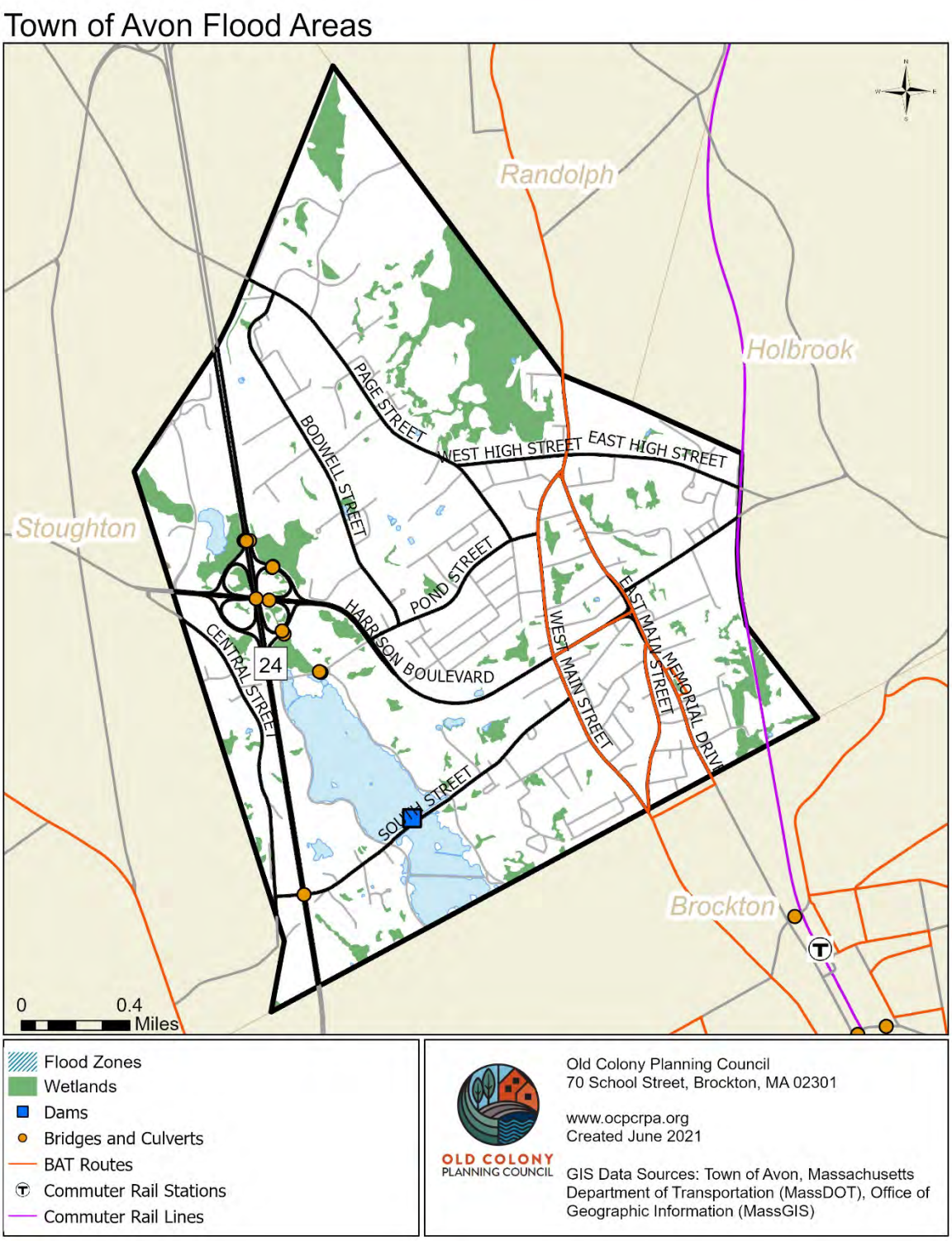
Avon

The Municipal Vulnerability Preparedness Workshop for Avon was held on September 21, 2020. The process was led by a core committee and included key stakeholders. The group reviewed public comments, discussed the impacts of natural hazards affecting the town, developed the goals for addressing impacts, and developed a mitigation and implementation plan. The Avon Plan assesses the potential impacts to the town from a variety of natural disasters including flooding, high winds, winter storms, brush fire, geologic hazards, extreme temperatures, and drought. Figure 12 shows potential flood impacts to Bodwell Street, South Street, and Route 24 and the Route 24 Harrison Boulevard exit.

Avon Improvement Recommendations:

According to interviews with Town officials, an emergency drinking water interconnection with surrounding communities is a high priority improvement recommendation for the long term for the Town. Contamination of wells is also a priority issue. The Town is also in the process of stormwater mapping and septic to sewer conversion was cited as a priority. Other priorities for the Town include green infrastructure to recharge water within catchment areas and repairing water storage tanks. Figure 12 shows the potential flood risk and its potential impact on the road and passenger rail infrastructure in Avon.

Figure 12


Town of Avon Flood Areas
Randolph
Holbrook
Stoughton
Brockton
PAGE STREET
BODWELL STREET
WEST HIGH STREET
EAST HIGH STREET
POND STREET
HARRISON BOULEVARD
CENTRAL STREET
24
WEST MAIN STREET
EAST MAIN STREET
MEMORIAL DRIVE
SOUTH STREET
0
0.4
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
OLD COLONY PLANNING COUNCIL
Old Colony Planning Council
70 School Street, Brockton, MA 02301
www.ocpcrpa.org
Created June 2021
GIS Data Sources: Town of Avon, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Bridgewater

The Town of Bridgewater held a kick-off meeting on November 29, 2018 for its Community Resilience Building (CRB) workshop process and the development of its MVP Plan. The town went on to hold two four-hour workshops (February 14, 2019 and February 21, 2019). The process to identify Climate Change vulnerabilities considered Infrastructural, Societal and Environmental factors. Action steps were then developed to build the Town's resilience to extreme weather-related conditions in the future based on EOEEA climate change projections. The MVP goals included developing a plan that satisfies the requirements and approval of the MA EOEEA, and achieving town eligibility for the MVP Action Grant, developing an MVP Plan that compliments and builds upon the Town's previous efforts (conservation, recreation and revitalization efforts), and developing an MVP Plan that minimizes infrastructure impacts from flood and other weather-related hazards.

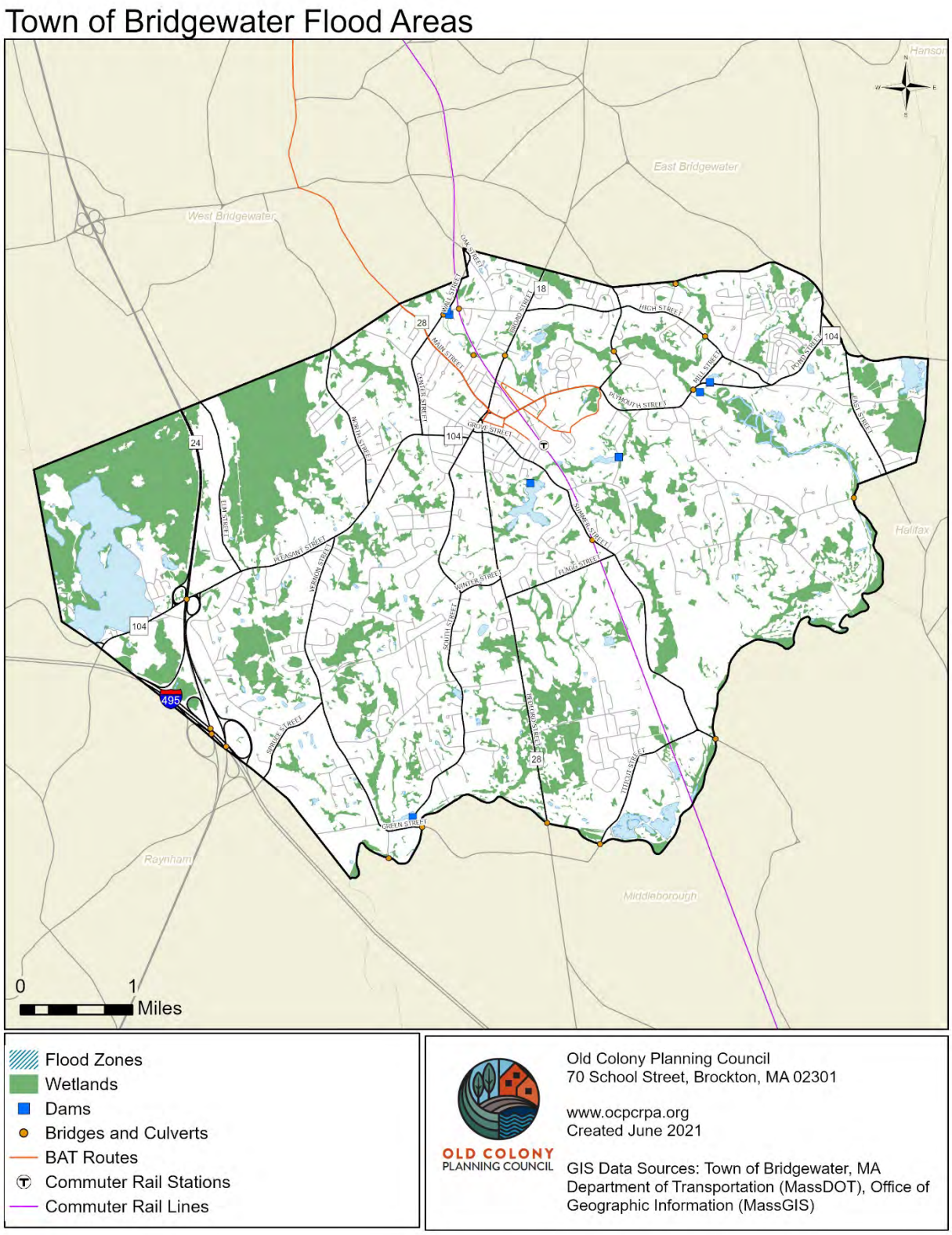
Figure 13 shows the potential flood risk and its potential impact on the road and passenger rail infrastructure in Bridgewater. A number of areas were impacted from the March 2010 storm event. According to the Bridgewater Highway & Forestry Department, the following roads were flooded due to the March 2010 storm event:

- Bridge Street Bridge at the Matfield River
- Water/Wood Street at South Brook
- Cherry Street at the Taunton River
- Summer Street at the Taunton River
- Titicut Street at the Taunton River
- Hayward Street at the Town River
- Hayward Street (foot bridge) Brook from Skeeter Mill Pond
- Riverview Drive at the Matfield River

<u>Bridgewater Improvement Recommendations:</u>
The Town cited a number of action priorities including:

- Obtain an effective hydraulic computer models from FEMA and developing a Town-wide Hydrologic and Hydraulic (H&H) models based on UMass climate change (CC) projections for the 2050's and 2090's (2019 Engineering MVP Action Grant).
- Develop a Climate Change Resiliency Action Plan for the Wastewater Treatment Plant (WWTP) (based on results of hydraulic computer models, MVP Action Grant).
- Develop a Climate Change Resiliency Action Plan for the Town's water supply wells and treatment facilities (based on results of hydraulic computer models, MVP Action Grant).
- Review and update the Town's Stormwater Ordinance relative to Climate Change Projections.
- Review and update zoning requirements to address Climate Change Resiliency.
- Purchase and Install an emergency generator at the Senior Center and develop an emergency back-up power plan for other public facilities that serve vulnerable populations.
- Develop a Town-wide emergency transport and food supply emergency action plan for vulnerable populations.
- Develop a culvert and bridge improvement master plan.
- High Street Dam Removal and Bridge Replacement.

Figure 13


Town of Bridgewater Flood Areas
East Bridgewater
West Bridgewater
Halifax
Raynham
Middleborough
0
1
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
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Brockton

The City of Brockton began its MVP process in 2018 (kick-off meeting October 24, 2028). The Community Resilience Building (CRB) workshop was held on December 5, 2018 at the Nature Conservancy. A comprehensive, baseline climate change and natural hazard vulnerability assessment report was completed by a consultant, which included a list of priority actions for the City. A core team was developed to determine initial concerns and identify stakeholders and set goals for the process. The CRB workshop's central objectives included defining top local natural and climate-related hazards of concern; Identifying existing and future strengths and vulnerabilities; Developing prioritized actions for Brockton; and Identifying immediate opportunities to collaboratively advance actions to increase resilience. Specific areas of concern focused on flooding, severe Storms, and Extreme Temperatures and Drought.

The CRB report concluded that Brockton's developed areas are in close proximity to the Salisbury Plain River and several vulnerable brooks and wetlands. Therefore, culverts and bridges are a City-wide concern. Culverts and bridges were designed to accommodate historic patterns of precipitation and run-off but are increasingly inadequate as a result of impacts due to climate change. Brockton's Belmont Avenue Bridge, which was built in 1910, is acting as a flood control structure by limiting flows because it is undersized. As precipitation events become more intense and less predictable, undersized culverts are expected to pose a greater threat of failure and flooding.

The report stated that Brockton implemented a bridge replacement program to raise bridges and roadways out of the floodplain and reduce flooding. Flooding in the Belmont Road area was reduced; however, the removal of the upstream constrictions is leading to increased flooding in West Bridgewater.

The report also cited a need for a systematic, detailed inventory of the size and condition of culverts and bridges City-wide. In addition, dams in the city do not have much additional flood storage capacity in their current state, based on a dam safety investigation by a consultant for the city. D.W. Field Park dams provide upstream flood storage and protect heavily populated, downstream areas along the Salisbury Brook and Salisbury Plain River. Workshop participants recognized the critical importance of the upstream dams to the City and the need to have them assessed for safety and infrastructure improvements. Patterns of urban growth and development in Brockton have resulted in extensive imperious surfaces, which prohibit stormwater infiltration and lead to issues with storm water runoff. There is a need for strategies to increase flood water storage capacity in the City and implement green infrastructure approaches to increase resiliency.

Stormwater runoff was recognized as a concern affecting properties City-wide, especially at the Westgate Shopping Mall. The MA MS4 permit addresses stormwater runoff issues and mitigating polluted discharges affecting waterways and water quality. New development, since 1985, has had to abide with provisions that provide for no-net increase in stormwater runoff. The City is also exploring a stormwater utility that would help to generate the funding to implement green infrastructure retrofit strategies.

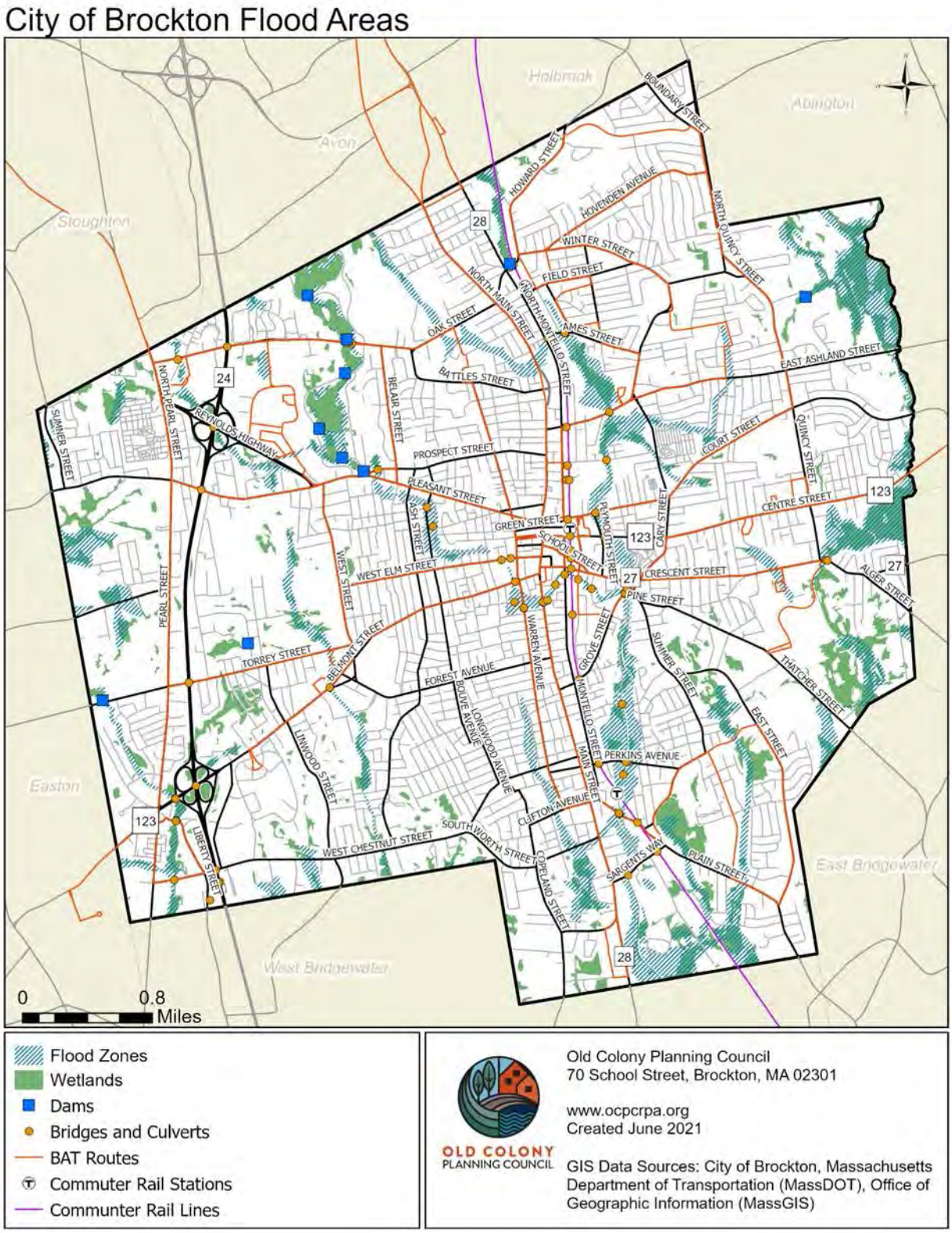
The CRB report cited that climate change is increasing the frequency of weather-related risks and vulnerability of the city's roads. These include flooding, snow and ice, and new patterns of freezing and thawing, which lead to an increase in potholes and sink holes and can compromise the city's ability to

provide emergency services. Roadways in the City are also susceptible to blockages from trees and power lines brought down by windstorms. Additional consideration was given to regional evacuation routes for the homeless and elderly during times of emergency. In addition, Brockton's communications infrastructure which is vital to providing emergency services, is vulnerable to a variety of climate-related hazards, including wind, but also flooding, snow, and ice.

The CRB report also stated that Brockton has strong public transit assets and maintaining its public transportation facilities during emergencies and extreme weather is a priority in order that those residents who rely on mass transit have access to transportation for provisions, medical care, and other needs.

Figure 14 shows the potential flood areas in Brockton. It shows the Salisbury plain area that extends through the middle of the city and impacts the downtown. It also shows dams, culverts, bridges, BAT routes, and the passenger rail stations in Brockton in relation to the areas prone to flooding.

Figure 14


City of Brockton Flood Areas
Halbmak
Abington
Avon
Stoughton
Easton
West Bridgewater
East Bridgewater
BOUNDARY STREET
HOWARD STREET
HOVENDEN AVENUE
NORTH QUINCY STREET
WINTER STREET
FIELD STREET
NORTH MAIN STREET
NORTH MONTELLO STREET
AMES STREET
OAK STREET
EAST ASHLAND STREET
BATTLES STREET
BELAIR STREET
NORTH PEARL STREET
REYNOLDS HIGHWAY
SUMNER STREET
PROSPECT STREET
COURT STREET
QUINCY STREET
PLEASANT STREET
ASH STREET
GREEN STREET
CENTRE STREET
PLYMOUTH STREET
CARY STREET
SCHOOL STREET
WEST ELM STREET
WEST STREET
CRESCENT STREET
ALGER STREET
PINE STREET
PEARL STREET
WARREN AVENUE
GROVE STREET
SUMMER STREET
THATCHER STREET
TORREY STREET
BELMONT STREET
FOREST AVENUE
BOUVE AVENUE
LONGWOOD AVENUE
MONTELLO STREET
EAST STREET
LINWOOD STREET
MAIN STREET
PERKINS AVENUE
CLIFTON AVENUE
SOUTH WORTH STREET
WEST CHESTNUT STREET
LIBERTY STREET
SARGENTS WAY
PLAIN STREET
COPELAND STREET
24
28
123
27
0
0.8
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
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Brockton Improvement Recommendations:

The Brockton's Highest Priorities included:

- Developing an integrated all-waters approach to increase flood resiliency. This includes a City-wide assessment of the viability of using nature-based solutions such as restoration of wetlands and river channels or implementation of green infrastructure to develop a list of specific priority projects where reduction of stormwater runoff and increased flood storage capacity could mitigate flooding risk.
- Conducting a thorough study of the City's dams to understand how they work together, where they are effectively contributing to flood storage capacity, or where dam removals may be a more effective means of encouraging resiliency, as well as evaluating areas where additional stormwater infrastructure (including green or grey infrastructure) may be necessary or where stormwater structures may require enlargement in order to accommodate high volume or high velocity stormwater runoff.
- Assessing feasibility and cost, ranking priority projects in terms of climate resilience potential, and developing concept designs for key projects, as well as reviewing and updating City regulations to support green infrastructure and low-impact development approaches. Explore multi-community and public-private partnerships to address interrelated flooding issues that cross over community and jurisdictional boundaries.
- Conducting a field inventory of culverts and bridges that builds upon the City's existing bridge replacement program to rank and prioritize projects for increased flooding resiliency.
- Integrating Green infrastructure, Low-Impact Design, and other nature-based solutions with infrastructure improvements to establish approaches in the face of natural hazards and climate-change scenarios.
- Conducting engineering and hydrology studies on the City's dams to identify and prioritize repair needs.
- Improve flood resiliency through redesign and installation of an automated gate at the spillway of Ellis Brett Pond Dam.
- Conducting a comprehensive assessment of aging infrastructure such as the transmission lines from the desalination plant in Dighton and from Silver Lake with options for an additional back-up water supply.
- Performing a risk assessment of the wastewater treatment plant and pump stations
- Increasing maintenance of catch basins, conveyances and detention ponds and review and improve maintenance schedule and budgets to increase frequency of street sweeping and catch basin cleaning.
- Reviewing and updating City regulations to improve stormwater management and mitigate flooding risk and developing and adopting a wetlands ordinance and stormwater ordinance for compliance with the MA MS4 Permit (promoting infrastructure improvements and increase infiltration of stormwater)
- Increasing capacity for oversight and enforcement relative to existing wetlands, and incorporate new standards such as requirements for green space and tree preservation and/or planting in development projects.
- Developing methods to disincentivize development within the City's flood zones, and ensure new development and building construction meets improved permitting standards.

- Assessing needs and vulnerabilities in the City's emergency communication systems and determine where communication breakdowns are occurring or may occur during a hazard event. Develop a plan to overcome internal communication barriers within City departments and between the City and community partners or residents.
- Improving outreach and education efforts to ensure City residents, especially vulnerable populations and residents for whom English is not a first language, can access accurate and up-to-date emergency information, shelters, heating and cooling centers, evacuation routes, provisions and services during emergencies.
- Developing an urban agriculture initiative centered around Gerry's Farm in order to foster urban agriculture and local food resiliency.

The 2019 Municipal Vulnerability Preparedness (MVP) Action Grant

As a result of the MVP process and plan, the City of Brockton received a Municipal Vulnerability Preparedness (MVP) Action Grant in 2019 from the Massachusetts Executive Office of Energy and Environmental Affairs to conduct a study to develop an accurate understanding of risks to infrastructure, environment, and residents resulting from flooding events in the city. The specific purpose of the grant was to identify solutions to address flood risks and increase flood resiliency along the Salisbury Brook and the Salisbury Plain River. The study included an assessment of the viability of using nature-based solutions such as the restoration of wetlands and floodplain, as well as green infrastructure to address riverine flooding and stormwater drainage-driven flooding, and to prioritize future projects to increase flood storage capacity and mitigate flooding risk.

The Salisbury Brook and Salisbury Plain River corridor bisects the city from north to south. Hydraulic and hydrologic modeling of the Salisbury Brook and Salisbury Plain River corridor was conducted by the consultant working for the city on the study to document the predicted limits of flood inundation during different size storm events. The results of the analyses identified how far and wide floods will spread to those areas most susceptible to frequent flooding.

Modeling showed the bridges most susceptible to flooding during significant rainfall events. Bridges throughout the river system expected to overtop during a 10-year flood event include Prospect Street, Belmont Avenue, North Arlington Street/Newbury Street, Pine Avenue, and Perkins Avenue.

The study included the following recommended nature-based solutions (Nature-based solutions focus on restoring and/or enhancing natural habitat and flood storage functions of pond or floodplain areas to increase flood storage and lower water flood elevations):

- The Installation of a spillway gate at Ellis Brett Pond - A remote-controlled bottom-hinged crest gate will allow Brockton to enhance existing flood storage in Ellis Brett Pond. The gate will allow water levels to be lowered before large storm events. In addition, then the gate could be raised to allow for detention of runoff for later release to the river in a controlled manner.
- Excavation, expansion, and ecological enhancement of Ellis Brett Pond Ellis - Brett Pond is impounded by a dam and generally maintained under dry conditions. Excavation and wetland restoration and enhancement, primarily to the north of the existing impoundment, is recommended to increase the available storage area below the typical water surface elevation.
- Floodplain restoration of undeveloped parcels near Sargent's Way – The study recommends excavation at three undeveloped city-owned parcels between Plain Street and Sargent's Way.

This will create an additional 18,300 cubic yards of floodplain storage. An additional 22,500 cubic yards of flood storage will also be created through excavation at three undeveloped areas within privately-owned parcels immediately downstream of Sargent's Way along a constricted section of the river channel.

The study recommends that the city explore green infrastructure applications for on-site stormwater management, including for any future redevelopment of the K-Mart Plaza or Westgate Mall properties. Modeling from the study shows that because of the Westgate Mall's small size relative to the watershed, along with the high degree of impervious cover throughout the watershed, installing green infrastructure at the mall will have little impact on flooding on a city-wide scale; however, wider implementation of green infrastructure throughout the watershed and throughout the city can have significant impacts on downstream flooding by infiltrating water in place and reducing peak flows. These types of mitigation methods also have significant value in improving water quality.

Duxbury

The *Duxbury Climate Vulnerability Assessment and Action Plan* was completed in 2018. The report summarizes the climate risks, evaluates the vulnerability of critical infrastructure and resources, and creates an action plan for resilience. The report cited that Duxbury routinely experiences coastal flooding and inundation with even just a lunar high tide. Projected sea level rise and changes in intensity of storm and precipitation events requires further assessment of the vulnerability of the infrastructure.

The *Duxbury Climate Vulnerability Assessment and Action Plan* stated that disruption in its mass transit access would likely occur due to the Whitman and Hanson MBTA stations being within a 1 percent Annual Chance Flood Zone. In addition, portions of the commuter rail line rail are susceptible to 1 percent Annual Chance Flood by the Jones River (though the line is elevated above the river), between the Hanson and Whitman Stations and before the Abington MBTA Station. The commuter rail line is adjacent to a 0.2% Chance Annual Flood Zone at the boundary of Halifax and Hanson, and as the rail line approaches Quincy and Braintree into Boston, the line becomes more exposed to extreme heat with a lack of tree cover and dense urban environment.

The *Duxbury Climate Vulnerability Assessment and Action Plan* state that road infrastructure would likely experience an acceleration in asphalt deterioration from the combination of extreme temperatures, increased precipitation, and flooding. The thermal expansion of metal due to extreme temperatures for long periods would also stress bridge infrastructure.

The study reported roadways already subject to coastal flooding in Duxbury include Gurnet Road, Washington, King Caesar Road, St. George Street, Bay Road, and Congress Street. Plantation Drive, adjacent to the South River, has beaver activity causing inland flooding. King Caesar, Washington and St. George are low-lying streets with no flood mitigation measures. The greatest risk with coastal flooding with roads is the loss of access to emergency services during major storm events.

Flooding concerns at bridges include the Bluefish River and the Marshall Street Bridge; both have had improvements that have alleviated some flooding. Modeling studies in 2013 indicated that the Powder Point Bridge, Bluefish, and Marshall Street bridges are sufficiently high enough to not be impacted by coastal flooding today or into the future with Category 1 Storm Surge. However, sea level rise in 2088 will greatly impact Washington Street in Snug Harbor, King Caesar and Powder Point Roads, Gurnet Road, Duxbury Beach Access Road, Marginal Road, Pine Point Road and Marginal Road.

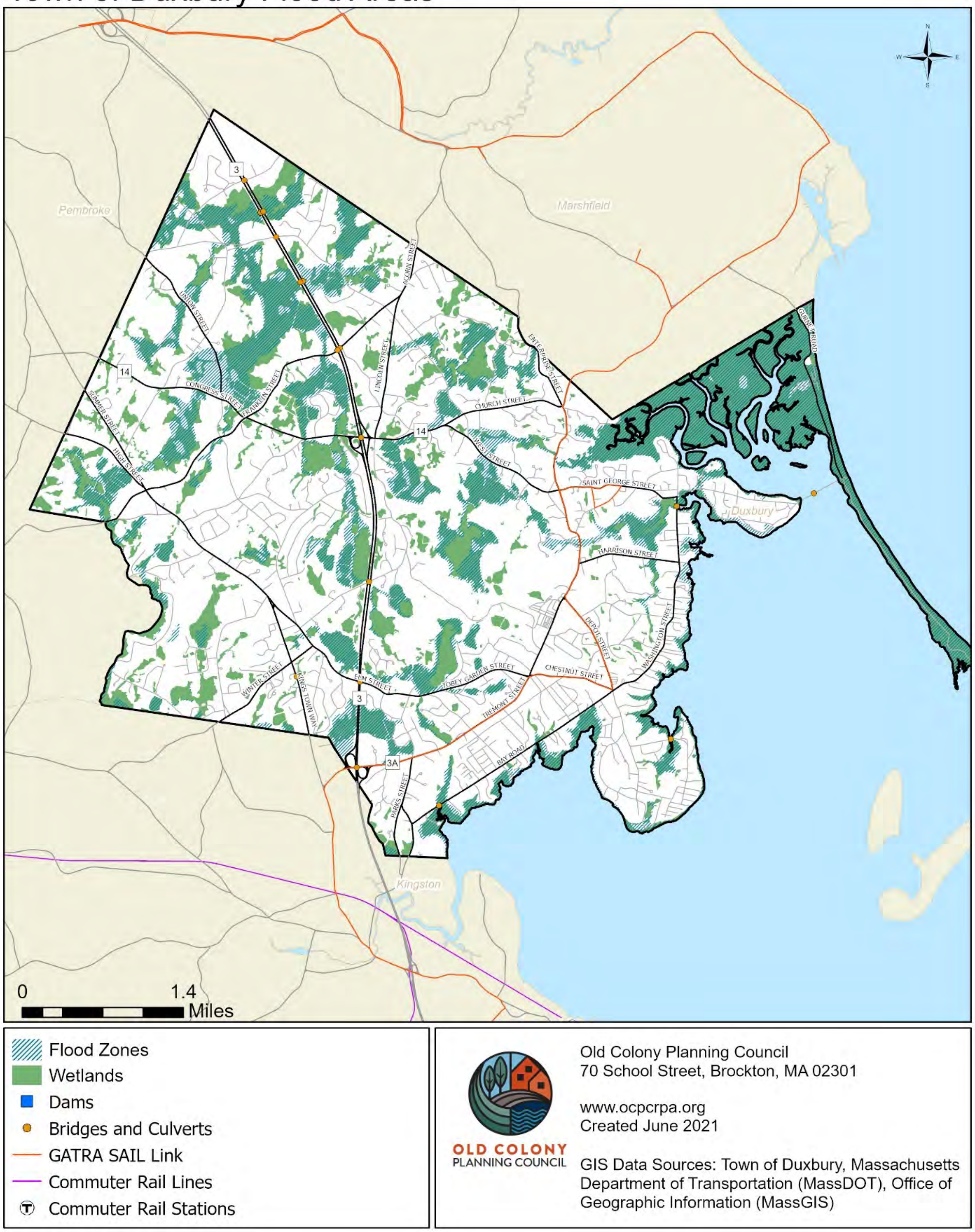
Duxbury Improvement Recommendations:

The Town has hired a consultant through an MVP implementation grant (to be completed in the spring 2021) for determining the coastline sea level rise impacts to roads, bridges, culverts in 10-year, 50-year horizon. The assessment will be coordinated with state agencies including MassDOT.

Figure 15 shows the potential flooding in Duxbury in relation to the bridges, roads, culverts, mass transit (GATRA), and dams. Figure 15 shows that mush of the potential flooding is along the coastline' however, there is much potential flooding inland with impacts to Route 3, Route 3A, as well as other principle and minor arterials.

Figure 15

Town of Duxbury Flood Areas



East Bridgewater

East Bridgewater is currently undertaking the Municipal Vulnerability Plan (MVP) process. The submission of the MVP is expected in March 2021. The town hopes to gain an action grant through the submission of the MVP for implementation of the plan.

The Town's public works department provided a list of areas in East Bridgewater that are problematic for flooding in the *OCPC 2010 Climate Change Transportation Impact Study:*

- Spring Street at the Matfield River
- Bedford Street (Route 18) and Whitman Street (Route 106) at the Matfield River
- Winter Street at an unnamed brook
- West Union Street at the Matfield River
- Pleasant Street at the Matfield River
- Belmont Street at the Matfield River
- South Street at a low-lying property
- Church Street at a low-lying property
- Harvard Street at Meadow Brook
- Willow Avenue at an unnamed brook

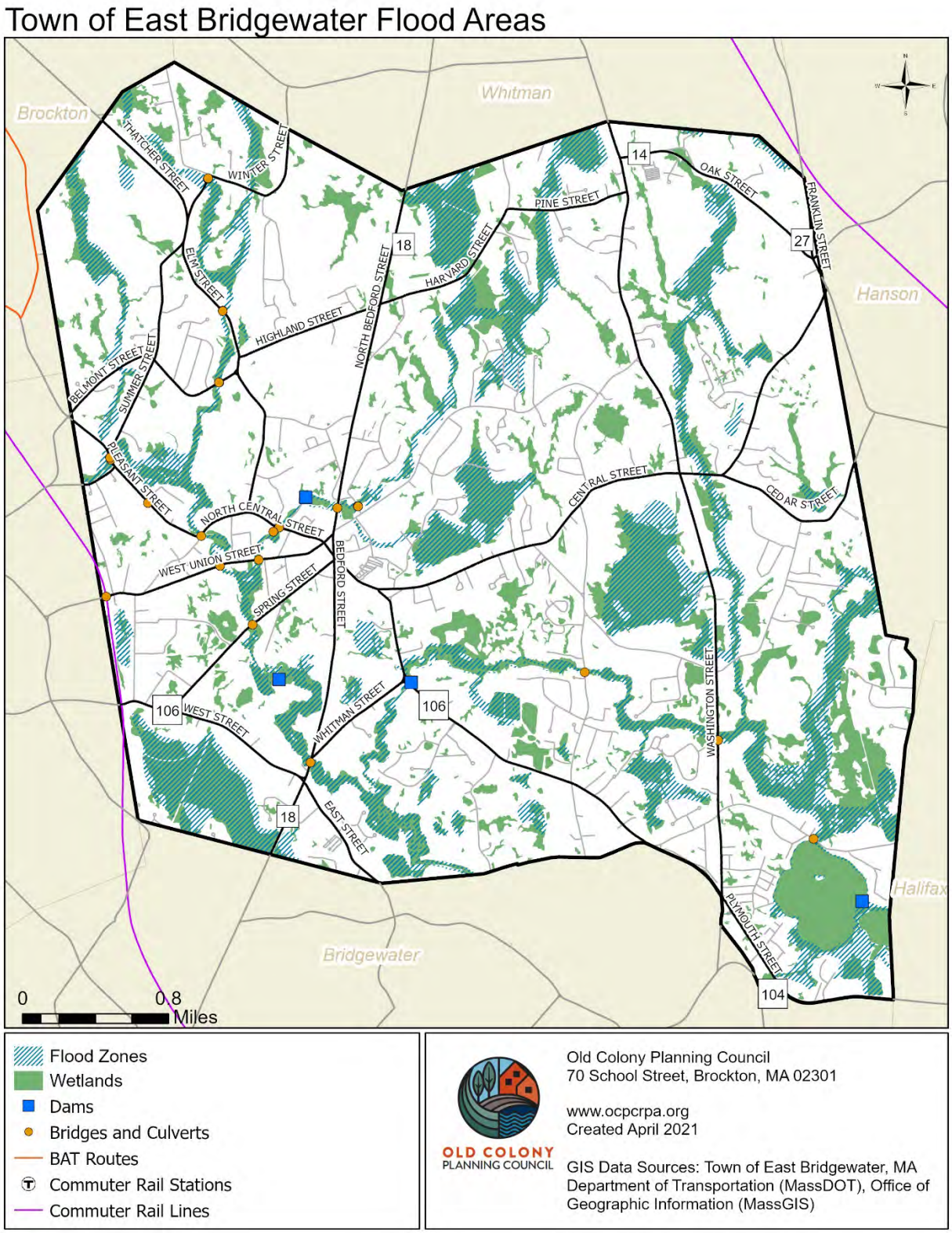
<u>East Bridgewater Improvement Recommendations:</u>

The East Bridgewater DPW identified three main areas of flooding on three different roads in East Bridgewater. These roads listed as follows have been closed for multiple days due to flooding.

- West Union Street at the bridge near Oregon Street.
- Spring Street near Park Avenue.
- Route 18 south of Whitman and north of Route 106 West Street.

In addition, bridges and culverts in East Bridgewater along the Salisbury Plain River were inspected and maintained by the town with town funds. These are culverts and bridges that do not make the minimum criteria to be included in the state inspections. The Town of East Bridgewater has also received a small bridge grant for Elm Street for $497,000, which is currently in design. Other areas that are problematic for flooding include Forge Pond off of Route 18 has settlement problems with sediment filling upstream. Figure 16 shows the potential flooding in East Bridgewater in relation to roads, bridges, culverts, dams, and transit.

Figure 16


Town of East Bridgewater Flood Areas
Brockton
Whitman
Hanson
Halifax
Bridgewater
THATCHER STREET
WINTER STREET
ELM STREET
HIGHLAND STREET
NORTH BEDFORD STREET
HARVARD STREET
PINE STREET
OAK STREET
FRANKLIN STREET
BELMONT STREET
SUMMER STREET
PLEASANT STREET
NORTH CENTRAL STREET
WEST UNION STREET
SPRING STREET
BEDFORD STREET
CENTRAL STREET
CEDAR STREET
WEST STREET
WHITMAN STREET
EAST STREET
WASHINGTON STREET
PLYMOUTH STREET
14
18
27
106
106
18
104
0
0.8
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
OLD COLONY PLANNING COUNCIL
Old Colony Planning Council
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Created April 2021
GIS Data Sources: Town of East Bridgewater, MA Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Easton

A summary report of the Easton MVP Community Resilience Building Workshop was completed in 2018. The summary stated that there were three hazards of the highest concern for Easton, which included wind from extreme storms, flood-drought cycle, and extreme temperatures. According to the report, most Easton residents have septic systems in areas where the water table is high, and heavy precipitation poses the risk of contamination. Strong winds during storms have damaged utility lines, toppled trees, and blocked vehicles on the roads. The Canoe River Aquifer was designated an area of critical environmental concern (ACEC) in 1991 due to a prolonged drought. The pattern of intense storms and longer dry spells is expected to have greater impacts as the climate changes. Easton has seven dams with mixed public and private ownership. Flyaway Pond Dam and Monte Pond Dams are two of these dams that have been breached in the past.

Culverts and localized flooding areas of concern in Easton included:

- Sawmill Pond Rd at Bay Rd around #486, Prospect Road around #80 and #33
- Culvert under Route 138 near the mobile home park
- Bay Rd near #224 has a confluence of three culverts
- Purchase Street at the “Dog Leg” near Easton Country Club

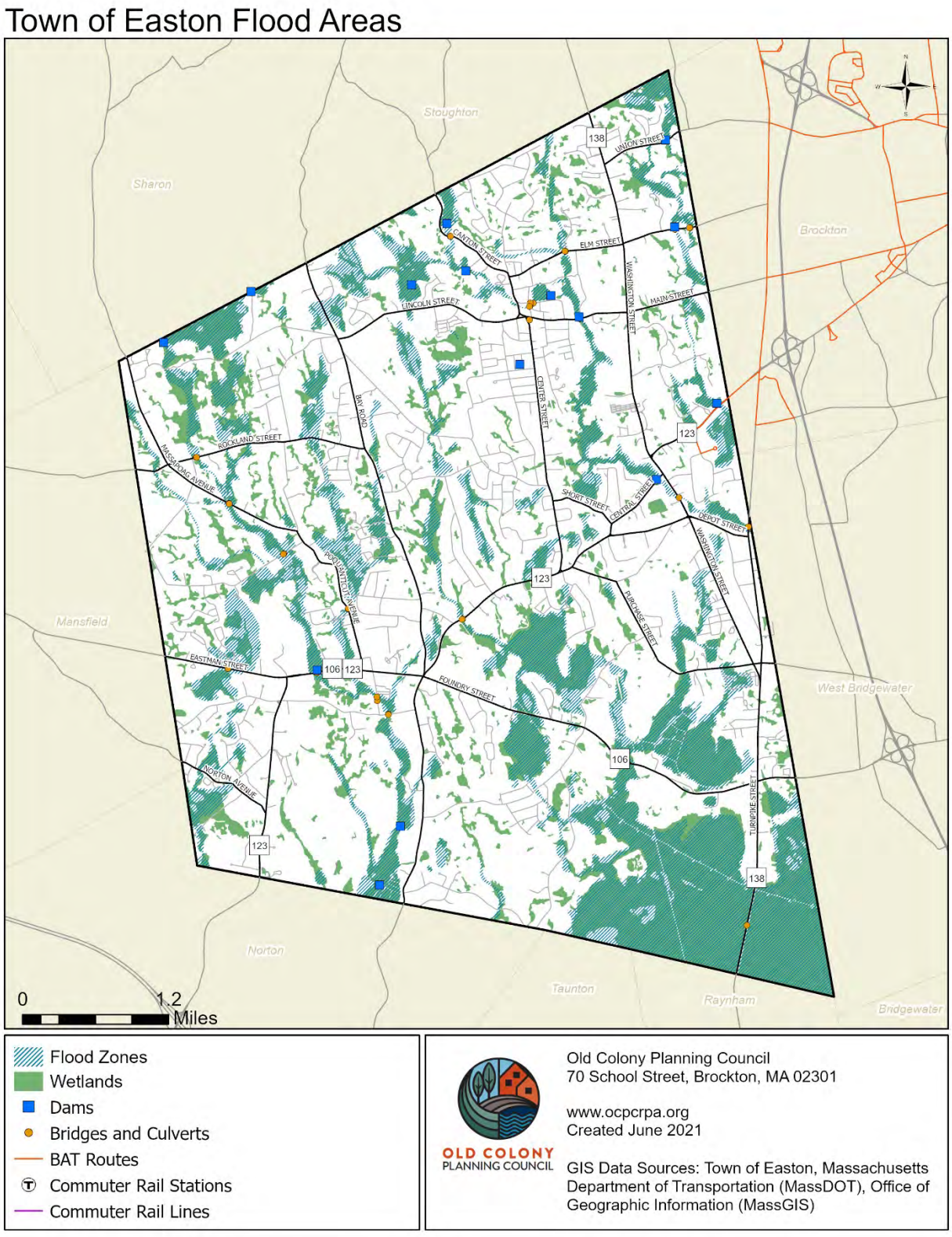
The Town’s public works department provided a list of areas in Easton that have a potential for flooding in the OCPC 2010 Climate Change Transportation Impact Study.

List of Flooded Areas from Easton’s Public Works Department:

- Bay Road between Highland Street and Dean Street
- Union Street at French's Pond
- Depot Street between Blackbrook Road and Center Street
- Elm Street near Whitman Brook Drive
- Chestnut Street
- Canton Street near the Stoughton Town Line
- Purchase Street near the Easton Country Club
- Prospect Street near the Railroad Right-of-Way

Figure 17 shows the potential for flooding in Easton in relation to roads, bridges, culverts, dams, and transit.

Figure 17


Town of Easton Flood Areas
Stoughton
Sharon
Brockton
Mansfield
West Bridgewater
Norton
Taunton
Raynham
Bridgewater
UNION STREET
CANTON STREET
ELM STREET
WASHINGTON STREET
MAIN STREET
LINCOLN STREET
CENTER STREET
BAY ROAD
ROCKLAND STREET
MASSAPOAG AVENUE
SHORT STREET
CENTRAL STREET
DEPOT STREET
PLYMOUTH AVENUE
BLACKHAKE STREET
EASTMAN STREET
FOUNDRY STREET
NORTON AVENUE
TURNPIKE STREET
138
123
106
0
1.2
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
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GIS Data Sources: Town of Easton, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Easton Improvement Recommendations

Stakeholder feedback from the town cited that The Easton Conservation Commission has secured an MVP Action grant to reconstruct wetland and floodplain in the Mulberry Brook (in the Sam Wright Field at 445 Bay Rd). The Town completed permitting and construction is expected to be completed in the spring of 2021. Easton is participating in a regional group collaboration for planning conservation measures around the Canoe River Sole Source Aquifer, which could involve floodway improvements.

Halifax

Halifax undertook the Municipal Vulnerability Plan process in April 2021 along with a Hazard Mitigation Plan in an integrated plan process. As a result of the MVP workshops, a number of vulnerabilities were identified, and priority areas identified for road locations susceptible to flooding.

Route 58 in Halifax runs along a narrow strip of land between the West and East Monponsett Pond. Input for the Halifax MVP workshop cited that the storm flows for Monponsett Pond may be more challenging in the future due to climate change. Halifax needs a wider range of options to regulate stormwater flow due to storm events. The water levels for Monoponsett Pond are regulated by the City of Brockton, which diverts water to Silver Lake. A management plan for the regulation of the pond level is needed in collaboration with the City of Brockton. In addition, in the south part of the town, there are a series of bridges over the Winnetuxet River that are susceptible to flooding. These include South Street, East Street and River Street.

Based on stakeholder responses, the Stump Brook/Snake River, which runs from West Monponsett Pond to Brockton's dam in the Burrage Pond Wildlife Refuge is overgrown and requires regular maintenance and Halifax does not have the resources for that maintenance. The inability to quickly respond to rapid increases in the water level of the pond means that some beaches, septic systems, and, in extreme cases, homes may be flooded.

The following locations have been identified as areas where flooding has historically occurred:

- Aldana Road @ Oak St.
- East Street at the Winnetuxet River
- Franklin Street from Monponsett Brook to Old Franklin St
- Hayward St. At Hilda Lane.
- Hayward St. @ Monponsett Brook
- Hayward Street from Franklin Street to Monponsett Brook
- Hemlock Lane at the Halifax Highway Department (60 Hemlock Lane)
- Lake Street at Stetson Brook
- Monponsett Street (Route 58) at the culvert connecting East and West Monponsett Ponds
- Plymouth Street (Route 58) at Cumberland Farms (292 Plymouth Street)
- Plymouth Street (Route 58) at Stop & Shop (341 Plymouth Street)
- River Street at Wood Street at the Winnetuxet River
- South Street at the Winnetuxet River, Monponsett Brook and Colchester Brook
- South Street from Hayward Street to East Street
- Thompson Street (Route 105) at Pratt Street at Winnetuxet River and Bartlett’s Brook
- Thompson Street (Route 105) across from Thompson Cemetery
- Twelfth Avenue
- Wood Street at Ravin Brook

- Flooding occurs along the Winnetuxet River in the southwestern section of Halifax.

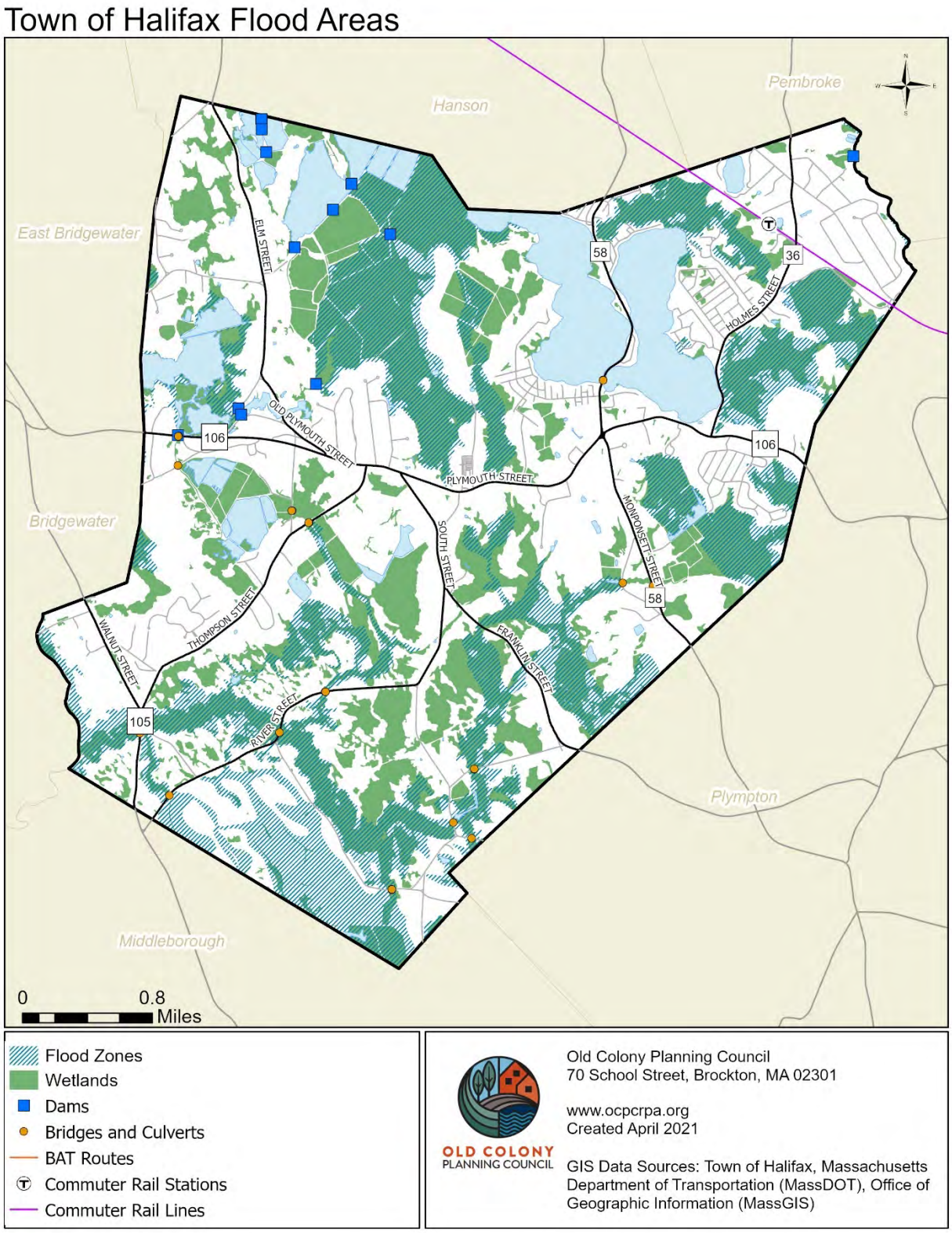
A list of areas most likely to be flooded based on information from Halifax's Highway Department includes:

- South Street, two locations, a total of 500 feet
- Hayward Street on the north side of the culvert, 300 feet
- Three locations on Wood Street, a total of 600 feet
- Pratt Street at Thompson Street, 300 feet at intersection
- Before and after the Bridge on East Street, 250 feet
- Oak Street and Aldana Street, 200 feet under Railroad Bridge

The Route 58/Route 106 intersection was cited as the town's greatest concern as there are no convenient alternative routes if and when this intersection becomes non passable during a flood.

Figure 18 shows the potential for flooding in Halifax in relation to roads, bridges, dams, culverts and passenger rail.

Figure 18


Town of Halifax Flood Areas
Hanson
Pembroke
East Bridgewater
Bridgewater
Plympton
Middleborough
ELM STREET
OLD PLYMOUTH STREET
PLYMOUTH STREET
SOUTH STREET
MONPONSETT STREET
HOLMES STREET
THOMPSON STREET
WALNUT STREET
RIVER STREET
FRANKLIN STREET
58
36
106
105
0
0.8
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
OLD COLONY PLANNING COUNCIL
Old Colony Planning Council
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GIS Data Sources: Town of Halifax, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

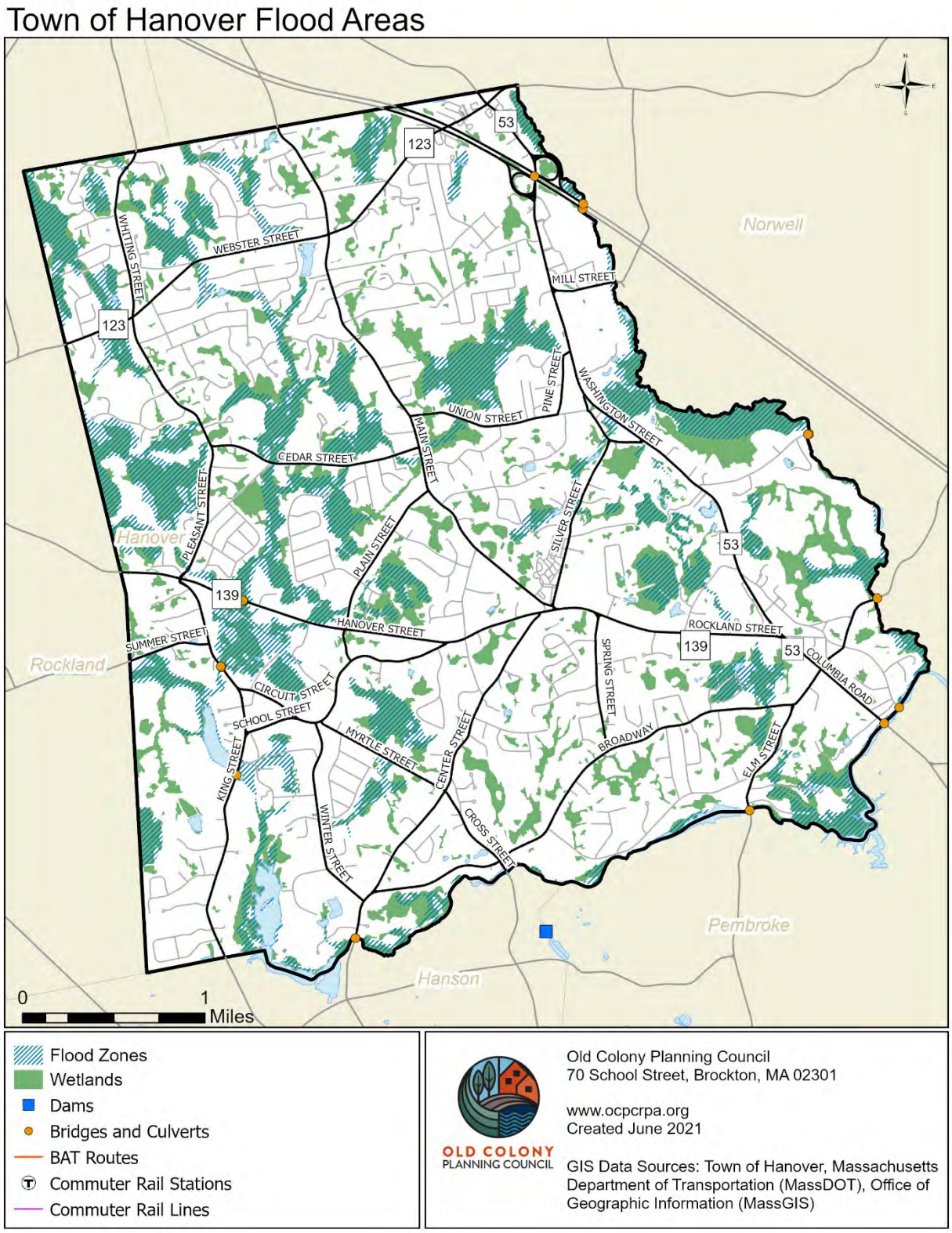
Hanover

The Town of Hanover has not yet begun the Municipal Vulnerability Preparedness plan process; however, the town has completed a Hazard Mitigation Plan in 2015. The Hanover Hazard Mitigation Plan (HMP) identified a number of mitigation measures to reduce the town's vulnerability to natural hazard events, including building upon current actions taken to maintain the drainage system to alleviate flooding, as well as to address other natural hazards such as fires, winter storms, and high winds.

The recommendations from the HMP included conducting a hydraulic analysis of the Indian Head River Watershed, conducting a hydraulic analysis of Forge Pond, Factory Pond, the Indian Head River, and all relevant dams and bridges. Flooding on King Street has been the result of increased stormwater runoff upstream and bottlenecks caused by the King Street Bridge and the Forge Pond Dam. It was recommended that the town perform a hydraulic analysis of the entire Indian Head River to determine the effectiveness of widening bridges and dams along the river.

Figure 19 shows the potential areas for flooding in Hanover in relation to roads, bridges, culverts, and dams.

Figure 19


Town of Hanover Flood Areas
Norwell
Hanover
Rockland
Pembroke
Hanson
123
53
139
WHITING STREET
WEBSTER STREET
MILL STREET
PINE STREET
WASHINGTON STREET
UNION STREET
MAIN STREET
CEDAR STREET
PLEASANT STREET
PLAIN STREET
SILVER STREET
HANOVER STREET
SUMMER STREET
ROCKLAND STREET
SPRING STREET
COLUMBIA ROAD
CIRCUIT STREET
SCHOOL STREET
MYRTLE STREET
CENTER STREET
BROADWAY
ELM STREET
KING STREET
WINTER STREET
CROSS STREET
0
1
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
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GIS Data Sources: Town of Hanover, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Hanson

The Town of Hanson began a process in 2020 to complete its Municipal Vulnerability Preparedness Plan along with its Hazard Mitigation Plan by combining both plans in an integrated process. Resiliency building workshops were held remotely in 2020 along with a public listening session for public comment input in early 2021. A final integrated plan with FEMA approval and state MVP designation is expected in 2021, and subsequent adoption of the plan by the town is expected in late 2021 or early 2022.

The report for the integrated plan process, *The Hanson Hazard Mitigation and Municipal Vulnerability Preparedness Plan,* included a number of infrastructure needs and concluded that most of the roads are in good condition, although Maquan Street needs resurfacing.

The Town Center (Factory Mill Dam, Thomas Mill Dam, Wampatuck Pond Dam) is prone to flooding. The dams at the Town center need repair. This is a high priority and should be done over the short term. Both the Hanson Town Hall and the Hanson Fire Station are located in the town center next to Wampatuck Pond.

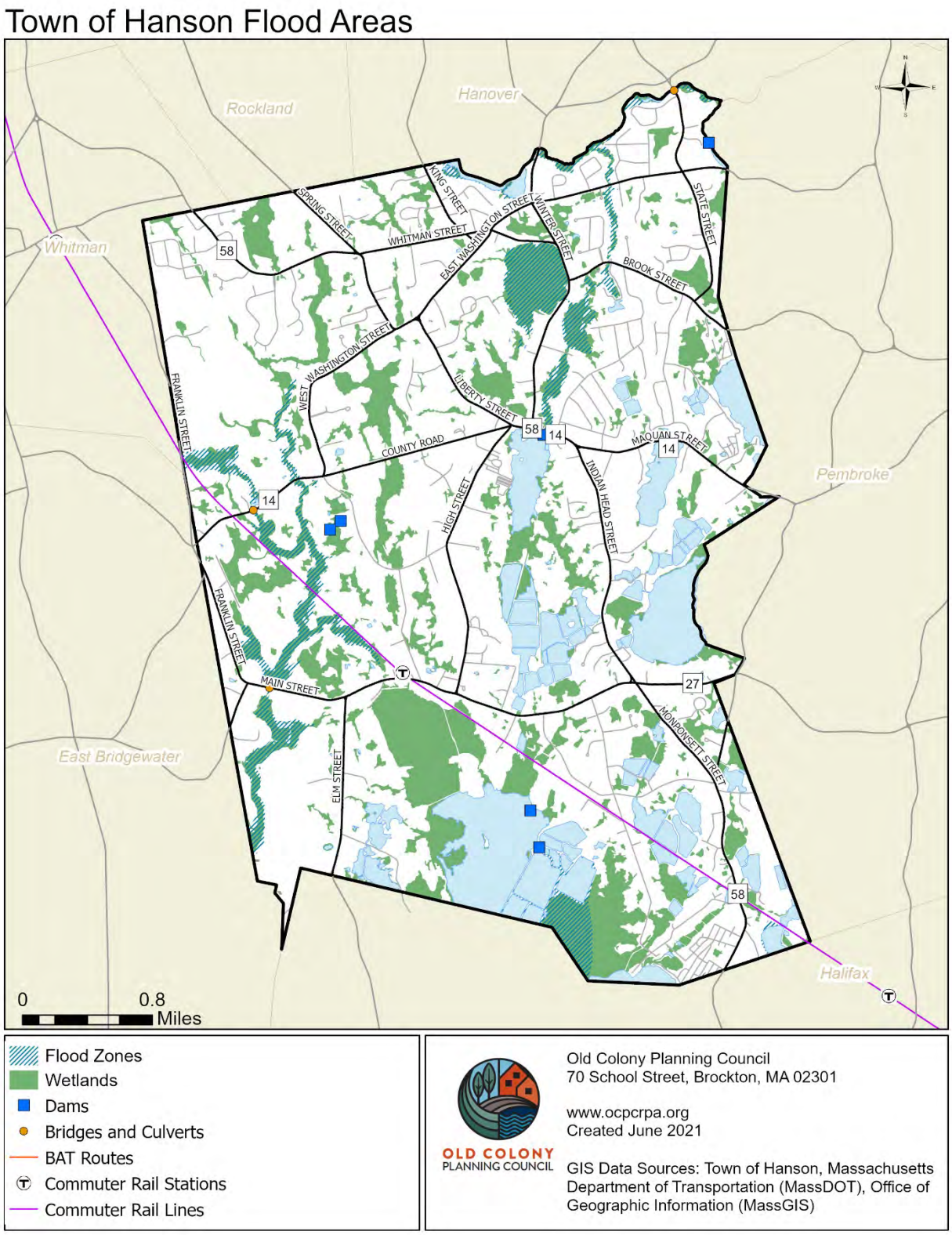
As an ongoing priority, the integrated MVP and HMP plan report stated that the town will continue to identify those areas most in need of flood hazard reduction with detailed engineering analysis to identify specific drainage "hot spots", and develop engineering plans to improve bridges, culverts, channels, and other infrastructure. The town will identify funding for projects lessen the likelihood that future floods will cause harm to existing and future buildings.

Hanson's Highway Department cited a number of areas that are problematic for flooding:

- Maquan Street (Route 14) near Pinegrove Avenue
- West Washington Street (Route 14) near House #708
- West Washington Street near Pennsylvania Avenue
- Indian Trail near House #97
- Pleasant Street near House #564
- East Washington Street at the Pembroke Town Line
- Winter Street near House #264
- King Street near House #264
- Robinson Street near Main Street (Route 27)
- Squantum Avenue near Monponsett Street (Route 58)

Figure 20 shows the potential flood areas for the Town of Hanson in relation to the culverts, dams, and roads.

Figure 20


Town of Hanson Flood Areas
Rockland
Hanover
Whitman
Pembroke
East Bridgewater
Halifax
KING STREET
SPRING STREET
WHITMAN STREET
EAST WASHINGTON STREET
WINTER STREET
STATE STREET
BROOK STREET
WEST WASHINGTON STREET
FRANKLIN STREET
LIBERTY STREET
COUNTY ROAD
MAQUAN STREET
HIGH STREET
INDIAN HEAD STREET
MAIN STREET
ELM STREET
MONONSETT STREET
58
14
27
0
0.8
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
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Created June 2021
GIS Data Sources: Town of Hanson, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Hanson Recommended Improvements

A number of infrastructure improvements were cited as high priorities during the MVP process. Culvert maintenance and repair at various locations are warranted including the need for maintenance of the culverts on Woodman Terrace, Maquan Street, King Street, Winter Street, Pratt Place, and Indian Head Street. There is a need to inventory and prioritize culverts for repair and or replacement.
Flooding of Katy Did Lane and the connection to Camp K and Woodman Terrace (Gated access) is a high concern and ongoing need. implementation. The property next to the police station should be assessed, and if nature-based solutions if feasible, should be used to ameliorate the problem.

Kingston

Flooding in Kingston has an impact on Kingston Downtown, based on the FEMA flood maps 100-year storms. The town has been able to manage some of the flooding through dam removal, including removal of Head of the Tide dam and Wapping Road Dam. Although the removal of the dam was for fish passage, it has helped with reducing flooding in the Kingston Downtown. The town is now working with the owner of a dam (located just north of Maple Street) on Stoney Brook to remove that dam. In general, the Town of Kingston needs a re-assessment of its catch basin and drainage system in its downtown.

The Culvert beneath Route 3A for Stoney Brook (sometimes called Halls Brook) is an old stone culvert, which is currently not in need of improvement. There is currently a state improvement project (non-federal aid), Kingston Systematic Bridge preservation, K-01-011 (AGD), ROUTE 3 OVER JONES RIVER. The project has completed the design phase of the process and this project is to repair the bridge, which has concrete spalling and exposed rebar.

An additional bridge project in Kingston, which was completed in 2014, is the Bridge Replacement Project K-01-002, Elm Street over the Jones River. This project consisted of the replacement of a structurally deficient town-owned bridge in the Town of Kingston. This project is 100 percent complete (2014).

Stakeholders noted consistent flooding beneath the MBTA bridge over Landing Road as well as rising waters from the Jones River and Cape Cod Bay that consistently flood the Jones River Watershed building and adjacent roadways.

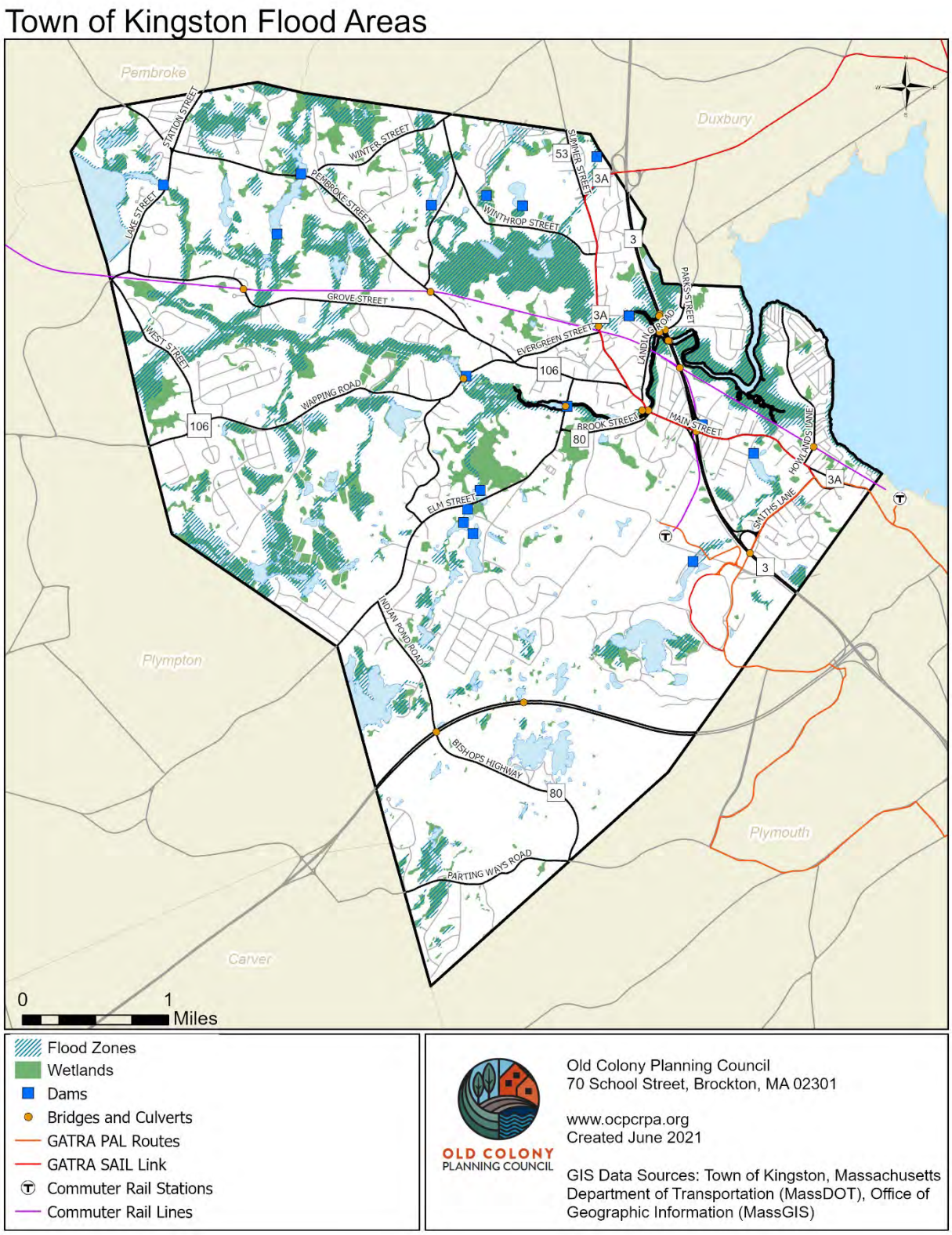
The Kingston Highway Department cited the following areas as problematic for flooding:

- Brook Street (Route 80) at the Second Brook
- Main Street (Route 106) in front of St. Joseph‘s Church

Improvement Recommendations in Kingston

Based on stakeholder interviews, the Town of Kingston has received a grant from the Seaport Economic Development Council to develop a Maritime Resilience Plan, specifically to study the impact of sea level rise in Kingston. This includes the bridge over Stoney Brook (sometimes called Halls Brook). The town has awarded a consultant with a contract to complete the study. Figure 21 shows the potential flood areas for the Town of Kingston in relation to the culverts, dams, passenger rail, and roads.

Figure 21


Town of Kingston Flood Areas
Pembroke
Duxbury
Plympton
Carver
Plymouth
STATION STREET
WINTER STREET
PEMBROKE STREET
LAKE STREET
SUMMER STREET
WINTHROP STREET
GROVE STREET
WEST STREET
EVERGREEN STREET
LANDING ROAD
PARK STREET
WAPPING ROAD
BROOK STREET
MAIN STREET
HOWLANDS LANE
SMITHS LANE
ELM STREET
INDIAN POND ROAD
BISHOPS HIGHWAY
PARTING WAYS ROAD
53
3A
3
106
80
0
1
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
GATRA PAL Routes
GATRA SAIL Link
Commuter Rail Stations
Commuter Rail Lines
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Created June 2021
GIS Data Sources: Town of Kingston, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Pembroke

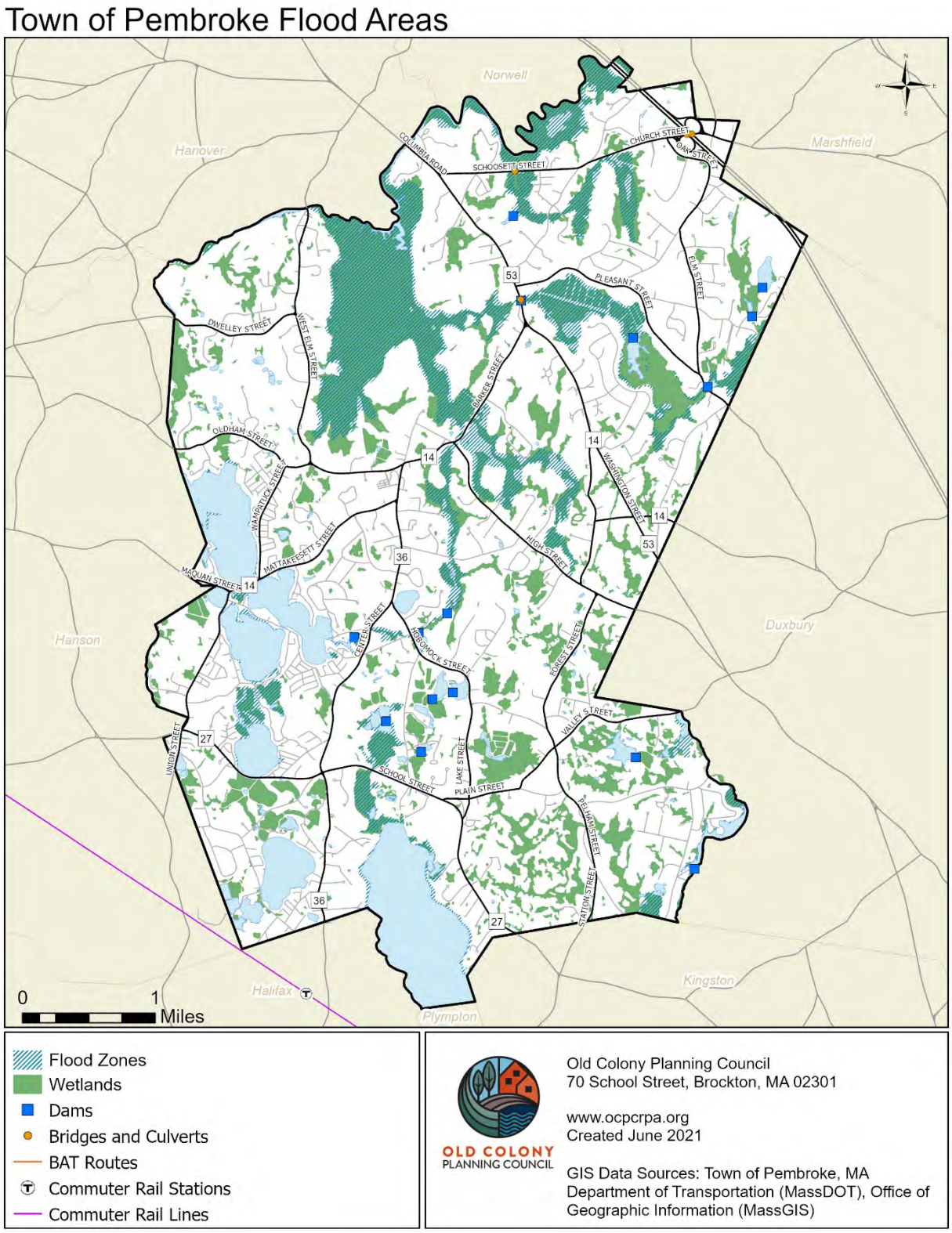
The Town of Pembroke is undertaking the MVP process in 2021 after a delay due to the Covid pandemic emergency. The North River, which flows through Pembroke, Norwell, and Marshfield and Scituate on the coast, is prone to flooding during coastal storm events such as N'oreasters and Hurricanes. Although Pembroke is not a coastal coammunity, coastal flooding during storm events impacts the North River in Pembroke and has the potential to inundate Route 3 at the Pembroke/Norwell line, as the river passes under Route 3 at this location.

Figure 22 shows the potential flood areas for the Town of Pembroke in relation to the culverts, dams, passenger rail, and roads.

The list of flooded areas based on information from the Pembroke's Public Works Department includes:

- Mill Pond Road (Homes flooded, DPW assisted)
- Glenwood Road (Homes flooded, DPW assisted)
- Brenda Lane at Plymouth Street (Water flowing across the street, not pumped, leech CB's back-up and culvert (cross) can't handle)
- Dwelley Street at the Hanson Town Line
- Birch Street at the Duxbury Town Line
- Mill Street (Houses getting flooded, pumped off for first time on April 1 via fire truck, low point was at House #54 and #66 and it was crossing the road)
- Lake Shore Drive (Culvert from Lower Chandler Pond could not handle the volume and went over road, with a danger of washing out the road, but eventually subsided)
- Mill Pond off Hobomock Street (Control structure could not handle, danger washing out Hobomock Street, removed fish ladder and sandbagged to prevent structure from failing)
- Indian Head River dam at West Elm Street at the Hanover Town Line
- Valley Street at Duxbury Town Line-Upper Chandler Pond (Culvert handled it, road not breached with these last 2 storms, but has in the past. Cranberry owners dropped level before a storm, and it was O.K.)

Figure 22


Town of Pembroke Flood Areas
Norwell
Hanover
Marshfield
Hanson
Duxbury
Halifax
Plympton
Kingston
COLUMBIA ROAD
SCHOOSETT STREET
CHURCH STREET
OAK STREET
PLEASANT STREET
ELM STREET
DWELLEY STREET
WEST ELM STREET
CHARLES STREET
OLDHAM STREET
HANOVER STREET
MATTAKEESETT STREET
MAQUAN STREET
WASHINGTON STREET
HIGH STREET
CENTER STREET
HOROMOCK STREET
FOREST STREET
VALLEY STREET
UNION STREET
SCHOOL STREET
LAKE STREET
PLAIN STREET
PELHAM STREET
STATION STREET
14
53
36
27
0
1
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
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GIS Data Sources: Town of Pembroke, MA Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Plymouth

The Town of Plymouth began its MVP process in January of 2020 and completed an MVP report in June 2020. The process involved several focus groups, workshops, a public forum, and an on-line public forum. The MVP process cited the Saquish neighborhood as the greatest risk to flooding. The neighborhood is located on a peninsula with access only through Duxbury. The area has significant coastal erosion, limited shoreline protection on only two residences, and a high flood risk access road. Saquish is low-lying except for Gurnet Point where significant coastal erosion is occurring. Access to Saquish is through Duxbury on a private dirt road owned by the Duxbury Beach Reservation. This road is known to flood on windy days with lunar hightides in addition to coastal storms.

The second highest risk to flooding in Plymouth is in Manomet and includes the area from White Horse Beach to Manomet point (including Taylor Avenue). The area is relatively low-lying with high exposure with both hard and natural shoreline protection structures in place. Manomet point experiences extreme coastal erosion as does White Horse Beach.

The reconstruction of Taylor Avenue, from White Horse Road to Manomet Point Road was recently completed. This work included the replacement of the bridge carrying Taylor Avenue over Bridge Dam Brook. This project included roadway reconstruction, sidewalk installation, and reconstruction, installation of a closed drainage system. The purpose of the project was to improve roadway functionality, pedestrian/bicycle mobility and existing drainage issues on Taylor Avenue.

The third highest risk neighborhood based on the MVP report is Downtown Plymouth/Plymouth Long Beach. This area has a one percent annual chance of flooding. The area is also vulnerable to sea level rise by 2050. Plymouth Long Beach has a rock barrier and sea wall at its entrance; however, there is significant coastal erosion at Plymouth Long Beach as these structures were recently damaged in Winter Storm Riley in March 2018 and require maintenance, repair, and reconstruction. Most of the shoreline is protected in downtown Plymouth with sea walls and revetments and the area is sheltered from intense wave energy by Plymouth Long Beach and the jetty in Plymouth Harbor.

One of the strategies to deal with Climate Change for the residential area at Plymouth Long Beach for the town to acquire the properties where the cost of the repair and reconstruction of protection exceeds the financial ability of the town Plymouth has acquired a few houses utilizing grant money and created more public natural space along the barrier beach.

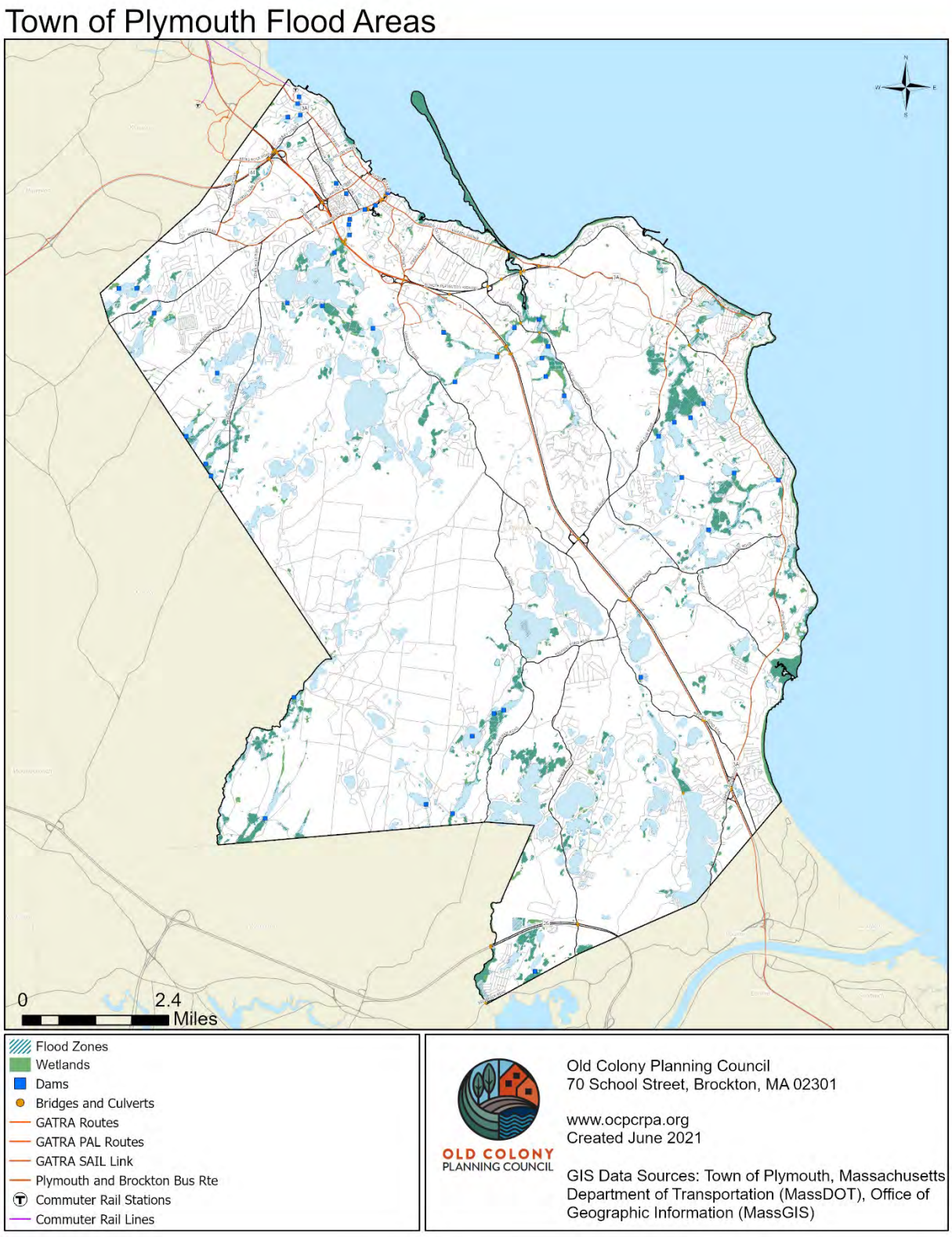
Water Street is the most vulnerable road in Plymouth exposed to sea level rise and flooding hazards. It is an important road with access to Plymouth Downtown, which includes businesses, municipal operations, historic areas, and festivals and community events. The MVP listed twelve roads with greater than 3 feet of erosion since 1970. 17 roads in risk of sea level rise by the year 2050, 25 roads with an annual chance of flood, and nineteen roads with a 1 percent annual chance of flood. Frequent flooding has been reported on Route 3A and Warren Avenue.

Figure 23 shows the potential flood areas for the Town of Plymouth in relation to the culverts, dams, passenger rail, and roads.

The list of flooded areas from Plymouth's Public Works Department include:

- Cherry Street at P.A. Landers
- Fitzgerald Avenue at Beacon Street
- Goldfinch Lane
- Newfield Street
- Lisa Avenue
- Sandwich Street by Obery Street
- 11 Hallorans Way
- Madlyn Street at Lancaster Avenue
- 18 Nickerson Street
- Standish Avenue System behind Goddard Court
- Buttermilk Bay Area-Multiple Locations
- Blueberry Lane
- Long Pond Road (Unpaved Southern Section)
- Kings Pond Plain Road Subdivision
- Taylor Avenue
- Hedge Pond System near Hedge Elementary School, Standish Avenue
- Tall Pines Subdivision
- Federal Furnace Road in the vicinity of House # 590, Diane Lane, Saby‘s Pond and
- the American Legion Building

Figure 23


Town of Plymouth Flood Areas
0
2.4
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
GATRA Routes
GATRA PAL Routes
GATRA SAIL Link
Plymouth and Brockton Bus Rte
Commuter Rail Stations
Commuter Rail Lines
OLD COLONY
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Created June 2021
GIS Data Sources: Town of Plymouth, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Improvement Recommendations in Plymouth

Based on feedback from Plymouth stakeholders, Bartlett Brook and Eel River have their outlets to the sea blocked by sand when there is a nor'easter or hurricane event This causes Route 3A and adjacent properties to be flooded until the outlets are cleaned.

Additionally, Plymouth is reconstructing the Harbormaster building raised to accommodate flood waters. Due to the presence of municipal sewer, center of economy, and existing armoring, Downtown Plymouth could increase its resilience score with some accommodations at the parcel level that limit water entry during storms and minimize risk of damage with flood proof buildings. These are discussed in Section VI. Climate Ready Healthy Plymouth Action Plan.

The MVP recommendations included adding measures to protect Plymouth's shoreline using both structural and natural approaches, including sea wall maintenance, rigid revetments, dune nourishment, habitat restoration, and flood parks.

Specific shoreline protection projects include:

- Plymouth Long Beach, Beach nourishment seaward of the dike from the main beach to the Crossover
- Nourishment/create cobble berm on harborside north of Crossover
- Mixed sediment nourishment at Warren's Cove
- Nourishment/stabilization of shoreline day parking to Crossover
- Marsh restoration on the harborside White Horse Beach
- Dune and beach nourishment Manomet Point
- Maintain coastal structure Ellisville Harbor
- Coastal shoreline and inlet protection at Ellisville Marsh Plymouth Harbor
- Reconstruct bulkhead at harbor between Wood's Seafood and Lobster Hut
- Reconstruct seawalls and revetments along Water Street – Plymouth Harbor Continue Restoration Efforts focused on dam removal, flood mitigation, wetland and forest habitat expansion, while also monitoring and celebrating conservation successes (e.g. Living Observatory). Specific projects include: Jenney Pond Dam
- Repairs to Jenney Pond Dam
- Dredging of Jenney Pond
- Construction of bypass at Jenney Pond Dam Cranberry Bog Natural Restoration 130
- Restore decommissioned cranberry bogs back to natural wetlands – town wide

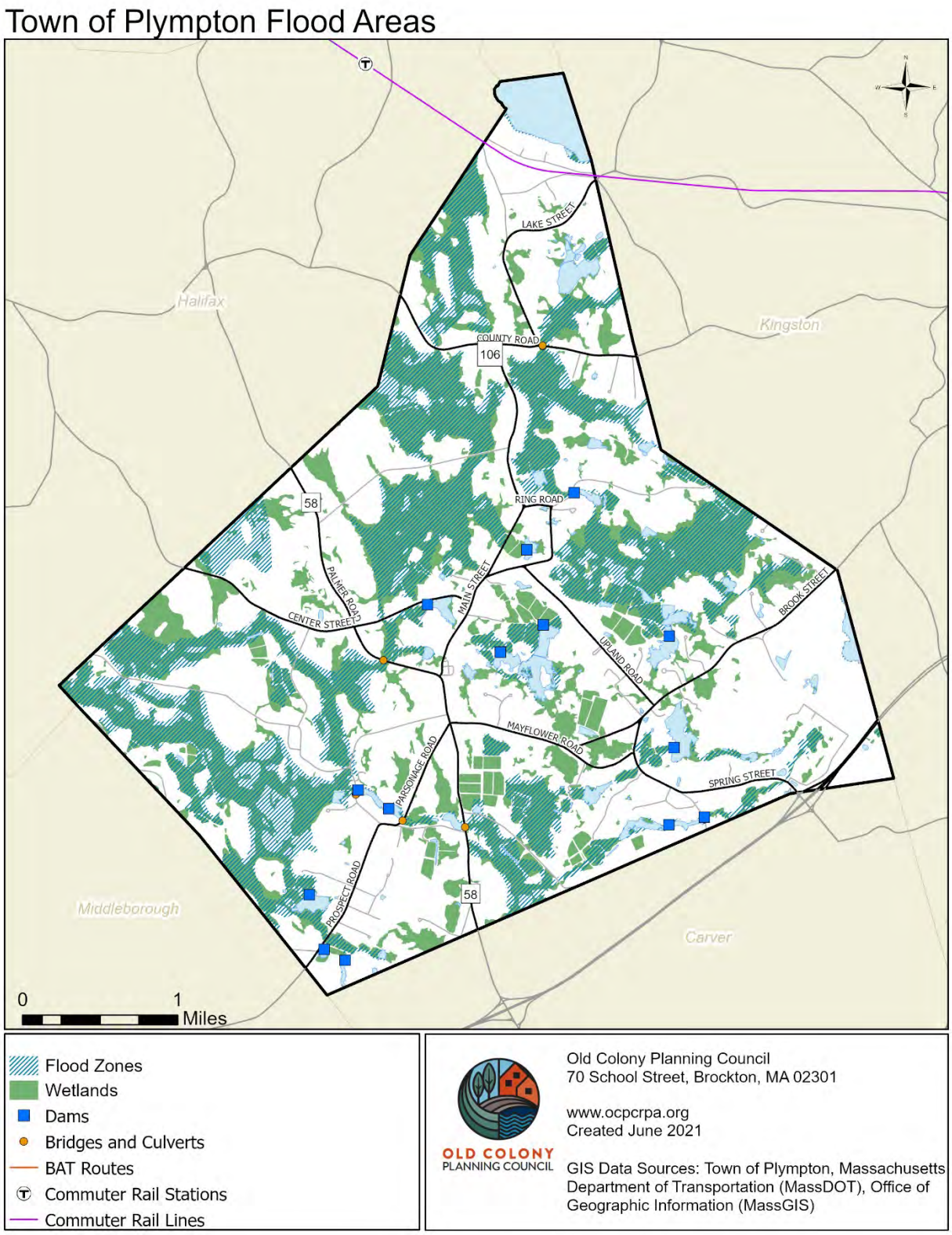
Plympton

The Town of Plympton completed the MVP process and an *MVP Community Resilience Program Resilience Building Report* was completed by a consultant in February of 2020. Based on this report, the Town is concerned about a number of hazards and impacts related to climate change. These include drought hazard as the community relies solely on private wells for drinking water and pumper trucks for firefighting. In addition, inland flooding is an issue for a number of areas throughout town, which have experienced historical flooding over the past ten years. Loss of power during winter and windstorms are also existing problems, which are expected to worsen because with extensive forests, rural roadways and a small population, Plympton is often one of the last Towns to have power restored after a storm event.

Figure 24 shows the potential flood areas for the Town of Plympton in relation to the culverts, dams, passenger rail, and roads.

Prospect Street, just south of Parsonage Road and Winnetuxet Road was cited as the Plympton Highway Departments priority for repetitive flooding.

Figure 24


Town of Plympton Flood Areas
LAKE STREET
COUNTY ROAD
106
RING ROAD
58
PALMER ROAD
CENTER STREET
MAIN STREET
BROOK STREET
UPLAND ROAD
MAYFLOWER ROAD
SPRING STREET
PARSONAGE ROAD
PROSPECT ROAD
58
Halifax
Kingston
Middleborough
Carver
0
1
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
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Created June 2021
GIS Data Sources: Town of Plympton, Massachusetts Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Stoughton

In response to climate change impacts, the Town of Stoughton completed the Municipal Vulnerability Preparedness (MVP) Program process in 2020 to identify and address Climate Change vulnerabilities in Town.

The objectives of the MVP process included:

- Defining the top natural and climate-related hazards to the town
- Identifying existing and future strengths and vulnerabilities
- Developing prioritized actions for the community to address Climate Change impacts

A number of hazards were identified through the MVP process as having the greatest Climate Change impact in the Town of Stoughton. These include:

- Flooding
- Extreme Temperature
- Drought
- Extreme Weather
- Intense/Severe Storms
- High Winds
- Ice/Snow
- Invasive Species

The MVP summary report stated that Stoughton experienced a number of weather-related events in recent years, and these events are expected to increase due to climate change. The report stated that flooding in the low-lying areas and along rivers and ponds or near dams are a high concern for the town. Severe winter storms were cited as another major concern as these storms result in fallen trees and downed power lines, which isolates elderly people and vulnerable groups. Slippery roads affect people who walk to work or use public transportation and many of these people are in environmental justice populations.

<u>Improvement Recommendations in Stoughton</u>

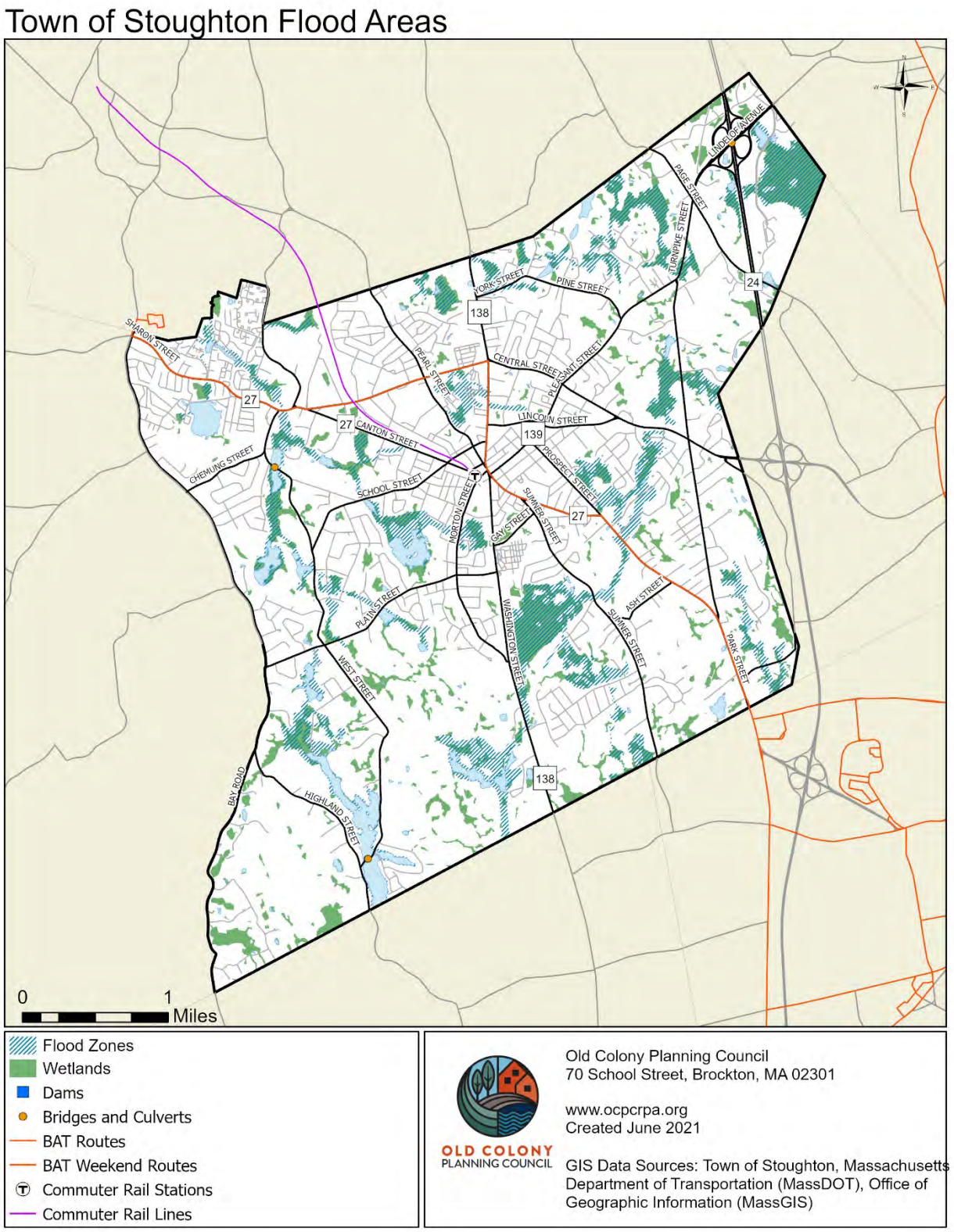
Improvements recommended in the MVP summary report include:

- Road Infrastructure: Route 139 improvements, catch basin cleaning.
- Institute Low Impact Development (LID)/Green Infrastructure Measures, maintain proper drainage to avoid standing water, maintain stormwater detention at Elementary Schools and other town facilities, review regulations to incorporate advocacy of LID measures, minimize impervious surfaces, continue and expand streetscape project, and continue smart water management.
- Extending Stoughton's sewer system to those areas that are not covered and use septic systems. This is important in those areas of Stoughton that have septic near high ground water or drinking water sources.
- During high wind or heavy snowstorm events, downed trees and branches cause major maintenance problems in Town. Tree trimming is important preventative maintenance for utility preservation. The town encourages power companies to continue to keep up with tree trimming, as many of these trees are not maintained by the Town.
- Dams are a concern as projected rains and heavy rain events increase, it puts a higher need for Stoughton to manage the increase in flow through the drainage system, and other mitigation efforts.

- Identify, survey, and evaluate culverts that need upgrading and schedule for maintenance, replacement, and upgrades. There is a need for an overall culvert maintenance and improvement plan.
- Communication Systems: Run frequent tests, civil preparedness.
- Power Grid: Increase community solar and other alternative energy sources, increase redundancy, expand relationship and communication with utility companies, back-up power, harden electric system, tree management (utility companies), debris management (town), burying utilities & strengthening systems Evaluation
- Vulnerable Age Populations: Identify (list) vulnerable people to contact during extreme events, institute neighbor check in, option for transport to shelter, work with Council on Aging for Emergency Preparedness Training, create inventory of available resources, continue outreach, Reverse 911, coordinate communication with emergency response team, establish public education plan for notification of shelter facilities and resources, note dangers of heat related injuries, generator safety education, continue to utilize OASIS services and expand to other demographics, Emergency Preparation Training, utilize free lunch program for outreach opportunities, education camps for students, pest control, MBTA evacuation.

Figure 25 shows the potential flood areas for the Town of Stoughton in relation to the culverts, dams, passenger rail, and roads.

Figure 25


Town of Stoughton Flood Areas
0
1
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
BAT Weekend Routes
Commuter Rail Stations
Commuter Rail Lines
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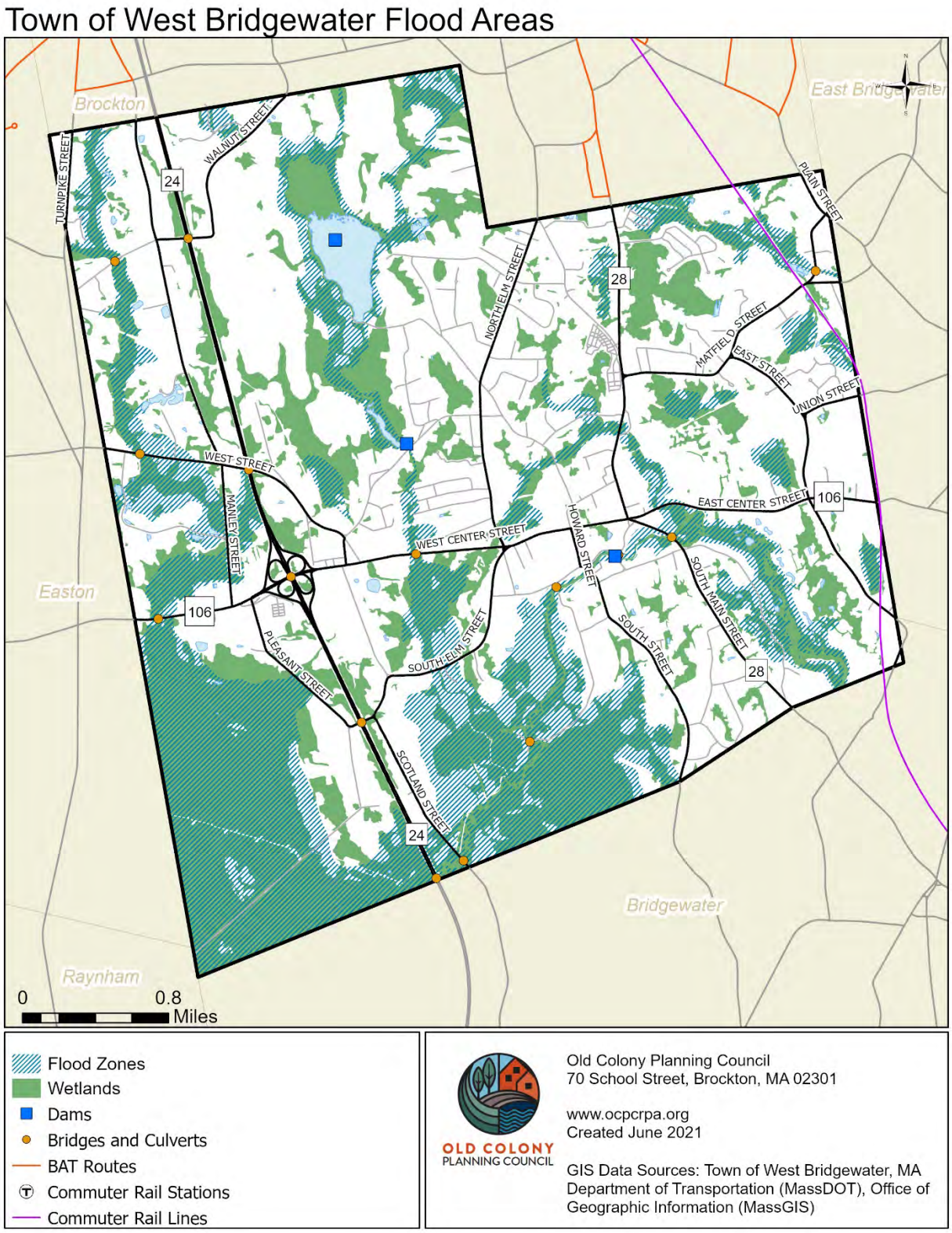
West Bridgewater

Much of the area in southwestern West Bridgewater is located in the Hockomock Swamp (Area of Critical Environmental Concern, ACEC). Both Route 24 and Route 106 traverse through the Hockomock Swamp. The Hockomock Swamp is a vast wetland encompassing much of southeastern Massachusetts (16,950-acres), which is considered the largest freshwater swamp in the state. It acts as a natural flood control mechanism for the region and is within the Taunton Watershed. The Hockomock Swamp includes areas of Bridgewater, Easton, Norton, Raynham, Taunton, and West Bridgewater within its ACEC boundaries. The wetlands act as a huge water reservoir and serve as the headwaters for the Town River, which flows into the Taunton River. The wetlands and floodplains are connected hydrologically with an extensive underlying system of medium- and high-yield aquifers. There are three public water supply wells located in the ACEC. It is a unique and irreplaceable wildlife habitat and the location of at least 13 rare and endangered species.

Figure 26 shows the potential flood areas for the Town of West Bridgewater in relation to the culverts, dams, passenger rail, and roads.

As of this time, West Bridgewater has not undergone the MVP process. Figure 26 shows that both Route 24 and Route 106 are vulnerable for potential flooding.

Figure 26


Town of West Bridgewater Flood Areas
Brockton
East Bridgewater
Easton
Bridgewater
Raynham
TURNPIKE STREET
WALNUT STREET
PLAIN STREET
NORTH ELM STREET
MATFIELD STREET
EAST STREET
UNION STREET
WEST STREET
MANLEY STREET
EAST CENTER STREET
WEST CENTER STREET
HOWARD STREET
SOUTH MAIN STREET
SOUTH STREET
SOUTH ELM STREET
PLEASANT STREET
SCOTLAND STREET
24
28
106
0
0.8
Miles
Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines
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GIS Data Sources: Town of West Bridgewater, MA Department of Transportation (MassDOT), Office of Geographic Information (MassGIS)

Whitman

The Town of Whitman completed the Integrated Municipal Vulnerability Preparedness and Hazard Mitigation Plan (MVP-HMP) process in April of 2020. The Summary of Findings Report states that the purpose of the process was to define top local natural and climate-related hazards of concern, Identify existing and future strengths and vulnerabilities, develop prioritized actions for Whitman, and to Identify immediate opportunities for actions to increase resilience against Climate Change.

Several workshops and listening sessions were held during the MVP process for stakeholder and community engagement. Four top hazards were identified as part of the public outreach process, which include: 1. Inland Flooding – (resulting from moderate precipitation over several days, intense precipitation over a short period, or melting snowpack, developed areas that have impervious areas can contribute to inland flooding.) 2. Hurricanes and Tropical Storms – (Violent wind and rainstorms with wind speeds of 74 to 200 miles per hour.) 3. Extreme Wind and Thunderstorms 4. Snowstorms and Nor'easters – (Severe storms include ice storms, nor'easters, heavy snow, blowing snow, and other extreme forms of winter precipitation.)

Problems identified during the MVP process include, the drainage system is prone to flooding and the town needs a culvert maintenance and repair plan with long-term implementation to protect natural resources. In addition, a microburst resulted in an electrical grid power loss for more than a week in 1997, and a tree trimming and easement maintenance plan is needed to protect against power loss.

Mitigation actions determined by the Community Resilience Workshop include Identifying flood prone areas and conducting an inventory of culverts and bridges, creating a culvert maintenance and repair plan with long-term implementation prioritization to improve infrastructure and lessen the likelihood of loss due to climate change. This includes culvert resizing and replacing projects for increased flooding resiliency and storm hardening. Green infrastructure, low-impact design, and other nature-based solutions should be integrated with hard-infrastructure improvement plan to enhance the improvement plan. The implementation of this improvement is scheduled between September 2021 and September 2024.

The public outreach workshops identified the following culverts at the following locations:

- Auburn Street (Route 14) at Pine Haven Drive
- Bedford Street at Stop & Shop (at an unnamed brook, just north of May Street)
- Pond Street near South Avenue and the MBTA Station
- Woodlawn Circle at Pine Haven Drive
- Temple Street (Route 27) at Joyce Terrace
- Temple Street (Route 27) over Rock St.
- Belmont Street at Meadow Brook
- Plymouth Street at Shumatuscacant River
- Oldman Drive near Route 14
- Star Street
- Bedford Street culverts

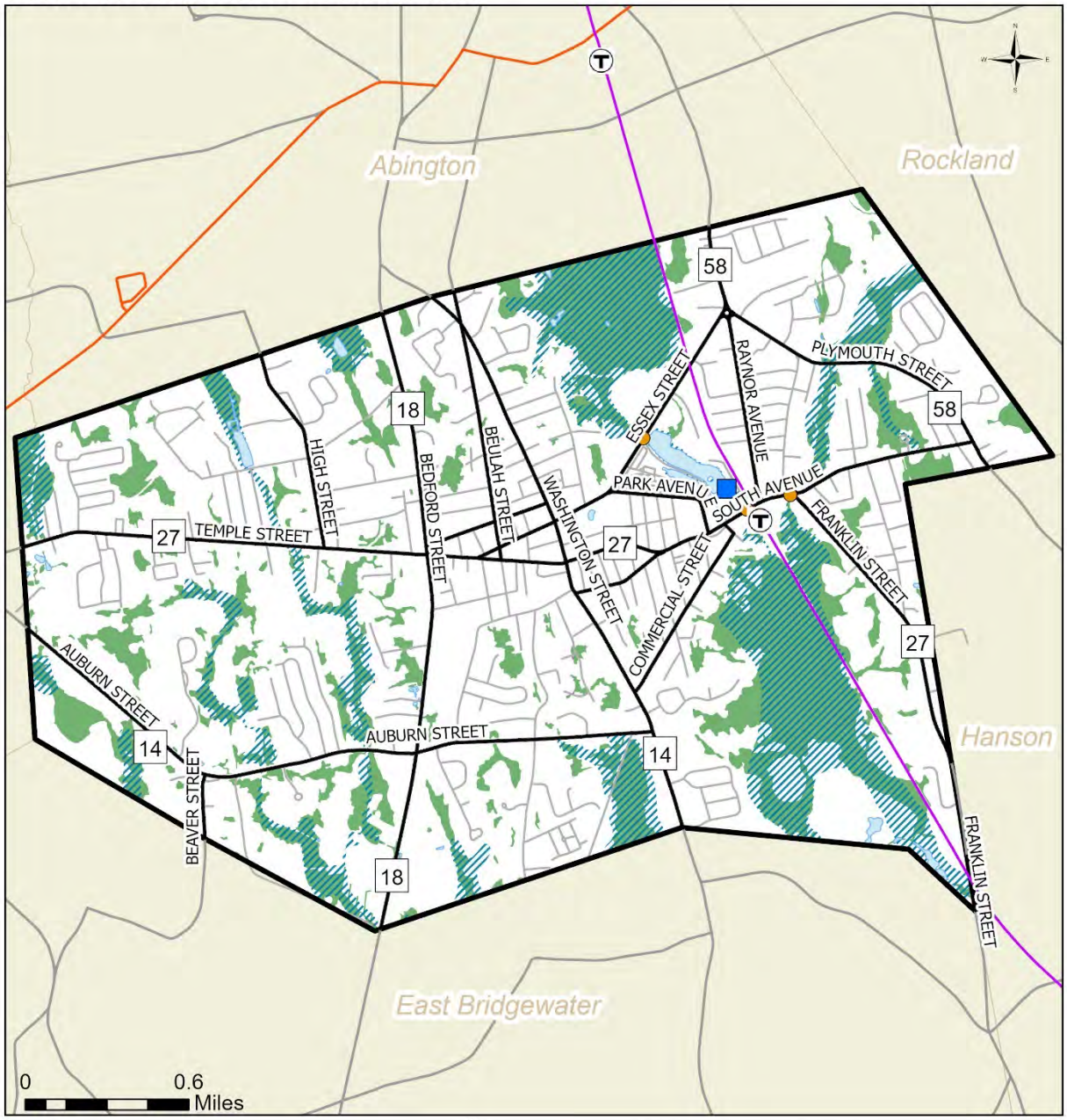
Identify key road networks and develop safe evacuation routes. Goal 1, 2, 4 Action Description Install evacuation route signage; Develop a robust local transportation plan that addresses emergency access

to transportation and the social and economic consequences that accompany service interruptions. Planning should include supplemental funding and equipment for snow removal, a review of available drivers, and the understanding of potential insurance and union contracts issues that may influence access to certain transportation resources. Access to critical resources such as childcare and provisions should be considered. Promote public transportation to reduce cars on the road during inclement weather and reduce greenhouse gas emissions. Traffic and roadway improvements plan to deal with more people. Medium Lead Department Emergency Management Partners Highway Dept. Cost Low Possible Funding Sources General Fund, Staff Time Hazards Changes in Precipitation, Flood, Drought. Rising Temperatures: Average/Extreme Temperatures Extreme Weather: Hurricanes/Tropical Storms, Severe Winter Storm/Nor'easter. Type of Mitigation Project Emergency Preparedness and Readiness Critical Facility Protection No Community Components Infrastructure Implementation Schedule September 2021-September 2024

Figure 27 shows the potential flood areas for the Town of Whitman in relation to the culverts, dams, passenger rail, and roads.

Figure 27

Town of Whitman Flood Areas



Flood Zones
Wetlands
Dams
Bridges and Culverts
BAT Routes
Commuter Rail Stations
Commuter Rail Lines

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Created June 2021

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Climate Change Projects in the OCPC Region

The *2015 Natural Hazard Mitigation Plan for the Old Colony Region* lists a number of projects for each of the OCPC communities that are designed to specifically address the impacts of Climate Change. The purpose of the 2015 plan was to develop an inclusive, comprehensive and long-term plan to prepare for disasters before they occur. The 2015 plan supports communities in their response to The Federal Disaster Management Act of 2000 (DMA 2000), which established a national program for regional mitigation the administration of disaster relief. The Federal DMA 2000 mandates that all localities must review and revise their local natural hazard mitigation plans every five years to reflect changes in development, progress in mitigation efforts and changes in priorities. Table 6 includes Climate Change projects by town in the region, originally compiled in the 2015 plan and updated to include projects since the completion of that study.

Table 6

Community	Project/Action	Source
Abington	Removed and replaced several "blocked" drain lines in various locations throughout town, including Nash Memorial Drive, Jennings Drive, Spruce Street, West Street and Central Street.	2015 Plan (prior to 2015)
Abington	Cleared and cleaned pipe inverts in the following areas: Island Grove Pond, Central Street, Centre Avenue, North Avenue, Lincoln Street, Colonel Hunt Drive, Shaw Avenue and others.	2015 Plan (prior to 2015)
Abington	Conducted regular maintenance of storm drains utilizing a catch basin digger.	2015 Plan (prior to 2015)
Abington	Replace the superstructure Central Street over the Shumatuscacant River to rehabilitate and replace a structurally deficient bridge (MassDOT Project # 607346).	Old Colony TIP in design
Avon	Cleaned pipes and outlets on Route 24 during the Resurfacing and Related Work on Route 24 Project (MassDOT Project ID# 605238).	Old Colony TIP
Avon	Replaced the Ladge Street culvert over the Trout Brook with a new larger culvert after it collapsed due to heavy rains during the March 2010 floods.	2015 Plan (prior to 2015)
Avon	Improved drainage on the following roadways with the addition of culvert enlargements, larger pipes and additional catch basins: o East High Street o East Spring Street o Page Street o Pond Street o Brentwood Subdivision Avenue Subdivision (partially completed)	2015 Plan (prior to 2015)
Avon	Completed drainage improvements in the Nichols Avenue, Johnson Road, Howard Lane and Lawson Street neighborhood.	2015 Plan (prior to 2015)
Avon	Cleared brooks and streams of trash and vegetation throughout town to allow for the free flow of water and to mitigate flooding.	2015 Plan (prior to 2015)
Bridgewater	At Halifax line bridge replacement Cherry Street over the Taunton River (MassDOT Project # 601280)	Old Colony TIP completed 2002)
Bridgewater	Installed catch basins and built-up aprons to control drainage on Bedford Street (Routes 18/28) during the Resurfacing and Related Work on Route 18 & 28 Project from the Bridgewater to the Middleboro Rotary (MassDOT Project ID# 601104).	Old Colony TIP
Bridgewater	Replaced the Bedford Street (Route 18) Bridge over the Taunton River with a reinforced concrete drain pipe and catch basins during the Bedford Street Bridge Replacement Project (MassDOT Project ID# 603385).	Old Colony TIP Complete 2008
Bridgewater	Installed catch basins with curb inlets and reinforced concrete drain pipes at the intersection of Bedford Street (Routes 18/28) at Winter Street during the Signalization & Improvement Project (MassDOT Project ID# 603568).	Old Colony TIP

Bridgewater	Replaced the Summer Street Bridge over the Taunton River during the Summer Street Bridge Replacement Project (MassDOT Project ID #604415).	Old Colony TIP Complete

Table 6 (Continued)

Community	Project/Action	Source
Bridgewater	Installed a closed drainage system to convey stormwater from North Street during the Reconstruction of North Street, from Pleasant Street (Route 104) to Village Gate Drive Project (MassDOT Project #604958).	Old Colony TIP
Bridgewater	Replaced the Bridge Street Bridge over the Town River after it partially collapsed during the March 2010 floods.	2015 Plan (prior to 2015)
Bridgewater	Replaced the Hayward Street Bridge over the Town River after it partially collapsed during the March 2010 floods.	2015 Plan (prior to 2015)
Bridgewater	Repaired the Northfield Drive culvert.	2015 Plan (prior to 2015)
Bridgewater	Repaired damage to Bridge Street at the approach to the bridge after damage due to March 2010 floods.	Town project
Brockton	BROCKTON- INTERSECTION IMPROVEMENTS AT LYMAN STREET/GROVE STREET/SUMMER STREET & REPLACEMENT OF GROVE STREET BRIDGE, B-25-005, OVER SALISBURY PLAIN RIVER	Old Colony TIP (in Design)
Brockton	Bridge replacement on Allen Street over the Salisbury Brook (MassDOT project #600649).	TIP completed 2002
Brockton	Installed catch basins, with curb inlets and drainage manholes and reinforced concrete drain pipes as part of the reconstruction of West Chestnut Street from Pearl Street to Burke Drive (MassDOT Project ID# 601339).	Old Colony TIP
Brockton	Installed catch basins with curb inlets, drainage manholes and reinforced concrete drain pipes as part of the Reconstruction of Winter Street from Howard Street to North Cary Street (MassDOT Project ID #601347).	Old Colony TIP
Brockton	Replaced the Bartlett Street Bridge over the Salisbury Brook during the Bartlett Street Bridge Replacement Project (MassDOT Project ID #601393).	Old Colony TIP complete
Brockton	Installed catch basins with curb inlets, drainage manholes and reinforced concrete drain pipes as part of the Signal & Intersection Improvements Project at Montello Street (Route 28) and Howard Street (Route 37) (MassDOT Project ID #602557).	Old Colony TIP
Brockton	Installed catch basins, catch basins with curb inlets, gutter inlets and reinforced concrete drain pipes as part of the Signal & Intersection Improvements Project at Pleasant Street (Route 27) and Belair Street and Moraine Street (MassDOT Project ID #604595).	Old Colony TIP
Brockton	Replaced the White Avenue Bridge over the Salisbury Brook during the White Avenue Bridge Replacement Project (MassDOT Project ID #604419).	Old Colony TIP Complete
	BROCKTON- BRIDGE REPLACEMENT, BR# B-25-059 SPRING STREET OVER SALISBURY BROOK (602539)	Old Colony TIP complete
Brockton	Installed catch basins, new drainage manholes and reinforced concrete drain pipes as part of the Reconstruction of Pleasant Street (Route 27) at West Street and Westgate Mall Drive (MassDOT Project ID# 604741).	Old Colony TIP
Brockton	Completed Emergency Action Plans (EAP) for city-owned dams: Ellis Brett Pond Dam, Thirty Acre Pond Dam, and Waldo Lake Dam.	2015 Plan (prior to 2015)
Brockton	Installed a Bandalong Litter Trap in the Salisbury Plain River to capture and remove floating litter preventing trash dams, impair the free flow of water.	2015 Plan (prior to 2015)
Brockton	The city completed over $110 million in wastewater, sewer and clean water infrastructure improvements throughout the city.	2015 Plan (prior to 2015)
Brockton	$1.6 million in upgrade for the booster station.	2015 Plan (prior to 2015)
Brockton	Infrastructure improvements to the earthen Brockton Reservoir Dam in Avon, including replacing the wooden spillways with newer concrete spillways, as well as high and low level outlet control valves.	2015 Plan (prior to 2015)
East Bridgewater	Repairs at the Forge Pond Dam, which is rated in “Poor” condition.	2015 Plan (prior to 2015)

East Bridgewater	Reduced streamside risks by removing selected structures from floodway and reconfiguring banks for storage and safe dry weather open space/habitat use.	2015 Plan (prior to 2015)
East Bridgewater	Adopted stormwater treatment and retention requirements for new developments.	2015 Plan (prior to 2015)
East Bridgewater	Replaced and elevated the Department of Public Works office building to prevent flooding from heavy rains.	2015 Plan (prior to 2015)
East Bridgewater	Placed snow fencing in snowdrift prone areas throughout town.	2015 Plan (prior to 2015)

Table 6 (Continued)

Community	Project/Action	Source
Easton	Replaced the Central Street Bridge over the Queset Brook during the Central Street Bridge Replacement Project (MassDOT Project ID #602836).	Old Colony TIP complete
Easton	Installed catch basins, catch basins with curb inlets and drainage manholes and reinforced concrete drain pipes as part of the Reconstruction of the Intersection of Routes 106 & 123 (Five Corners) (MassDOT Project ID# 604658).	Old Colony TIP
Easton	Installed catch basins, catch basins with curb inlets, drainage manholes, gutter inlets, leaching basins and reinforced concrete drain pipes as part of the Reconstruction of Foundry Street (Route 123) from Route 106 to the Norton Town Line (MassDOT Project ID# 601332).	Old Colony TIP
Easton	Made improvements to dams in town: Ames Long Pond Dam, Langwater Pond Dam, and Shovelshop Pond Dam.	2015 Plan (prior to 2015)
Duxbury	Bridge Replacement (48H & 48J), Route 3 (PILGRIM HIGHWAY) NB/SB over Franklin Street (MassDOT Project ID 605294).	Old Colony TIP (under Design)
Duxbury	Bridge Replacement D-14-003 (438), Powder Point Avenue over Duxbury Bay (MassDOT Project ID 612006).	Old Colony TIP (under Design)
Halifax	Replaced the riprap around the culvert on Plymouth Street (Route 106) across from the Police Station.	2015 Plan (prior to 2015)
Hanover	HANOVER- PEMBROKE- BRIDGE REHABILITATION, BR# H-06-005=P-05-005 ROUTE 53 (WASHINGTON STREET) OVER THE NORTH RIVER	Old Colony TIP project complete
Hanson	Installed drainage manholes, reinforced concrete drain pipes, and catch basins with curb inlets during the Reconstruction of Franklin Street (Route 27) (MassDOT Project ID# 600397).	Old Colony TIP
Hanson	Replaced smaller drainage pipes with larger ones on Maquan Street across from Maquan Pond.	2015 Plan (prior to 2015)
Hanson	Purchased a new jet rodder for $44,000 to flush drains throughout town. The new more powerful and efficient jet rodder replaces an aging 1961 rod that was used to flush drains.	2015 Plan (prior to 2015)
Hanson	Completed a drainage project on Crescent Street to alleviate flooding issues.	2015 Plan (prior to 2015)
Kingston	Bridge repair and concrete work systematic bridge preservation Route 3 over the Jones River (MassDOT Project # (609376).	Old Colony TIP
Kingston	Improvements to a structurally deficient bridge Route 3 over the Jones River by replacing the superstructure (MassDOT project #607268).	Old Colony TIP (in design)
Kingston	Replaced the Elm Street Bridge over the Jones River during the Elm Street Bridge Replacement Project (MassDOT Project ID #24090).	Old Colony TIP project complete
Kingston	Installed drainage manholes, reinforced concrete drain pipes, catch basins and catch basins with curb inlets, drop inlets, leaching basins and gutter inlets during the Reconstruction of Pembroke Street (Route 27) (MassDOT Project ID# 600413).	Old Colony TIP
Kingston	Acquired property on Elder Avenue to mitigate flooding.	2015 Plan (prior to 2015)
Kingston	Acquired the Halfway Preserve property off of Route 106 to mitigate flooding.	2015 Plan (prior to 2015)
Kingston	Replaced the Brookdale Street culvert that washed away during the March 2010 floods.	2015 Plan (prior to 2015)
Kingston	Purchased a Vactor sewer cleaning truck to clean catch basins as needed.	2015 Plan (prior to 2015)
Kingston	Embarked on a program to reduce the amount of road salt being used when treating roadways in inclement weather.	2015 Plan (prior to 2015)
Kingston	Implemented a Reverse 911 public safety communications system to notify residents via telephone of emergency situations in town.	2015 Plan (prior to 2015)
Pembroke	Installed drainage manholes, catch basins and catch basins with curb inlets and gutter inlets with gutter mouths during the Corridor Improvements on Route 139 (Plain Street) Project (MassDOT Project ID# 604915).	Old Colony TIP
Pembroke	Replaced backup diesel fuel engine with a Natural Gas backup generator and automatic transfer switch at Drinking Water Pumping Station #2.	2015 Plan (prior to 2015)

Table 6 (Continued)

Community	Project/Action	Source
Pembroke	Replaced angle drive natural gas engine and replacing it with a Natural Gas backup generator and automatic transfer switch at Drinking Water pumping Station #3.	2015 Plan (prior to 2015)
	NORWELL- PEMBROKE- BRIDGE REPLACEMENT, N-24-004=P-05-008, ROUTE 3 (NB & SB) OVER NORTH RIVER This project is intended to replace a structurally deficient bridge on Route 3 in Norwell and Pembroke over the North River.	Old Colony TIP (in design)
Pembroke	Replaced failed leach basins and paved roadway at 14 Glenwood Road.	2015 Plan (prior to 2015)
Pembroke	Replaced failed box culvert with 24" RCP and tied it into existing headwalls at Monroe Street.	2015 Plan (prior to 2015)
Pembroke	Drainage project improvement to reroute stormwater runoff to alleviate flooding in the McKenzie Orchard subdivision as well as on Oldham Street.	2015 Plan (prior to 2015)
Plymouth	PLYMOUTH- BRIDGE REPLACEMENT, BR# P-13-012 RIVER STREET OVER EEL RIVER (602591)	Old Colony TIP complete 2004
Plymouth	Installed gutter inlets, catch basins, catch basins with curb inlets, reinforced concrete pipes and leaching basins at the Intersection of Route 3A, Manomet Point Road and Strand Avenue (MassDOT Project ID# 603468).	Old Colony TIP
Plymouth	Installed catch basins, reinforced concrete drain pipes during the Resurfacing and Related Work Project on Route 3 (MassDOT Project ID #604223).	Old Colony TIP
Plymouth	Plymouth DPW project improvements to existing stormwater outfalls for the Billington Sea 319 Stormwater Project. Improving capacities and treatment of sediments, nutrients, and bacteria's discharged to coastal sea beds.	2015 Plan (prior to 2015)
Plymouth	Plymouth DPW improvements to Samoset Street 319 Stormwater Project focusing on improvements to drainage, stormwater treatment and water quality in Plymouth Harbor.	2015 Plan (prior to 2015)
Plymouth	Water management and modeling software installed to improve simulations that assess hydraulic and aquifer performance, determine firefighting capabilities and facilitate environmental impacts and design.	2015 Plan (prior to 2015)
Plymouth	Improvements to the recreational boating pump-out facility within the Town of Plymouth.	2015 Plan (prior to 2015)
Plymouth	Town-wide DPW drainage projects (95 total) for the reconstruction of swales and conventional drainage systems, and the design and installation of stormwater mitigation areas and culverts.	2015 Plan (prior to 2015)
Plymouth	Town-wide DPW Catch Basin Maintenance and Repair Operations (3,600) to improve stormwater capacity and limit localized problem flooding areas.	2015 Plan (prior to 2015)
Plymouth	Plymouth's Environmental Management Division obtained 11 grant awards for the design and execution of the Eel River Headwaters Mitigation Project.	2015 Plan (prior to 2015)
Plymouth	Plymouth DPW completed phase 1 inspection of 12 municipally owned dams and initiated dam removal projects with private/public owners.	2015 Plan (prior to 2015)
Plymouth	Plymouth DPW and Planning Departments completed extensive GIS improvements to map stormwater drainage systems, coastal erosion and flooding areas affecting Plymouth Bay and the Buzzards Bay Watershed Areas.	2015 Plan (prior to 2015)
Plymouth	PLYMOUTH- RECONSTRUCTION OF TAYLOR AVENUE, FROM WHITE HORSE ROAD TO MANOMET POINT ROAD, INCLUDES BRIDGE REPLACEMENT OF P-13-010 Work on this project will consist of roadway reconstruction, sidewalk installation and reconstruction, installation of a closed drainage system and replacement of the bridge carrying Taylor Avenue over Bridge Dam Brook. The work will improve roadway functionality, pedestrian/bicycle mobility and existing drainage issues in the Taylor Avenue corridor. (Project # 605038)	Old Colony TIP Complete
Plympton	Installed catch basins and catch basins with curb inlets, gutter inlets with gutter mouths and gutter inlets during the Reconstruction of Main Street and Palmer Road (Route 58) (MassDOT Project ID# 602337).	Old Colony TIP

Plympton	Completed Phase 1 of the Dam Management Plan for the Winnetuxet Road Pond Dam.	2015 Plan (prior to 2015)
Plympton	Removed and cleared debris from culverts throughout town.	2015 Plan (prior to 2015)
Plympton	Worked with NSTAR to proactively trim trees around utility lines throughout town.	2015 Plan (prior to 2015)
Plympton	PLYMPTON- BRIDGE REPLACEMENT, P-14-001 (445), WINNETUXET ROAD OVER WINNETUXET RIVER	Old Colony TIP (in Design)
Stoughton	Replaced a culvert on Bay Road in 2010.	2015 Plan (prior to 2015)
Stoughton	Installed Beehive drainage grates on Grove Street at Lincoln Street in 2010.	2015 Plan (prior to 2015)
Stoughton	Replaced a culvert on Lake Drive in 2011.	2015 Plan (prior to 2015)
Stoughton	Installed Beehive drainage grates at the Pratt Court Treatment Plant in 2011.	2015 Plan (prior to 2015)
Stoughton	Replaced a culvert on Pratt Court at in 2012.	2015 Plan (prior to 2015)
Stoughton	Installed catch basins on Sharon Street.	2015 Plan (prior to 2015)
Stoughton	Installed Beehive drainage grates on Walker Road.	2015 Plan (prior to 2015)

Table 6 (Continued)

Community	Project/Action	Source
West Bridgewater	Replaced the South Street Bridge over the Town River during the South Street Bridge Replacement Project (MassDOT Project ID #130200).	Old Colony TIP complete
West Bridgewater	Installed catch basins, new drainage manholes and reinforced concrete drain pipes as part of the Reconstruction of Manley Street from West Center Street (Route 106) to the Brockton City Line. (MassDOT Project ID# 601854).	Old Colony TIP
West Bridgewater	Replaced the Scotland Street Bridge over the Town River during the Scotland Street Bridge Replacement Project (MassDOT Project ID #603515).	Old Colony TIP Complete
West Bridgewater	Installed catch basins during the Park & Ride Upgrade Project (MassDOT Project ID# 604814).	Old Colony TIP
West Bridgewater	Cleaned existing pipes and outlets on Route 24 during the Resurfacing and Related Work on Route 24 Project (MassDOT Project ID# 605558).	Old Colony TIP
West Bridgewater	Updated FEMA Flood Maps were adopted by the town.	2015 Plan (prior to 2015)
West Bridgewater	Made repairs were made to both the Maple Street culvert and the Manley Street culvert.	2015 Plan (prior to 2015)
West Bridgewater	WEST BRIDGEWATER- BRIDGE REPLACEMENT, W-18-012, ROUTE 106 (WEST CENTER STREET) OVER THE HOCKOMOCK RIVER The existing stone arch and reinforced concrete arch carrying West Center Street over the Hockomock River are anticipated to be replaced with a single span superstructure of approximately 65 feet. The superstructure system of first choice is a precast arch. (Project 605351)	Old Colony TIP Complete
Whitman	Rebuilt existing drainage structures during the Cold Planing and Resurfacing of Bedford Street (Route 18) Project (MassDOT Project ID# 604160).	Old Colony TIP
Whitman	Replaced the crumbling headwall of the Harding's Pond Dam with a new poured concrete headwall.	2015 Plan (prior to 2015)
Whitman	Cleared trees and brush away from the river and stream banks throughout town every winter to allow for the free flow of water.	2015 Plan (prior to 2015)
Whitman	Used a sewer jet to clean drains of sediment and roots in various neighborhoods throughout Whitman as needed.	2015 Plan (prior to 2015)
Whitman	Dredged the following rivers and streams of sediment to reduce the risk of flooding: Unnamed stream at Route 18 and the Stop & Shop Driveway Unnamed stream at Route 58 between Simmons Avenue & Indian Trail Unnamed stream at Route 14 and Homeland Drive	2015 Plan (prior to 2015)

Electric Vehicles in Massachusetts

The global automobile industry decreased by sixteen percent due to the Covid-19 pandemic. Nevertheless, electric vehicle sales over the past year have been rising steadily. The International Energy Agency (IEA) states that the number of electric vehicles on the road worldwide is forecast to grow from 11 million this year to 145 million by the end of the decade. With electric vehicle sales expected to surge, this will decrease the demand for oil, resulting in a decreased carbon footprint.

Massachusetts has joined the nine-state coalition, Transportation Climate Initiative, a regional collaboration of Northeast and Mid-Atlantic jurisdictions, working together since 2010 to improve transportation, develop the clean energy economy, and reduce emissions from vehicles and fuels. In addition, in the 2015 Massachusetts Zero Emission Vehicle Action Plan, there are 80 recommendations for automakers, dealers, utilities, charging and fueling companies and other key partners to rapidly accelerate consumer adoption of zero emission vehicles, including plug-in hybrid, battery electric and hydrogen fuel cell vehicles. The state's plan is to dramatically cut greenhouse-gas emissions in the next decade and beyond through several changes, including mandating that all new cars sold in the state be

electric by 2035. Massachusetts currently has about 30,000 electric vehicles on the roads, the goal by 2035 is to reach 750,000 electric vehicles.

With the number of electric vehicles on the road going up, the number of electric vehicle charging stations needs to increase as well. Many people might not be able to afford installing a charging station at their home, so public charging station availability is crucial. Currently, Massachusetts has 1,817 public charging stations with 4,107 charging outlets. This number should increase in order to be able to handle the number of electric vehicles on the road by 2035. Figure 28 shows the number and locations of charging stations in Massachusetts. Figure 29 shows the location of electric vehicle charging stations in the OCPC Region.

Figure 28

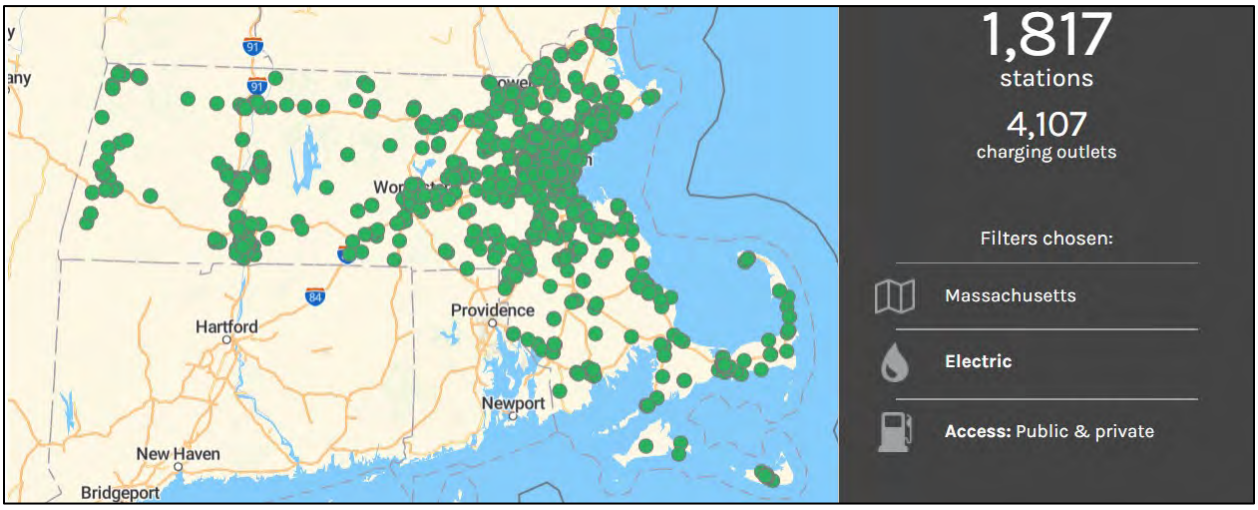
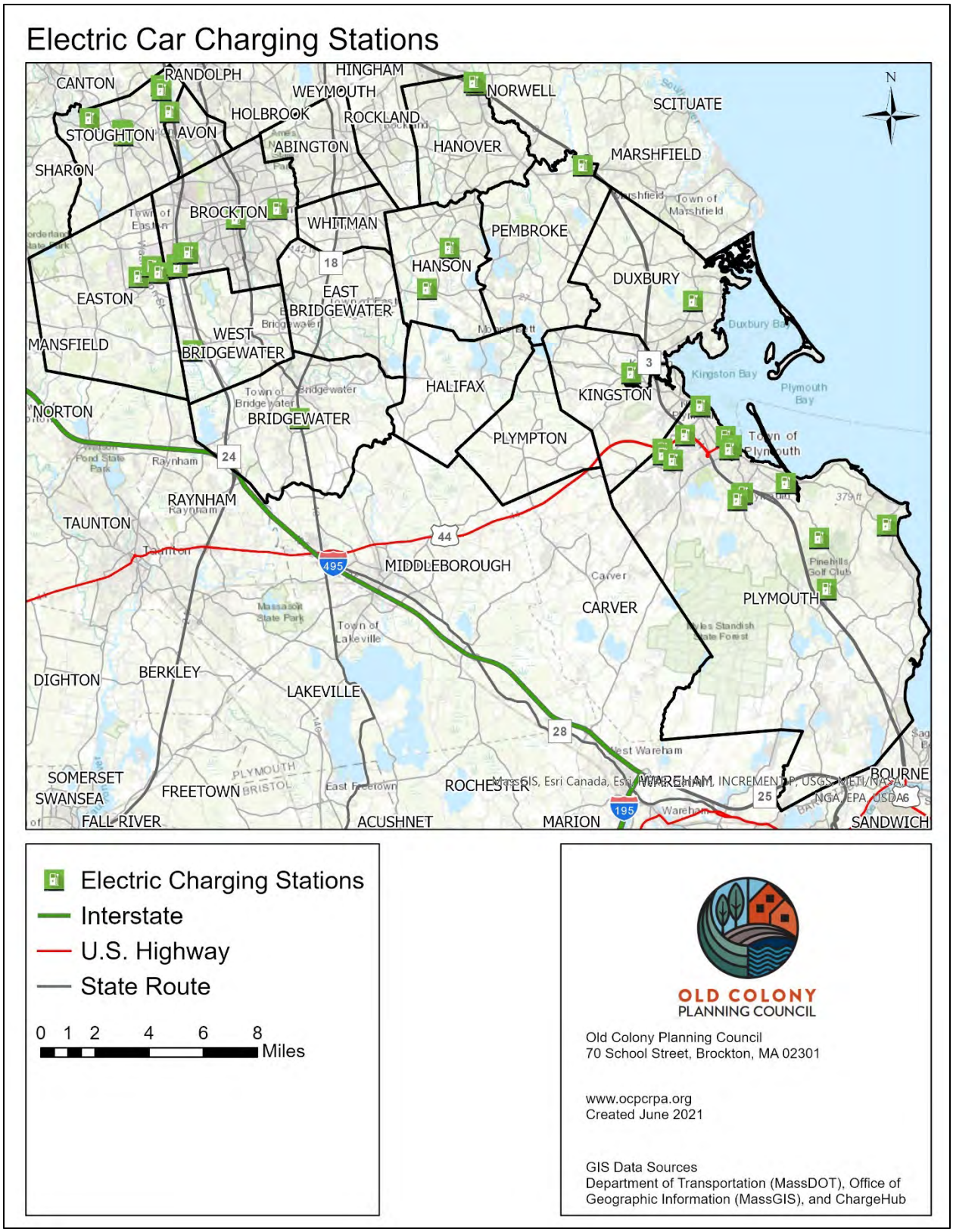


Figure 29


Electric Car Charging Stations
CANTON
RANDOLPH
HINGHAM
WEYMOUTH
NORWELL
SCITUATE
HOLBROOK
ROCKLAND
STOUGHTON
AVON
ABINGTON
HANOVER
MARSHFIELD
SHARON
BROCKTON
WHITMAN
PEMBROKE
HANSON
DUXBURY
EASTON
EAST BRIDGEWATER
WEST BRIDGEWATER
MANSFIELD
HALIFAX
KINGSTON
NORTON
BRIDGEWATER
PLYMPTON
Town of Plymouth
RAYNHAM
TAUNTON
MIDDLEBOROUGH
CARVER
PLYMOUTH
Massasoit State Park
Town of Lakeville
DIGHTON
BERKLEY
LAKEVILLE
SOMERSET
SWANSEA
FREETOWN
ROCHESTER
West Wareham
BOURNE
FALL RIVER
ACUSHNET
MARION
SANDWICH
N
Electric Charging Stations
Interstate
U.S. Highway
State Route
0 1 2 4 6 8
Miles
OLD COLONY
PLANNING COUNCIL
Old Colony Planning Council
70 School Street, Brockton, MA 02301
www.ocpcrpa.org
Created June 2021
GIS Data Sources
Department of Transportation (MassDOT), Office of Geographic Information (MassGIS), and ChargeHub

There are a number of government incentives for electric vehicle purchases. These include:
MOR-EV Rebate Program – Under this Massachusetts program, a buyer can receive a $2,500 rebate up to a final purchase price of $50,000 for battery electric vehicles (BEVs) as well as fuel cell electric vehicles (FCEVs). Plug-in Hybrid vehicles also qualify for the program with a final purchase price up to $50,000 for a $1,500 rebate.
Grants for Fleets - This MassDEP open grant program provides incentives to Massachusetts cities, towns, state agencies, and public colleges and universities to acquire electric vehicles and charging stations. Grants help offset the higher initial costs of these advanced technologies.
Grants for Workplace Charging - This MassDEP open grant program provides incentives to employers for the acquisition of Level 1 and Level 2 electric vehicle (EV) charging stations.
General Motors (GM) is going all in when it comes to Electric Vehicles. The company is investing $35 billion for EV purposes and by 2025, GM plans on bringing to market "at least" 30 new EV models. Fast forward a decade from there and the company thinks EVs will account for 100% of sales.
United States Department of Energy Federal Incentive Program – Under this program a buyer can receive up to $7,500 in federal tax credits for buying an Electric Vehicle.
Clean Vehicle Project - This Department of Energy Resources project will replace more than 200 public and private vehicles powered by gasoline and diesel with alternatively fueled vehicles. The alternative fuels and power sources will be natural gas, propane (auto gas), battery, hybrid, and solar electric, as well as hydraulic hybrid. The Clean Vehicle project will also provide funding for the electric vehicle charging and natural gas infrastructure. This project will cover the differential cost for the various clean fuels. The Clean Vehicle Program is funded by the Congestion Mitigation and Air Quality (CMAQ) improvement program sponsored by the U.S Department of Transportation's Federal Highway Administration.

The locations of the Electric Charging Stations in the OCPC region are as follows (by community:

Stoughton:
- 204 Tosca Drive, Stoughton, OHB Corporation
- 630 Washington Street, Stoughton, Sonic Drive-In
- 55 Monk Street, Stoughton
- 105 Porter Street, Stoughton
- 1 Hawes Way, Stoughton
- 1 Ikea Way, Stoughton
- 449 Page Street, Stoughton, Hampton Inn & Suites Boston/Stoughton

Easton
- 8 Island Court, Easton, Water Pointe
- 320 Washington Street, Easton, Stonehill College
- 99 Belmont Street, Easton, 99 Restaurant

Brockton
- 110 Liberty Street, Brockton
- 122 Liberty Street, Brockton, Copeland Volkswagen of Brockton
- 1016 Belmont Street, Brockton, Nissan 24
- 940 Belmont Street, Brockton, Veterans Affairs Boston Healthcare System
- 2-20 Crescent Street, Brockton, Brockton Parking Garage
- 680 Centre Street, Brockton, Signature Healthcare Brockton Hospital Emergency Room

West Bridgewater

- 726 West Center Street, West Bridgewater, National Grid

Bridgewater
- 545 Bedford Street, Bridgewater
- Bridgewater Town Hall, 66 Central Square Bridgewater
- Bridgewater State University Weygand Lot, 85 Burrill Ave, Bridgewater, MA

Hanson
- 1150 Main Street, Hanson
- 542 Liberty Street, Hanson

Hanover
- 1 Saturn Drive, Hanover, Coastal Volkswagen
- 2000 Washington Street, Jannell Ford of Hanover

Pembroke
- 146 Church Street, Pembroke

The Impact of Salt Deicers

Salt applied to roadways for winter maintenance eventually percolates through roadside soils and enters aquifers with precipitation recharge in the early spring. There are varying opinions as to the proportion of road salt runoff that infiltrates groundwater; however, the actual amount of road salt runoff that infiltrates groundwater depends upon features such as permeability, vegetation cover, gradients, and roadside drainage techniques. Studies show that up to 35 percent of road salt spread for winter maintenance can end up in the groundwater. The current knowledge regarding chemistry and physics of salt pollution indicates that groundwater contamination due to road salt for storm application can be problematic.[7] Increased sodium levels in drinking water can represent a health risk to people suffering from high blood pressure. Roadside vegetation is damaged by deicing salts through soil salt concentrations, which allow for salt absorption by roots, and by direct airborne salt spray on needles and branches.[8] Salt, which is sodium chloride, leaves residues of chloride ions on highway surfaces that not only contaminate surrounding ground water resources, but also corrode motor vehicles and bridge structures. Salt along the roadside may also be responsible for attracting deer to the side of the highways thereby contributing to accidents and injuries. The impacts of using salt for deicing include:

- Contamination of drinking water supplies
- Increased maintenance of roadside vegetation and removal of dead trees and shrubs
- Corrosive damage to bridge structures and vehicles

The use of alternative deicers to salt is one of the ways in which agencies can reduce the amount of salt infiltration. There are several alternatives that have been in use including calcium magnesium acetate (CMA), calcium chloride, and magnesium chloride; however, calcium chloride and magnesium chloride, like salt, also leave residues of chloride ions on the road surface, which contaminate ground waters and corrode motor vehicles and bridge structures.[9]

[7] Chemical Deicers and the Environment, Frank M. D'Itri, pages 24 and 25.
[8] Chemical Deicers and the Environment, Frank M. D'Itri, page 59.
[9] Is Highway Runoff a Serious Problem?, FHWA, USDOT Research and Development, Turner Fairbank Highway Research Center.

These different deicing alternatives vary in effectiveness depending upon the temperature. As the temperature drops, salt's effectiveness slows to the point that when it gets near 10 degrees and below, its effectiveness is greatly diminished. Calcium chloride is a hygroscopic material that attracts moisture from its surroundings, speeding the creation of brine to give melting action a fast start, and its lowest effective temperature is -25°F, which is below that of other common deicers. Magnesium chloride has an effective temperature of 0°F. CMA is typically used in blends with rock salt or other lower cost materials. It has a lowest effective temperature roughly equivalent to rock salt.

CMA can be an effective deicing alternative to road salt if handled and used properly. CMA is made from limestone and acetic acid (commonly found in vinegar) and is biodegradable and non-toxic. Studies show it has little or no effect on vegetation and water sources and is low in mammalian toxicity. The same equipment that handles road salt can also be used to apply deicer alternatives. In addition, CMA and calcium chloride can be applied with abrasives (sand and mineral aggregates) for application. A wholesale switch from salt to alternatives deicers can be expensive. CMA costs up to 20 times more per ton than road salt, and calcium chloride can cost up to 6 times more per ton than road salt. The drawback to using calcium chloride as a salt alternative is that it does not address the impact of chloride in the environment, although it does reduce the amount of sodium.

Funding for Improvements

The MassDOT publication, Project Development and Design Guide, explains the project development process in Massachusetts and design standards for transportation projects. MassDOT initiates new projects through a formal 3-step process using the Massachusetts Project Intake Tool (MaPIT). A GeoDOT account to log into MaPIT is needed to initiate new projects. The implementation of projects includes taking transportation improvements from the concept stage through to design and construction. Funding is an essential element in ensuring the implementation of recommended improvements.

- Step one – The proponent identifies the project need.
- Step two – Using MaPIT, project proponent works with a MassDOT District Office (District 5) or other MassDOT Section to define project scope, costs, timeline, impacts and responsibilities.
- Step Three – The District Office or other MassDOT Section submits project to the Project Review Committee for approval.

The MassDOT project development process includes the following:

- Problem/Need/Opportunity Identification
- Planning (A project planning report is completed)
- Project Initiation
  ✓ Identification of Appropriate Funding
  ✓ Definition of Appropriate Next Steps
  ✓ Project Review Committee Action
- Environmental Design and Right of Way (ROW) Process (Includes Plans, Specifications, and Estimates, P, S, & E)
  ✓ Environmental Studies and Permits
  ✓ Right-of-Way Plans
  ✓ Permits

- Programming (Old Colony TIP and State Transportation Improvement Program, STIP)
  ✓ Programming of Funds
- Procurement (Construction bids and contractor selection)
- Construction
- Project Assessment

On sections of roadway owned and maintained by the municipality, the community typically initiates a project (utilizing MaPIT) and provides for project planning and design. Similarly, for state owned facilities, the MassDOT initiates projects and provides planning and design on its section of roads.
A number of funding options are available for project construction as are outlined further. Note that some funding programs, such as the Congestion Mitigation and Air Quality (CMAQ) Program, are for specific types of projects that meet specific criteria, while other programs such as Chapter 90 can be utilized on a much broader range of projects. Federal aid eligible regional transportation needs have outpaced available funding in the Transportation Improvement Program (TIP) for the past several years. All projects on the TIP go through a comprehensive evaluation process to determine priority for funding; therefore, the programming of the TIP is a competitive process. In general, the process to fund a project through the TIP may take up to five years. Due to this limitation of TIP funding, communities are encouraged to seek alternate funding avenues for their high priority projects. Examples of such options include using Chapter 90 funds, developer mitigation, or public/private partnerships with local stakeholders. Funding Programs.

- Capital Improvement Program (CIP) and Local Funding: This program has historically been utilized to help provide the design and engineering of highway projects.
- Exactions (Developer Mitigation Agreements): Communities have increasingly turned to exactions as a means to meet new infrastructure and public service needs. Cities and towns use developer exactions as a strategy to offset the burdens of new development on the community. Exactions contribute to regional equity by ensuring that a new development pays a fair share of the public costs that they generate. Exactions consist of a developer's payment of funds to offset the cost of necessary construction, design, or maintenance of public infrastructure directly connected to the new development. Developers commit to an agreement for funding or constructing off-site improvements in exchange for the approvals to proceed with a development project.
- Bridge Replacement and Rehabilitation Program: This program provides funds for rehabilitation and replacement of any bridge on a public road. Bridges on the federal aid system or off the federal aid system are eligible for these funds.
- Chapter 90: This program provides State funding for highway construction, preservation, and improvement projects that create or extend the life of capital facilities. The level of funding is determined by a formula that is based upon public way mileage, population and level of employment in each community. The Chapter 90 Program is a reimbursement program, as the community must initially pay the cost of a particular project.
- Community Development Block Grant (CDBG) Program: This program provides for the development or expansion of economic opportunities and the provision of decent housing and public facilities. Eligible use of funds includes community development (construction or reconstruction of streets, water and sewer facilities, neighborhood centers, recreation facilities, and other public works).

- Congestion Mitigation and Air Quality Improvement Program (CMAQ): This directs funds toward transportation projects in Clean Air Act non-attainment areas for ozone and carbon monoxide. OCPC is located in the Boston non-attainment area for ozone.
- Highway Safety Improvement Program (HSIP): This program is a core Federal-aid program with the objective of achieving a significant reduction in traffic fatalities and injuries.
- National Highway Performance Program (NHPP): This program provides support for the condition and performance of the National Highway System, (NHS), for the construction of new facilities on the NHS, and to ensure that investments of federal-aid funds in highway construction are directed to support progress toward the achievement of performance targets established in the State's asset management plan.
- Non-Federal Aid (NFA): This program provides state funds for projects that due to federal fiscal constraints would not be able to receive federal funding. Projects under this category are listed for informational purposes only.
- Surface Transportation Block Grant Program (STBG): This is a block grant type program that may be used for any roads (including NHS) that are not functionally classified as local or rural minor collectors. These roads are collectively referred to as federal-aid eligible roads.
- Transportation Alternative Program (TAP): The TAP program provides Federal-aid funding for programs and projects defined as transportation alternatives, including on and off-road pedestrian and bicycle facilities, infrastructure projects for improving non-driver access to public transportation and enhanced mobility, community improvement activities, and environmental mitigation; recreational trail program projects; safe routes to school projects; and projects for planning, designing, or constructing boulevards and other roadways largely in the right-of-way of former Interstate System routes or other divided highways.
- Transportation Bond Bill (TBB): This authorizes and directs the MassDOT to expend monies for transportation projects such as reconstruction, resurfacing, rehabilitation or improvements of highways, bridges, and parking facilities. From this, the State will issue either general obligation or special obligation bonds.
- Federal appropriations: These allocate federal funding for federal aid eligible projects.
- Massachusetts Complete Streets Program: This program provides $12.5 million dollars for two years beginning in 2016 to municipalities to implement Complete Streets projects. Municipalities must adopt Complete Streets policies, develop a priority plan, and send staff for training for eligibility.
- MassWorks Infrastructure Program: In September of 2010, the MassWorks Infrastructure Program was instituted to provide a one-stop shop for municipalities and other eligible public entities seeking public infrastructure funding to support economic development and job creation in Massachusetts. The Program is an administrative consolidation of six former grant programs:

  Public Works Economic Development Grant (PWED)
  Community Development Action Grant (CDAG)
  Growth Districts Initiative (GDI) Grant Program
  Massachusetts Opportunity Relocation and Expansion Program (MORE)
  Small Town Rural Assistance Program (STRAP)
  Transit Oriented Development (TOD) Program

The MassWorks Infrastructure Program is administered by the Executive Office of Housing and Economic Development, in cooperation with the Department of Transportation and Executive Office for Administration & Finance.

Coastal Resilience Grants - The Coastal Resilience Grant Program provides funding and technical assistance to reduce risks associated with coastal storms, flooding, erosion, and sea level rise through innovative and transferable local projects. Coastal communities are eligible to apply for funding to assess vulnerabilities and risks, and redesign and retrofit vulnerable, municipally owned facilities and infrastructure. Additionally, both coastal communities and eligible nonprofit organizations may seek funding for public education and communication efforts to conduct proactive planning to address sea level rise impacts and implement non-structural (or green infrastructure) approaches that enhance natural shoreline resilience and provide coastal storm damage protection. These grants are offered by the Massachusetts Office of Coastal Zone Management (CZM).

Appendix

FEMA FLOOD ZONES

Zone A

The flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the Flood Insurance Study by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no Base Flood Elevations or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zones AE and A1-A30

The flood insurance rate zones that correspond to the 100-year floodplains that are determined in the Flood Insurance Study by detailed methods. In most instances, Base Flood Elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zone AH

The flood insurance rate zone that corresponds to the areas of 100-year shallow flooding with a constant water-surface elevation (usually areas of ponding) where average depths are between 1 and 3 feet. The BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zone AO

The flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. The depth should be averaged along the cross section and then along the direction of flow to determine the extent of the zone. Average flood depths derived from the detailed hydraulic analyses are shown within this zone. In addition, alluvial fan flood hazards are shown as Zone AO on the FIRM. Mandatory flood insurance purchase requirements apply.

Zone AR

The flood insurance rate zone used to depict areas protected from flood hazards by flood control structures, such as a levee, that are being restored. FEMA will consider using the Zone AR designation for a community if the flood protection system has been deemed restorable by a Federal agency in consultation with a local project sponsor; a minimum level of flood protection is still provided to the community by the system; and restoration of the flood protection system is scheduled to begin within a designated time period and in accordance with a progress plan negotiated between the community and FEMA. Mandatory purchase requirements for flood insurance will apply in Zone AR, but the rate will not exceed the rate for unnumbered A zones if the structure is built in compliance with Zone AR floodplain management regulations.

For floodplain management in Zone AR areas, elevation is not required for improvements to existing structures. However, for new construction, the structure must be elevated (or flood proofed for non-residential structures) such that the lowest floor, including basement, is a maximum of 3 feet above the highest adjacent existing grade if the depth of the base flood elevation (BFE) does not exceed 5 feet at the proposed development site. For infill sites, rehabilitation of existing structures, or redevelopment of previously developed areas, there is a 3-foot elevation requirement regardless of the depth of the BFE at the project site.

The Zone AR designation will be removed, and the restored flood control system shown as providing protection from the 1% annual chance flood on the NFIP map upon completion of the restoration project and submittal of all the necessary data to FEMA.

Zone A99

The flood insurance rate zone that corresponds to areas of the 100-year floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No BFEs or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone D

The designation on NFIP maps is used for areas where there are possible but undetermined flood hazards. In areas designated as Zone D, no analysis of flood hazards has been conducted. Mandatory flood insurance purchase requirements do not apply, but coverage is available. The flood insurance rates for properties in Zone D are commensurate with the uncertainty of the flood risk.

Zone V

The flood insurance rate zone that corresponds to the 100-year coastal flood plains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no BFEs are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone VE

The flood insurance rate zone that corresponds to the 100-year coastal flood plains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

Zones B, C, and X

The flood insurance rate zones that correspond to areas outside the 100-year floodplains, areas of 100-year sheet flow flooding where average depths are less than 1 foot, areas of 100-year stream flooding where the contributing drainage area is less than 1 square mile, or areas protected from the 100-year flood by levees. No BFEs or depths are shown within this zone.