TOWN OF PEMBROKE, MA

DRAFT

MUNICIPAL VULNERABILITY & HAZARD MITIGATION PLAN

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COMMITMENT & INTEGRITY DRIVE RESULTS

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EXECUTIVE SUMMARY

The Town of Pembroke, Plymouth County, is a 23.55-square mile, predominantly residential suburb 26 miles south of Boston in the south shore area of Massachusetts. It is home to approximately 18,000 residents and is part of the Old Colony Planning region lake communities area, notable for its numerous lakes, ponds, and major streams The Town is bordered by eight neighbor communities – the towns of Hanover, Norwell, Duxbury, Marshfield, Halifax, Kingston, Plympton, and Hanson.

As a result of climate change, the Town of Pembroke is experiencing increasingly intense storms and related hazard events, including extreme temperatures. As the first step toward managing community risk and reducing the costs associated with hazard-related damages, the Town has developed this Municipal Vulnerability & Hazard Mitigation Plan (MVHMP) to address both natural hazards and vulnerabilities associated with climate change. The MVHMP updates the Pembroke aspects of the 2015 Old Colony Regional Hazard Mitigation Plan (OCPC RHMP) and has been prepared in accordance with the requirements of the Massachusetts Municipal Vulnerability Program and the Federal Disaster Mitigation Act of 2000 (DMA 2000).

Planning Process

Planning for the Pembroke MVHMP was led by the MVHMP Steering Committee composed of staff from various Town departments involved with hazard mitigation and emergency response. The Steering Committee convened on multiple occasions beginning in early 2020 and continuing through the end of 2021 to plan and prepare natural hazard and climate change maps specific to Pembroke and to conduct its seminal public engagement component, the day-long Community Resilience Building Workshop which was held on October 6, 2021. One-hundred stakeholders, including the eight neighbor communities, were invited to participate in the Workshop ollowing which the Committee summarized the findings and presented them at the first of two Public Listening sessions, on October 18, 2021. Using the information developed during the Workshop and incorporating public comment on the findings, the Town prepared the Draft MVMP which was circulated for public comment on _____. On _____ the Town held the second Public Listening Session to hear comments and respond to community questions. All stakeholders were notified of the Public Listening Sessions by email and public notices for all public events were published in the local paper and provided on the Town website.

Hazard Characterization and Risk Assessment

The Pembroke MVHMP assesses the potential for the Town to sustain impacts from natural hazards common to the northeast region as well as those attributable to climate change. These include flood hazards/extreme precipitation, wind-related hazard events, winter storms, geologic hazards, wildfire hazards, extreme temperatures, and drought. Each of these hazards were assessed for frequency, magnitude/severity, and geographic extent in relation to the Town of Pembroke and following the Massachusetts State Hazard and Climate Action Plan template. Maps for each hazard type were developed for the Town and are presented in **Appendix A**; each layer includes the 93 critical infrastructure elements identified by the Town as essential to community function in both normal and emergency situations.

Hazard Mitigation Goals

The Town of Pembroke identified 9 goals for the MVHMP as follows:

1. Prevent or minimize loss of life, injury, public health impacts, and damage to property, the economy, and the environment from natural hazards and climate change.
2. Prevent or minimize damage to public and private infrastructure, buildings, and utilities from natural hazards and climate change.

3. Seek to use nature-based solutions as hazard mitigation whenever possible to reduce and minimize damage while accomplishing the accessory goals of environmental restoration and resource protection.
4. Ensure that future development within the Town meets federal, state, and local standards for climate resiliency and natural hazard mitigation.
5. Incorporate climate change resiliency and hazard mitigation policies, guidance, and requirements into relevant Town plans and policies.
6. Identify and seek funding to implement priority hazard mitigation projects identified in the MVHMP.
7. Collaborate with surrounding communities and state, regional, and federal agencies to ensure broad cooperation to maximize mitigation cost and effectiveness across multiple communities.
8. Promote awareness of hazard mitigation, priority project implementation, and MVHMP maintenance among municipal departments, committees, boards, and the public at large, with emphasis on vulnerable and isolated populations.
9. Maximize community participation in the development, implementation, and update of the MVHMP. Invite the business community, public institutions, educational sector, and non-profits, particularly those that work with sensitive or vulnerable populations, to review, implement, and contribute to development and maintenance of the Plan.

Hazard Mitigation Strategy

The MVHMP Steering Committee, working with community members and other stakeholders through the Community Resilience Building process, identified the top five hazards facing the Town, community strengths and vulnerabilities, and agreed on 18 priority mitigation actions to address the most pressing vulnerabilities likely to be affected by these hazards.

The Town of Pembroke MVHMP has been developed with a 5-year planning horizon and will be periodically updated as local conditions change and in response to public input.

1. INTRODUCTION

1.1 Background

Like communities across the country, the Town of Pembroke is facing increased occurrences of storms associated with natural hazards and climate change. Hazard mitigation is the first step toward managing risk and is the most effective way to reduce costs associated with hazard-related damages. Working with the State of Massachusetts, regional agencies, its neighboring communities, and resident stakeholders, the Town of Pembroke has developed this Municipal Vulnerability & Hazard Mitigation Plan (MVHMP or "the Plan") to address both natural hazards and municipal vulnerabilities associated with climate change. The Pembroke MVHMP updates the Pembroke aspects of the 2015 Old Colony Regional Hazard Mitigation Plan (OCPC RHMP) and includes Town and regional analyses and assessment of natural and climate hazards, risk, and capabilities. The plan has been prepared in accordance with the requirements of the federal Disaster Mitigation Act of 2000 (DMA 2000).

1.2 Federal Disaster Assistance and Mitigation Planning

The Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988 enabled funding for States, tribes, and local governments to undertake long-term mitigation efforts following a disaster declaration. In 2000, Congress passed the Federal Disaster Mitigation Act (DMA 2000) "to reduce the loss of life and property, human suffering, economic disruption, and disaster assistance costs resulting from natural disasters." DMA 2000 amended the Stafford Act by replacing its mitigation planning provisions with new requirements emphasizing the need for intergovernmental coordination in preparing mitigation plans and implementation projects. In addition to continuing to require State Mitigation Plans as a condition for disaster assistance funding, it extended the requirement to the local level, making preparation and approval of a Local Mitigation Plan a condition for municipal disaster awards.

Federal hazard mitigation planning and implementation grant programs are administered by the Federal Emergency Management Agency (FEMA) in collaboration with State emergency management agencies. In Massachusetts, these programs are administered by the Massachusetts Emergency Management Agency (MEMA) with the Massachusetts Department of Conservation and Recreation (DCR).

The Federal Emergency Management Agency (FEMA) has issued guidelines for the development of hazard mitigation plans and the Massachusetts Emergency Management Agency (MEMA) also supports plan development for jurisdictions in the State.

1.3 The Massachusetts Municipal Vulnerability Preparedness (MVP) Program

The Municipal Vulnerability Preparedness grant program (MVP) is administered by the Massachusetts Executive Office of Energy and Environmental Affairs and supports municipal planning and project implementation to improve climate change resiliency. The program offers two types of grants - Planning and Action (implementation) - through which local governments receive funding to complete community-based vulnerability assessments and develop action-oriented resilience plans. A municipality that successfully completes the planning portion of the MVP program is designated an MVP Community and becomes eligible to compete for MVP Action Grant funds to implement priority projects identified in its MVP Resilience Plan. At present, of 351 local governments in Massachusetts, 250 have received MVP designation and an additional 38, including the Town of Pembroke, are in the process of completing MVP Plans.

1.4 Purpose of the Municipal Vulnerability-Hazard Mitigation Plan (MVHMP)

Natural disasters and the effects of climate change can cause loss of life, damage property and public infrastructure, and adversely impact the economic, social, and environmental well-being of communities. Hazard mitigation involves

taking action to reduce or eliminate the long-term risk to human life, property, and resources posed by geologic hazards, increasingly severe weather events, and extreme temperatures and precipitation caused by climate change. Mitigation actions may involve physical approaches such as removing structures from flood-prone areas, elevating critical infrastructure, and improving culverts and stormwater systems to manage extreme flows; outreach and planning efforts such as public education to improve risk awareness; and adoption of plans and codes to improve land use decision-making.

Hazard mitigation planning is an iterative process to assess community hazards, vulnerabilities, and risks, and develop long-term policies, tools, and actions to mitigate those risks. Such advance planning can reduce human and financial consequences associated with natural and climate hazards, and ensure the health, safety, and welfare of the population.

In January 2020, the Town of Pembroke was awarded a Massachusetts MVP Planning Grant to conduct a Community Resilience Building Workshop and develop Summary Findings toward State designation as an MVP Community. As part of the process, and recognizing the similar planning purpose and requirements, Pembroke chose to also prepare a FEMA-compliant Local Hazard Mitigation Plan to refine and update its portion of the expiring May 2015 Old Colony Regional Planning Council *Natural Hazard Mitigation Plan for the Old Colony Region* (2015 OCPC HMP).

Pembroke's combined *Municipal Vulnerability and Hazard Mitigation Plan* is intended to achieve the following:

- identify significant natural hazards affecting the Town, including climate change effects,
- identify community strengths and weaknesses to respond to these hazards,
- assess infrastructure, societal, and environmental risks associated with these hazards,
- identify and prioritize hazard mitigation projects,
- incorporate climate resilience and vulnerability preparedness goals and actions, and
- outline a schedule to update the plan to incorporate new information every 5 years.

This Plan was prepared in accordance with the following regulations and guidance:

- MA EOEEA Municipal Vulnerability Planning Program requirements
- FEMA *Local Mitigation Planning Handbook*, March 2013
- Local Mitigation Plan Review Tool, in *Local Mitigation Planning Handbook*, March 2013 (Appendix B)
- FEMA *Integrating Hazard Mitigation into Local Planning*, March 2013
- DMA 2000 (Public Law 106-390, October 30, 2000)
- 44 CFR Part 201.6 (Mitigation Planning, Local Mitigation Plans).

The Planning Process is more fully discussed in Section 3.0 and the Planning Area consists of the Town of Pembroke **(Figure 1)**.

Figure 1. Town of Pembroke, MA Municipal Vulnerability and Hazard Mitigation Planning Area

2. COMMUNITY PROFILE

Community characteristics – transportation and land use patterns, population, natural resources, and growth and development trends - are important factors in assessing community vulnerability to hazards and climate change. The location and characteristics of transportation corridors determines their reliability during severe weather events. Population size, distribution, and other descriptors identify those most vulnerable to adverse effects associated with extreme climate and hazard events and affect the magnitude of potential impact. Population growth can drive demand for increased housing and associated service infrastructure which, if not properly planned, can exacerbate risk by adding impervious surface and increasing flooding, creating excessive demand on local resources, and increasing the numbers of residential and critical structures in high-risk areas. At the same time, population factors – age, income, and social considerations – affect the ability of residents to respond and adapt to emergency conditions created by climate and hazard stressors.

Settled in 1712, the Town of Pembroke, Plymouth County, is a 23.55-square mile, predominantly residential suburb 26 miles south of Boston in the South Shore area of southeastern Massachusetts. It is part of the Lake Communities area of the Old Colony Planning region, characterized by large areas of hydric soils and porous sand and gravel that underly numerous lakes, ponds and major streams.[1] The Town is bordered by eight neighbor communities: Hanover and Norwell to the north, Duxbury and Marshfield to the east, Halifax, Kingston, and Plympton to the south, and Hanson to the west. Pembroke is located off Route 3, a major highway that connects to Boston via I-93 to the north, to Route 128/I-95 and the suburbs west of Boston, and to Plymouth and Cape Cod to the south. Other regional highways include routes 14, 53, 27, 139, and 44 that connect to adjacent communities and Boston, Quincy, Brockton, Plymouth, and Taunton and Providence, Rhode Island. The Town also has access to MBTA Commuter Rail service in nearby Hanson, Halifax, and Kingston, and the MBTA Red Line in Braintree and Quincy.

Pembroke has an Open Meeting form of Town government with a five-member Board of Selectmen and a Town Manager; many of the Town operations are directed by elected and appointed boards and commissions. The Town maintains a website at http://www.pembroke-ma.gov/.

2.1 Demographics

The US Census American Community Survey (ACS) estimated Pembroke's 2018 population to be 18,304,[2] a 3.6% increase over the 2010 Census, with residents distributed over 6,489 households averaging 2.8 persons per each; population density approximated 777 per square mile. By comparison, the population of Plymouth County increased by 4.7% from 2010. The 2018 *Comprehensive Economic Development Strategy (CEDS) for the Old Colony Economic Development District* projects a 2020 Town population of 18,345, increasing to 18,733 by 2030, and dropping slightly to 18,622 by 2040.[3] By comparison, the Mass DOT Socio-Economic Projections for 2020 Regional Transportation Plans project slightly more growth, with Pembroke's population at 18,300 in 2020; 18,695 by 2030; and 18,931 by

[1] Old Colony Planning Council, *Natural Hazard Mitigation Plan for the Old Colony Region*, May 2015, 606 pp.
[2] US Census Bureau 2018 ACS 5-Year Estimates. https://data.census.gov/cedsci/all?q=Pembroke%20town,%20Plymouth%20County,%20Massachusetts&hidePreview=false&tid=ACSDP5Y2018.DP05The Town census recorded a population of 19,352 in 2016 and 18,897 in 2017.
[3] 2018 Comprehensive Economic Development Strategy for the Old Colony Economic Development District, Old Colony Planning Council, p.9. http://ocpcrpa.org/docs/econdev/CEDS_Report_2018.pdf

2040[4]. None of the cited projections anticipates significant population growth in the Town over the next 20 years **(Table 2-1)**.

Table 2-1. Population Projections for the Town of Pembroke

Projection	Year 2020	Year 2030 (% Change from prior decade)	Year 2040 (% Change from prior decade)	Overall Projected Growth
US Census 2018 ACS Population 18,304*	-	-	-	-
2018 OCPC CEDS	18,345	18,733 (+2.1%)	18,622 (-0.6%)	1.5%
Mass DOT 2020 RTP Projections	18,300	18,695 (+2.2%)	18,931 (+1.3%)	3.4%

(*2020 US Census pending)

Approximately 15% of Town residents are 65 years and older, a cohort expected to increase by 2,210 by the year 2030 (**Figure 2-1**).[5] Of Town residents younger than 65, 7.8% are disabled. Children under the age of 5 account for 4.2% of Town residents. Town-wide, 1.3% of residents identified as Hispanic or Latino, 1.5% as Asian, and 0.5% as Black or African American. According to the MA EOEEA, there are no Environmental Justice populations in Pembroke;[6] nevertheless, as part of its municipal vulnerability and hazard mitigation planning process, the Town took steps to reach households where languages other than English are spoken and to engage residents over 65.

The Town Comprehensive Emergency Management Plan (CEMP) calculates approximately 7.3% of the population present with a disability affecting at least one of the following areas: sensory, cognitive, ambulatory, self-care, or independent living. Other groups with function-based needs that may not be captured in demographic data may include the morbidly obese, pregnant women, people who require prescription medication for daily well-being, and people who lack personal transportation. Approximately 3.6% of the Town population speak a language other than English at home; non-native languages spoken in the Town include Portuguese.[7]

Pembroke's 2018 median household income (MHI) was $103,920 and per capita income (in 2018 dollars) was $43,339;[8] by comparison, the MHI for Plymouth County was $85,654 and the per capita income $41,343. Approximately 3% of Town residents fell below the poverty threshold, roughly half of the 6.2% for Plymouth County as a whole **(Table 2-2)**.

[4] Massachusetts Department of Transportation, Socio-Economic Projections for 2020 Regional Transportation Plans. https://www.mass.gov/lists/socio-economic-projections-for-2020-regional-transportation-plans

[5] Old Colony Planning Council 2018 Housing Production Plan, Pembroke MA, page 20 of 118. http://www.ocpcrpa.org/docs/projects/DLTA/Pembroke_Housing_Production_Plan.pdf

[6] Massachusetts EOEEA Environmental Justice Policy defines Environmental Justice populations as neighborhoods (census block group) where 25% of the households have an annual median household income ≤ 65% of the statewide median or 25% of the population is Minority or identifies as a household with English Isolation. Minority means individuals who identify as Latino/Hispanic, Black/African American, Asian, Indigenous, and otherwise non-white.

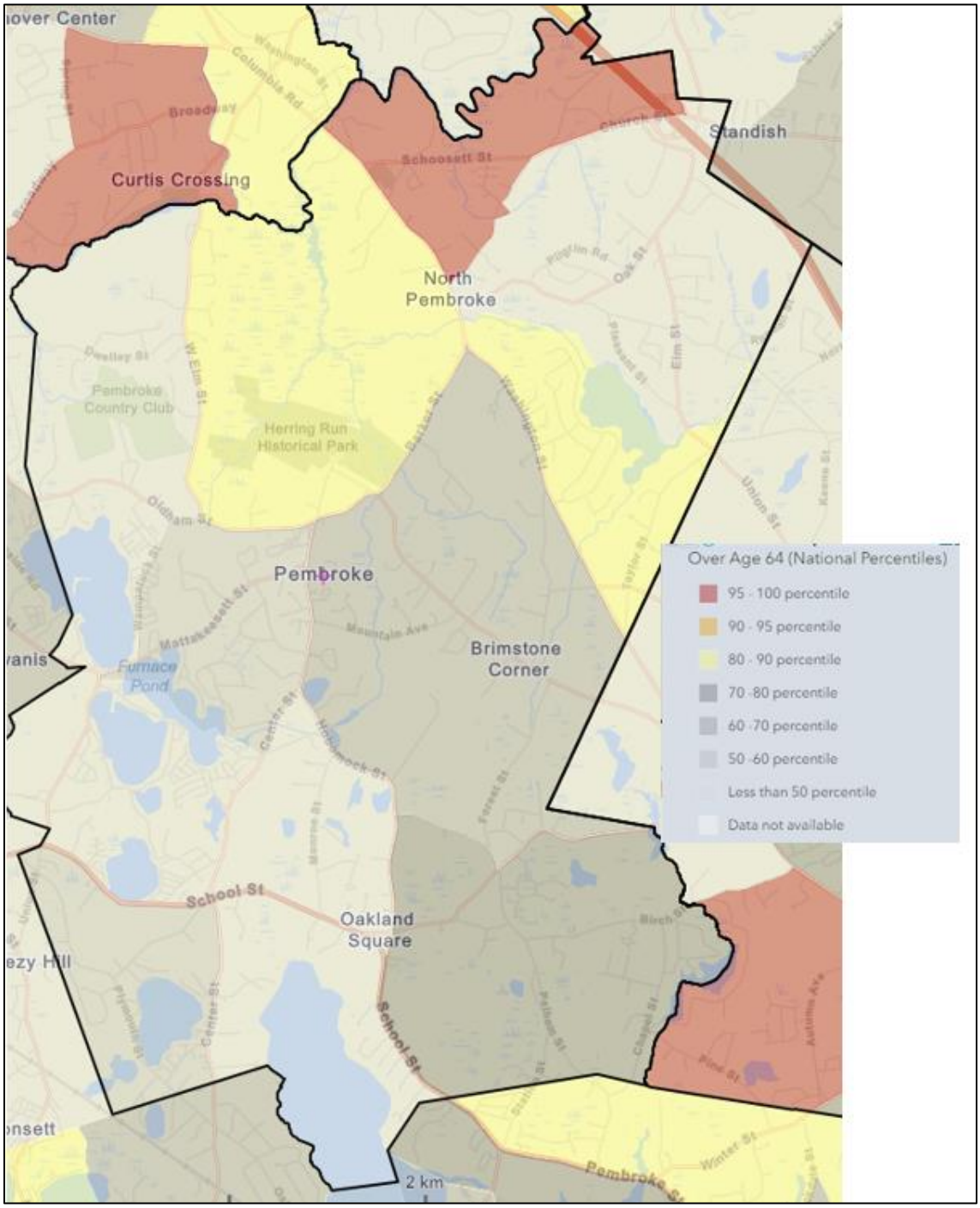
[7] Town of Pembroke, Draft Comprehensive Emergency Management Plan, p. 10.

[8] US Census Bureau 2018 ACS 5-Year Estimates.

Table 2-2. Town of Pembroke Income Characteristics

2018 Characteristic	Pembroke	Plymouth County
Median Household Income	$103,920	$85,654
Per Capita Income	$43,339	$41,434
% Below Poverty	3%	6.2%

Figure 2-1. Pembroke Over-64 Population Distribution

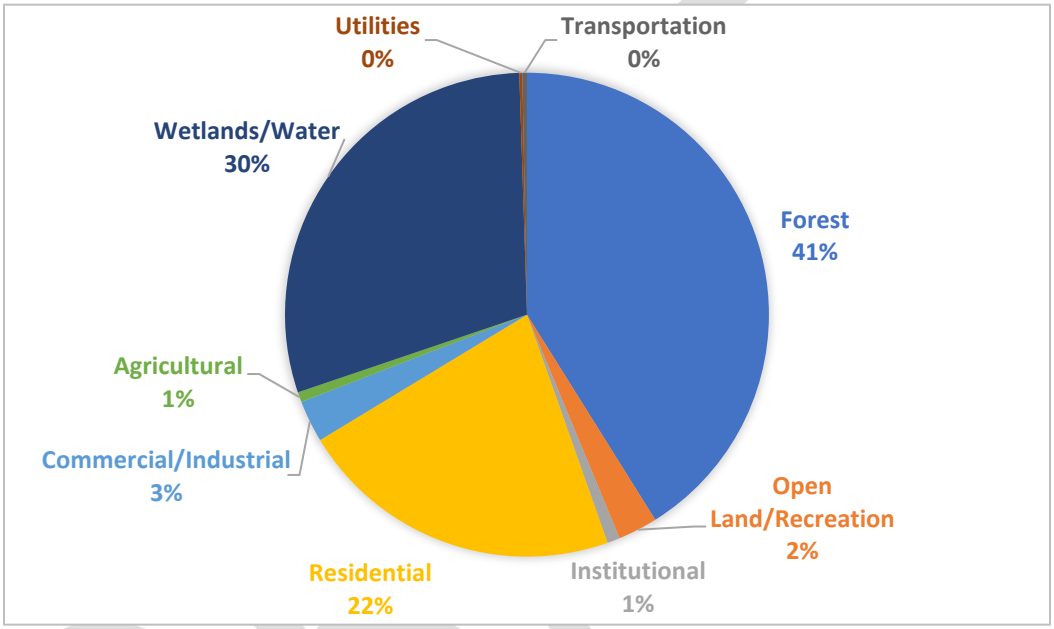


Source: USEPA EJ Screen (Data is 2013-17 5-Year ACS).

2.2 Land Use & Development Trends

Land use in Pembroke is dominated by residential development and a wealth of natural areas (Figure 2-2). The percentage of land that is forested, in commercial/industrial use, or developed for residential use is comparable to the Old Colony Planning region as a whole (45%, 3%, and 21%, respectively), while the area comprising wetlands and open water is nearly twice the regional average.[9] The Town's considerable water resources support its drinking water and recreational needs, buffer portions of the community from excessive rainfall and storm surge events, and, due to their protected status, provide a check on overdevelopment.

Figure 2-2. Pembroke Land Use



Through the 1800's, Pembroke was largely agricultural and industrial, becoming a center for vacation and recreation by the turn of the twentieth century. The Town's abundant water resources and proximity to Boston drove early development of the areas around lakes and ponds for seasonal homes, and many have since been converted to year-round residences. Today, the Town shorelines continue to be some of its most densely developed areas, dominated by residential land use that increased 3.14% (approximately 545 acres) from 1971 to 2005. Over the same time period, natural lands declined by roughly 440 acres, or 2.94%.[10] This local trend parallels that of the South Shore area over the last forty years, which has seen rapid development spurred by transportation and road improvements that allow commuters to live farther away from their places of employment. Approximately 92% of Pembroke's residents commute an average of 34 minutes to work locations outside of Town.[11]

[9] Ibid.
[10] The Old Colony Planning Council, *Conserving the Irreplaceable: Open Space and Recreation Plan, Pembroke MA, 2019*, pp. 28-29.
[11] US Census 2018 ACS 5-Year Estimates.

The MassGIS 2005 Land Use digital ortho data layer[12] is the most recent statistical set available for comparative purposes; because it assigns different categories of use, the 2016 Land Use data does not allow temporal comparisons.

Table 2-3. Pembroke Land Use 2005

Land Use	Acres	% of Total Town Area
Brushland/Successional	44.98	0.30
Cemetery	16.89	0.11
Commercial	309.61	2.05
Cranberry Bog	458.91	3.06
Cropland	21.37	0.14
Forest	6175.53	41.11
Forested Wetland	2007.29	13.36
Golf Course	87.76	0.58
High Density Residential	32.36	0.22
Industrial	95.47	0.64
Junkyard	0.87	0.01
Low Density Residential	2113.71	14.07
Medium Density Residential	823.47	5.48
Mining	10.80	0.07
Multi-Family Residential	99.76	0.66
Non-Forested Wetland	818.52	5.45
Nursery	22.45	0.15
Open Land	151.76	1.01
Participation Recreation	83.20	0.55
Pasture	57.55	0.38
Powerline/Utility	21.31	0.14
Transitional	30.09	0.20
Transportation	46.73	0.31
Urban Public/Institutional	109.44	0.73
Very Low Density Residential	196.65	1.31
Waste Disposal	9.46	0.06
Water	1177.58	7.84

[12] MassGIS http://maps.massgis.state.ma.us/map_ol/oliver.php?lyrs=Detailed%20Features~Basemaps_MassGISBasemapWithLabels2~%7CTax%20Parcels%20for%20Query~massgis:GISDATA.L3_TAXPAR_POLY_ASSESS~Blank_Polys_Max_18057&bbox=-71.31054721014736,42.29977971818713,-70.92190585272558,42.49576396926824&coordUnit=m&measureUnit=m&base=MassGIS%20Statewide%20Basemap&center=-7916622.1246186,5220762.7631612&zoom=12&opacity=1,1&baseO=1&filt=undefined%7Cundefined

Total	**15023.53**	**100.00**

(Source: MassGIS/, McConnell Land Use)

According to the 2005 data, commercial establishments in Pembroke are concentrated within the historic center district along Route 14 and in the northeast portions of town, along routes 3 and 53. These areas make up about 2.05% of the total area of the Town and also support most of the community's industrial development. Table 2-3 summarizes land use by acreage for Pembroke.

2.2.1 Development Since the 2015 Regional Hazard Mitigation Plan

Significant developments proposed or completed in Pembroke since issuance of the 2015 Old Colony Planning Council Regional HMP were evaluated with Town Planning Staff and are summarized in Table 2-4. Collectively, these developments represent a total of 229 housing units and 168,434 square feet of commercial space; individual homes built since 2015 are not included in this data. With the exception of River Marsh Village, none of the developments is located within the FEMA flood hazard area. River Marsh Village is pending and the final site plan will determine flood vulnerability, if any. All of the developments present a Non-burnable, very low, or low wildfire risk.

Table 2-4. Significant Pembroke Development Projects Approved or Pending Since 2014

Project	Status	Project Type	# Housing Units	Commercial SF Current / As-Built	Year Proposed
43 Mattakeesett Street	Proposed	Commercial (boat storage)		10,300 / Not Available	2020
50 Mattakeesett Street	Approved	Commercial (storage)		4,968 / Not Available	2020
Old Cart Path Lane Extension (70 Old Cart Path Lane)	Approved	Single-Family Subdivision	3		2020
Camp Pembroke (306 Oldham Street)	Approved	Institutional (overnight camp)			2019
Herring Brook Solar Project (~ 132 Hobomock Street)	Approved	Solar Power Array		Solar Array	2019
171 Mattakeesett Street	Approved	Light Industrial		Not Available	2019
345 Oak Street	Approved	Commercial (office)		Not Available	2019
Urgent Care Facility (296 Old Oak Street)	Complete	Medical		25,360	2018
Lisa's Lane (79 Taylor Street)	Under Construction	Single-Family Subdivision	5		2018
Brigham & Women's Medical Building (15 Corporate Park Drive)	Complete	Medical		30,000 GSF	2018
Irving Oil Gas Station (92 Washington Street)	Complete	Commercial (gas station)		1755	2018
Dominic's Way (56 Gorham Avenue)	Approved	Single-Family Subdivision	2		2018

Project	Status	Project Type	# Housing Units	Commercial SF Current / As-Built	Year Proposed
Magical Years Preschool (212 Schoosett Street)	Under Construction	Educational (child care)		5950	2018
204 Center Street (Pembroke Village)	Approved/ Litigation	Mixed-Use (mostly multifamily)	6		2018
260-280 Oak Street	Complete	Light Industrial		Not Available	2017
River Marsh Village (40b) (~274 Water Street)	Proposed	Multifamily (40b)	57		2017
Bristol Estates (73 Taylor Street)	Under Construction	Single-Family Subdivision	7		2017
56 Pembroke Woods Drive (Warehouse Expansion)	Complete	Light Industrial		55,750	2016
220 Center Street	Complete	Mixed-Use (multifamily)	14	3000	2016
Hobomock Solar Project (~158 Hobomock Street)	Complete	Solar Power Array		Solar Array	2016
Bridges at Pembroke (49 Cross Street)	Complete	Medical (assisted living)	48		2016
Brisan Way Extension (~ 25 Old Washington Street)	Under Construction	Single-Family Subdivision	12		2016
Shell Gas Station (223 Church Street)	Complete	Commercial (gas station)		3600	2015
Copperwood Circle (40b) (Copperwood and Ironwood Rds.)	Under Construction	Single-Family Subdivision (40b)	36		2015
590 Washington Street	Complete	Multifamily	9		2015
South Paws Doggie Day Care (275 Oak Street.)	Complete	Commercial (kennel)		9625	2014
593-595 Washington Street	Complete	Multifamily	12		2014
Panera & Taco Bell (156-166 Church Street)	Complete	Commercial (restaurants)		6354 and 11772	2014
599 Washington Street	Complete	Multifamily	18		2014
TOTAL			**229**	**168,434**	

Source: M. Heins, Pembroke Planning Board Staff.

2.2.2 Potential Significant New Development

Currently, the only foreseeable significant potential development in the Town involves the Pembroke Country Club on West Elm Street, a 164.5-acre parcel in the northwest corner of the Town that may be developed for multifamily

residences while retaining the golf course onsite. Since the property is already developed, the potential modification would represent an intensification of use.[13] None of the parcel (B11-33) lies within a FEMA Flood Zone.

All new development in Pembroke is regulated pursuant to the Town Zoning By-laws (revised May 2019) which contain Floodplain and Watershed Protection overlay districts as well as a Water Resource and Groundwater Protection District. Further, the General Town By-laws (updated May 2019) are enforced by the Town Planning Board with input from other Boards as required, and the Wetlands Protection By-law is enforced by the Conservation Commission. Importantly, the Fire Department participates in the review of all new development in the Town. This suite of regulations provides significant assurance that development can occur with no increase in hazard risk or significant impact on community resources.

2.2.3 Long-term Development Trends

Pembroke is a moderately sized, primarily residential community. According to the US Census Bureau NAICS Summary Statistics, in 2017 the Town supported 402 firms with 409 establishments; the bulk of these involved wholesale and retail trade (33 and 92, respectively), information (3), finance and insurance (15), real estate (15), professional services (44) , health care (44), arts and entertainment (11), and accommodation/food service (42). Only 6 establishments were identified as transportation and warehousing. The retail trade sector employed 1,243 in 2017, followed by healthcare/social assistance (1121), accommodation/food service (821), and professional services (519). The retail sector accounted for the highest revenue ($326,436), followed by the wholesale sector ($177,557). Professional services accounted for $90,029 in revenues, healthcare $88,629, and accommodation/food service $47,273. The Town does not anticipate significant changes in this economic profile.

The Town's long-term development trends are discussed in relation to resource concerns in its 2019 *Open Space and Recreation Plan:*[14] While regional growth projections for the Town are modest, the OSRP indicates the need to consider residential sprawl and potential impacts on wetlands and water resources, including the Town aquifer:

> *"Current population trends in combination with recent development practices and current zoning bylaws show that Pembroke will likely see increases in population as well as residential and commercial development. According to the UMASS Donahue Institute's population change estimates, Plymouth County will experience slight population increases within the next twenty-five years…. Population increases in Pembroke and Plymouth County will increase development and the pressures associated with development, like road maintenance and water distribution. Regionally, withdrawal from Pembroke's aquifer, which supplies water to other towns in Plymouth County, may increase which could threaten both the quality and quantity of water resources.*
>
> *Most of the town of Pembroke is zoned Residential A, requiring about one-acre of land to have ample room for a septic system that will not affect neighboring properties. Because most of the land is zoned residential (about 90%) and those residences have large lot size requirements, Pembroke has conditions that allow for residential sprawl…. From 2010 to 2015, 133 dwellings were constructed with an average of 22 per year. As residential development continues, the town risks continued infringement upon the numerous wetlands throughout the town.*
>
> *Massachusetts General Law Chapter 40B development projects have allowed for cluster development to become more common in Pembroke. As of 2014, 9.6 percent of Pembroke's dwellings were listed as affordable dwellings.*

[13] Email from Matthew Heins, Pembroke Planning Board Assistant to L. Tessier dated July 7, 2020.
[14] The Old Colony Planning Council, *Conserving the Irreplaceable: Open Space and Recreation Plan, Pembroke MA, 2019*, pp. 31-32.

To meet the 10 percent goal of the state, 40B development, which bypasses local zoning requirements, has taken place allowing for the construction of cluster houses in areas that usually require over an acre of land. Simultaneously, lakeside properties, which were once affordable housing units, have started to become renovated to increase their property values, diminishing the number of affordable housing units. These two trends combined create an environment suitable for negative ecological consequences. Renovations to lake houses may ensure better septic installations, but cluster housing may concentrate septic systems which could potentially pollute groundwater. As these trends continue, the town's residential development projects infringe upon wetlands, threatening the natural resources associated with wetlands, such as water and habitat. If these wetlands are lost, the town will lose ecosystem services like flood mitigation, stormwater infiltration, and pollution filtration. Through increased and more intensely concentrated construction as well as increased non-point source pollution from increased growth (e.g. brake dust, fertilizers, pesticides, pet waste, and road salt), wetlands may become more stressed and unable to properly handle contaminants. The danger of polluting water resources may be exacerbated by the construction of cluster housing near water resources due to the combined septic needs of the many residents. These effects all potentially threaten the quality of the aquifer."

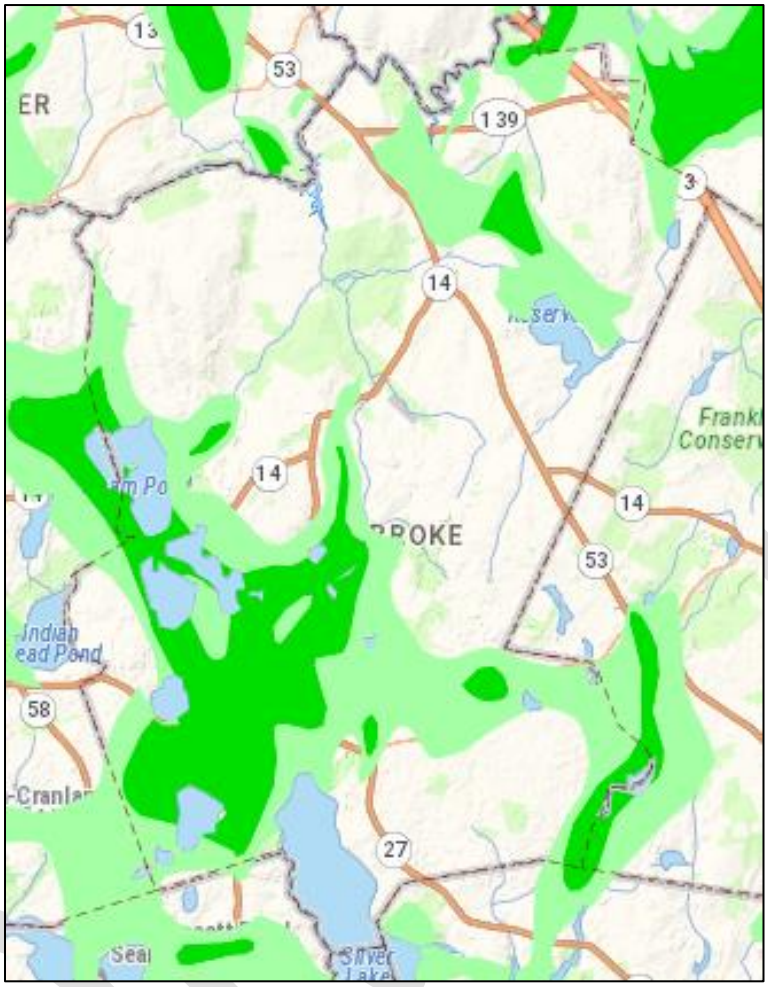
In 2018, with technical assistance from the Old Colony Planning Council, the Town completed a Housing Production Plan that assumes a population increase of 936 by 2030, declining slightly by 2040, and projects the addition of 1335 households to the Town by 2040.15 The Plan also acknowledges that while Pembroke has 521 acres of developable residential land, it is constrained by the Town's significant acreage of wetlands and floodplain, permanently protected open space (1651 acres), and lack of public sewerage. The Town Zoning, General, and Wetland Protection bylaws also provide tools to ensure responsible development.

2.3 Water Supply, Wastewater, and Stormwater

All but one of the communities in the Old Colony Planning District rely on local, publicly owned groundwater systems. The Pembroke Water Division operates and maintains the Town water supply with six full-time employees and a working foreman. Its water system consists of 135 miles of water main, 1000 fire hydrants, 3 water storage tanks, and 5 gravel-packed wells that draw from the aquifer in the western portion of Town (**Figure 2-2**). Although Pembroke maintains the infrastructure to supply municipal water to residents, the Town Water Division estimates that 250 residences are served by private wells.

[15] Old Colony Regional Planning Council, Housing Production Plan Pembroke Massachusetts, p. 12 of 118 pp. http://www.ocpcrpa.org/docs/projects/DLTA/Pembroke_Housing_Production_Plan.pdf

Figure 2-3. High and Medium Yield Aquifers in Pembroke



(Source: MassGIS OLIVER)

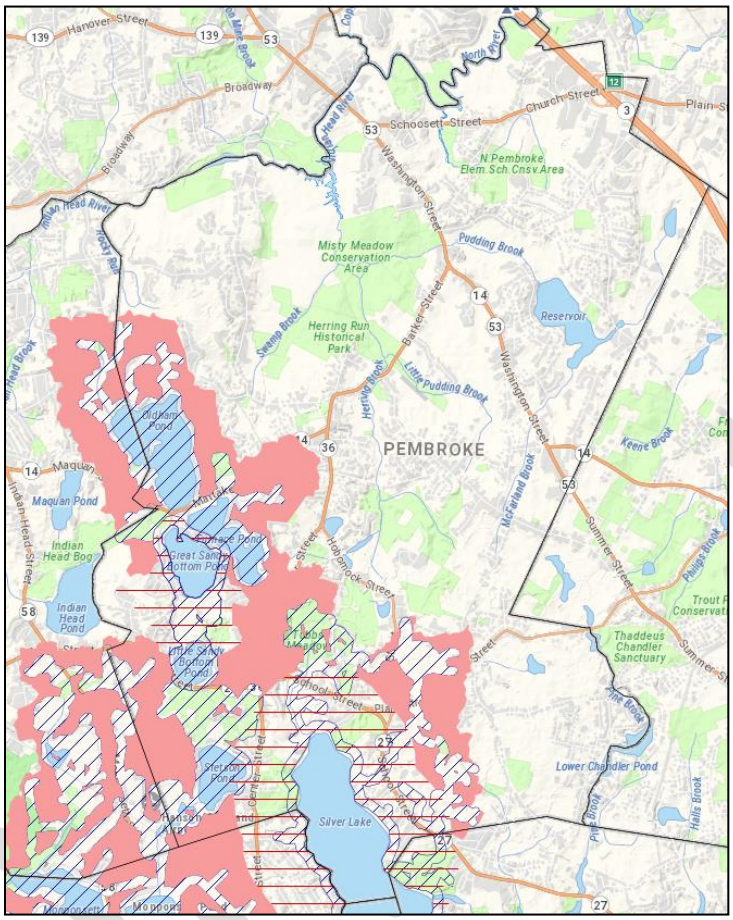
The Water Division recently acquired land around Pudding Brook near an abandoned cranberry bog to install a sixth well which would pump from a high yield aquifer in the northern part of Town. The sixth well is currently under review with the Massachusetts Department of Environmental Protection, awaiting final approval. The Town anticipates abandoning Well #1 in the near future, which with a sixth well anticipated to come online, would maintain the number of 5 total well sources.

The Town Water Department has acted with foresight to purchase properties important for aquifer protection and as possible future sites for drinking water wells. These include the Swanberg Property on Pleasant Street, the Edgewood/Elmer Street Bogs, the Zanaboni/Glenwood Bogs, and the Zanaboni/Center Street Bogs.

Pembroke's municipal drinking water supply is drawn from a number of sources including five wells in Pembroke as well as interconnections with the Marshfield Water Department, Halifax Water Department, and the Abington/Rockland Joint Water Works. The Town wells are protected under the Massachusetts Department of Environmental Protection Drinking Water regulations (310 CMR 22.00) which establish ownership and land use protection zones around well

sources of groundwater. The State requirements are implemented as part of the Town's Water Resource and Groundwater Protection District.

Figure 2-4. Surface Water Protection Areas in Pembroke



All residential and commercial wastewater needs in Pembroke are served by on-site septic systems. Since system function can vary by age, location, and level of maintenance, and can be compromised by elevated water tables and inadequate or excessive soil drainage conditions,[16] septics pose a threat to surface and groundwater resources (**Figures 2-3 and 2-4**). Increasing rainfall and storm intensities associated with climate change that raise the regional water table have the potential to exacerbate this risk.

Stormwater management infrastructure in Pembroke includes hundreds of catch basins, many of which drain to unmonitored outfalls. In addition, the 2011 Old Colony Planning Council *Climate Change Roadway Drainage and Runoff Study* noted that increased precipitation in 2010 "…revealed the vulnerabilities of this region's infrastructure to increased storm events."[17]

[16] According to the USDA NRCS Web Soil Survey, 89% of soils in Pembroke pose severe limitations to septic tank absorption fields.

[17] Old Colony Planning Council *Climate Change Roadway Drainage and Runoff Study*, September 2011. P.13

While all outfalls are a potential source of pollution to surface and ground water, those within the water supply protection zones are of particular community concern. The Town plans recognize that the use of Green Infrastructure to retrofit these outfalls would improve pollutant removal and enhance infiltration for climate resiliency.

2.4 Critical Infrastructure

Critical infrastructure is defined as assets, structures, systems, networks, and operations vital to the function of a community, the loss of which would threaten the security, public health, safety, property, and lives of residents. In practical terms, critical infrastructure provides, among other things, essential shelter, medical and care facilities; potable water; power to light, heat, and cool homes; transportation to secure food and services; and communications systems to connect residents with local supports. It is important for a community to understand the degree and magnitude of risk posed by each natural hazard to its critical assets to identify priority projects to mitigate that risk in advance of a hazard event.

The Town of Pembroke identified 93 structures and facilities critical to community function in both normal and emergency situations (**Table 2-5**). Of these, 13 serve as Mass Care Shelters, part of a Statewide coordination plan to help increase overall mass care and shelter capabilities, improve shelter-related information sharing between local and state government, identify a process to assist communities when they are overwhelmed, and better coordinate and allocate resources throughout the Commonwealth.[18] The plan is a scalable framework that can be implemented during all types of incidents, regardless of size and scope, initiated by the Massachusetts Emergency Management Agency (MEMA) in response to lessons learned from real-world incidents.

Additional critical elements include government centers and emergency services, bridges and dams essential to secure transportation, and potable water wells and storage facilities. Pembroke's municipal water is supplied by five local groundwater wells and from the Marshfield Water Department, Halifax Water Department, and Abington/Rockland Joint Water Works. Pembroke does not provide municipal wastewater service; all wastewater is treated by onsite septic systems.

The economic centers in Town include commercial and government service concentrations within the historic center district along Route 14 and in the northeast sector, along routes 3 and 53. These areas make up about 2.05% of the total area of Pembroke. The Town's five largest employers are the Pembroke Hospital, Pembroke Public Schools, Eye Health Service Inc., Home Instead Senior Care, and Kohl's;[19] however, most residents (over 90%) commute to jobs outside of Town.

Each of the critical infrastructure elements identified in Table 2-5 is assessed for natural hazard risk in Section 5.

[18] Commonwealth of Massachusetts Statewide Mass Care and Shelter Coordination Plan, June 2018, 53 pp.
[19] Massachusetts Department of Unemployment Assistance Labor Market Information. https://lmi.dua.eol.mass.gov/lmi/LargestEmployersArea/LEAResult?A=05&GA=000127

Table 2-5. Town of Pembroke Critical Infrastructure

ID	Category	Function	Facility	Location
1	Security	Police	Police Station	80 Center Street
2	Security	Fire/Mass Care Shelter	Pembroke Fire Department Headquarters	172 Center Street
3	Security	Fire	Pembroke Fire Department Station 1	42 School Street
4	Security	Fire	Pembroke Fire Department Station 2	399 High Street
5	Security	Fire	Pembroke Fire Department Station 3	380 Washington Street
6	Government	Town Hall/Mass Care Shelter	Town Hall	100 Center Street
7	Government	Public Works	Department of Public Works	387 Mattakeesett Street
8	Government	Senior Center	Pembroke Council on Aging	144 Center Street
9	Government	Mass Care Shelter	Hobomock Arena	132 Hobomock Street
10	Government	Mass Care Shelter	Bethel Chapel	155 Washington Street
11	Government	Mass Care Shelter	North Pembroke Community Club	27 Taylor Street
12	Government	Mass Care Shelter	St. Thecla Church	145 Washington Street
13	Government	Library	Pembroke Public Library	142 Center Street
14	Government	Library	Lydia Drake Library	340 High Street
15	Government	Library	Cobb Library	9 Union Street
16	Government	Recycling Center	Recycling Center	158B Hobomock Street
17	Services	Airport	Allen B. Sherman	210 Barker Street
18	Services	Postal & Shipping	USPS Bryantville Office	13 School Street
19	Services	Postal & Shipping	USPS Pembroke Office	3 Elliot Avenue
20	Services	Postal & Shipping	USPS N. Pembroke Office	288 Washington Street
21	Services	Food	Stop and Shop	24 Mattakeesett Street
22	Services	Cultural Resources	Adah F. Hall House	Barker Street
23	Services	Cultural Resources	Bryantville United Methodist Church	546 Mattakeesett Street
24	Services	Cultural Resources	First Church in Pembroke	105 Center Street
25	Services	Cultural Resources	North River Community Church	334 Old Oak Street
26	Services	Cultural Resources	Pembroke Assembly of God	786 Washington Street
27	Services	Cultural Resources	Pembroke Historical Society	116 Center Street
28	Services	Cultural Resources	Quaker Meeting House	Schoosett Street
29	Services	Housing Authority	Pembroke Housing Authority	0 Kilcommons Drive
30	Services	Special Needs	Road to Responsibility	7 Lydia Ford Road
31	Services	Special Needs	New England Villages	664 School Street
32	Services	Non-acute Hospital	Pembroke Hospital and School	199 Oak Street
33	Services	Assisted Care Facility	Bridges at Epoch	49 Cross Street

ID	Category	Function	Facility	Location
34	Services	Childcare	Bright Horizons Early Education & Child Care	334 Old Oak Street
35	Services	Childcare	Center Pre-School & Child Care	128 Center Street
36	Services	Childcare	Community Nursery Kindergarten	105 Center Street
37	Services	Childcare	Here We Grow Day Care, Inc.	42 Mattakeesett Street
38	Services	Childcare	Kidbridge Learning Centers, LLC	300 Oak Street Unit 1660
39	Services	Childcare	Kids Time Preschool & Daycare, Inc.	17 Lilah Lane
40	Services	Childcare	Little Neighbors Early Childhood Center	280 Center Street
41	Services	Childcare	The Magical Years Early Learning Center, Inc.	256 Church Street
42	Bridges & Dams	Bridges	Route 3 NB Bridge (Church Street)	N/A
43	Bridges & Dams	Bridges	Route 3 SB Bridge (Church Street)	N/A
44	Bridges & Dams	Dam	Arnold Reservoir Dam (Arnold Reservoir)	N/A
45	Bridges & Dams	Dam	Hill Pond Dam (Hill Pond)	N/A
46	Bridges & Dams	Dam	Iacabucci Dam	N/A
47	Bridges & Dams	Dam	Lower Chandler Pond Dam (Lower Chandler Pond)	N/A
48	Bridges & Dams	Dam	Mill Pond/Furnace Pond Dam (Mill Pond)	N/A
49	Bridges & Dams	Dam	Mill Pond Upper Dam (Mill Pond)	N/A
50	Bridges & Dams	Dam	Monroe Street Bog East Dam (Monroe Street Bog)	N/A
51	Bridges & Dams	Dam	Monroe Street Bog West Dam (Monroe Street Bog)	N/A
52	Bridges & Dams	Dam	Pleasant Street Pond Dam (Pleasant Street Pond)	N/A
53	Bridges & Dams	Dam	Randall Pond Dam (Randall Pond)	N/A
54	Bridges & Dams	Dam	Stump Pond Dam (Stump Pond)	N/A
55	Bridges & Dams	Dam	Stumpy Pond Lower Dam (Stumpy Pond)	N/A
56	Bridges & Dams	Dam	Stumpy Pond Upper Dam (Stumpy Pond)	N/A
57	Bridges & Dams	Dam	Trout Pond Dam (Trout Pond)	N/A
58	Bridges & Dams	Dam	Upper Chandler Pond Dam (Upper Chandler Pond)	N/A
59	Bridges & Dams	Dam	Washington Street Pond Dam (Washington Street Pond)	N/A
60	Water	Water Tank	High Street Tank	303 High Street
61	Water	Water Tank	West Elm Street Tank	64 West Elm Street
62	Water	Water Tank	Learning Lane Tank	Learning Lane
63	Water	Water Tank	Oak Street Tank	196 Oak Street
64	Water	Well	GP GW 2	570 Center Street
65	Water	Well	GP GW 3	316 School Street
66	Water	Well	GP GW 4 Filtration Plant	35 Sandy Lane
67	Water	Well	GP GW 5	100 Ridge Road
68	Water	Well	Proposed Edgewood Bogs Well	
69	Water	Surface Intake	Great Sandy Bottom Pond (Abington)	
70	Water	Surface Intake	Silver Lake (Brockton)	
71	Energy	Fuel Station	Cumberland Farms	137 Center Street
72	Energy	Fuel Station	Firehouse Gas	154 Center Street

ID	Category	Function	Facility	Location
73	Energy	Fuel Station	Gulf	226 Church Street
74	Energy	Fuel Station	Mobil	145 Church Street
75	Energy	Fuel Station	Mobil	208 Church Street
76	Energy	Fuel Station	Shell	243 Church Street
77	Energy	Fuel Station	Stop & Shop	125 Church Street
78	Energy	Fuel Station	Sunoco	355 Washington Street
79	Energy	Fuel Station	Stop and Shop	25 Mattakeesett Street
80	Telecom	Antenna	American Towers, Inc.	171 Mattakeesett Street
81	Telecom	Antenna	Industrial Tower & Wireless, LLC	47 School Street
82	Telecom	Antenna	T-Mobile Northeast	Birch Street Park
83	Telecom	Antenna	Sprint, T-Mobile & Metro PCS	High Street Tank
84	Telecom	Antenna	Sprint/Nextel	380 Washington Street
85	Education	School/Mass Care Shelter	Bryantville Elementary School	29 Gurney Drive
86	Education	School/Mass Care Shelter	Hobomock Elementary School	81 Learning Lane
87	Education	School/Mass Care Shelter	North Pembroke Elementary School	72 Pilgrim Road
88	Education	School/Mass Care Shelter	Pembroke High School	80 Learning Lane
89	Education	School/Mass Care Shelter	Pembroke Community Middle School	559 School Street
90	Services	Major Employer	Eye Health Services Inc.	146 Old Church Street
91	Retail	Major Employer	Kohl's	139 Church Street
92	Services	Major Employer	Home Instead Senior Care	31 Schoosett Street
93	Retail	Major Employer	Eye Health Services Inc.	4 Church Street

Source: MassGIS and Town of Pembroke.

Mass Care Shelters

3. PLANNING PROCESS & PUBLIC ENGAGEMENT

3.1 Planning Process Summary

The Town of Pembroke conducted the Municipal Vulnerability Planning process to achieve designation as an MVP Climate Community from the State of Massachusetts. As part of that process, the Town also prepared a Hazard Mitigation Plan update in accordance with FEMA guidelines. By preparing a combined Municipal Vulnerability and Hazard Mitigation Plan (MVHMP), Pembroke committed to a planning process and public participation effort under the rubric of the Massachusetts MVP Program Community Resilience Building model. Developed by the Nature Conservancy, Community Resilience Building (CRB) is a community-driven approach that integrates information, experience, and dialogue to allow residents and stakeholders to identify top hazards, community strengths, challenges, and priority actions to mitigate potential impacts from natural hazards and climate change.[20] The MVP rubric was amended as necessary to also meet the federal requirements for local hazard mitigation planning.

In preparing its combined Municipal Vulnerability Hazard Mitigation Plan (MVHMP), Pembroke emphasized honest engagement with stakeholders – including neighbor communities, involved agencies, and constituents - social equity in adaptation planning, and nature-based solutions as critical to project success. The planning process included the following major elements:

- Steering Committee member identification, Kick-off Meeting, and interviews (February 2020)
- Key Stakeholder identification and invitation to participate (including the 8 neighbor communities)
- One-day, 8-hour CRB Workshop conducted on October 6, 2021
- Public Listening Session #1 (during MVHMP Preparation) on October 18, 2021
- Public Listening Session #2 (Comment on Draft MVHMP) on _____.

3.2 The MA MVP Community Resilience Building Planning and Workshop

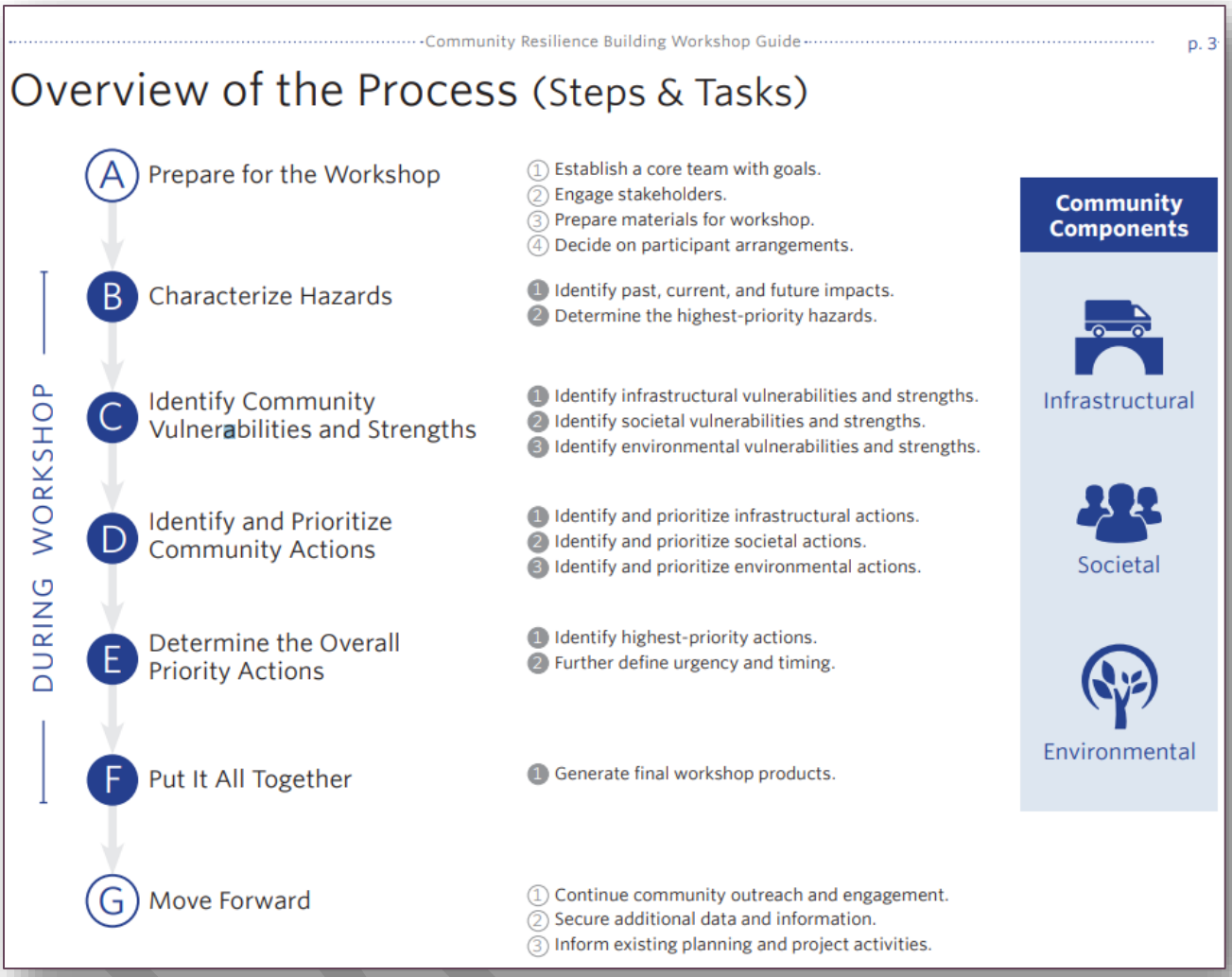
The Town had originally completed preparations to conduct a 1-day, 8-hour workshop on March 26, 2020; due to Covid, that workshop was canceled and the Town was granted an extension by the MA MVP Program to reschedule the Workshop to October 6, 2021. The purpose of the daylong session was to develop a grass-roots-driven vulnerability and hazard mitigation plan. The effort emphasized community collaboration with the following central objectives:

- Define local natural and climate-related hazards of greatest local concern to the public and stakeholders;
- Identify current and projected community strengths and vulnerabilities;
- Assess risks to critical infrastructure and residents;
- Define priority mitigation actions to address identified vulnerabilities; and
- Establish a schedule to implement priority mitigation actions to increase community resilience.

Figure 3-1 presents an overview of the CRB process and tasks.

[20] The Nature Conservancy. https://www.communityresiliencebuilding.com/

Figure 3-1. CRB Process Overview



Source: Community Resilience Building Workshop Guide, www.CommunityResilienceBuilding.org

As a first step in its planning process, the Town established a Steering Committee to develop a Municipal Vulnerability Preparedness Plan and simultaneously update its portion of the 2015 Old Colony Planning Council Regional Hazard Mitigation Plan to create a combined plan Municipal Vulnerability and Hazard Mitigation Plan (MVHMP) (**Table 3-1**). On February 7, 2020, the Committee held a Kick-off meeting with its MVP-certified provider, Woodard and Curran, and developed a list of 100 stakeholders that included Pembroke's 8 neighbor communities, State and regional emergency and planning agencies, town board and commission representatives, and community leaders, organizations, and businesses. The Committee also scheduled an 8-hour CRB Workshop for March 26 at the Pembroke Public Library. Following the Kick-off meeting, the Committee began to develop Workshop materials, including meeting announcements, stakeholder invitations and pre-workshop questionnaire, GIS-based multi-hazard maps for the community, slide presentations, speaker assignments, and agenda. The Committee also confirmed a list of 93 critical

community infrastructure elements for consideration by Workshop participants. The MVP-certified Provider, Woodard and Curran, interviewed Steering Committee members for their perceptions of top hazards and problem locations to further inform and amplify the Workshop discussion. Finally, the Steering Committee made available reports and other studies relevant to natural hazard and climate change assessment including but not limited to the following:

- Old Colony Planning Council Regional Hazard Mitigation Plan, 2015.
- Bylaws of the Town of Pembroke Massachusetts, Updated to Town Meeting of May 14, 2019.
- Town of Pembroke, Massachusetts, Recommendations for Development of a Capital Improvement Program & FY20-24 Capital Plan and FY20 Capital Budget, March 2019.
- Town of Pembroke Zoning Bylaws, June 2021.
- Town of Pembroke FEMA Flood Maps, 2021 (People GIS).
- Town of Pembroke Draft Local Comprehensive Emergency Management Plan, 2021.
- Old Colony Planning Council. "Conserving the Irreplaceable, Open Space and Recreation Plan, Pembroke MA," Fall 2019.
- Old Colony Planning Council. "Climate Change Roadway Drainage and Runoff Study." September 2011.
- Old Colony Planning Council. *Housing Production Plan, Pembroke, Massachusetts*. June 2018. 118 pp.
- Old Colony Planning Council, 2018 Comprehensive Economic Development Strategy (CEDS). June 2018. 151 pp.
- Massachusetts State Hazard and Climate Adaptation Plan (MEMA, EOEEA and EOPSS, 2018).

In January 2021, in consultation with the MVP program coordinator, the Town designed a 4-session virtual workshop for early May 2021. At the same time, the Town updated its Steering Committee membership to accommodate staff changes that had occurred in the intervening period; Woodard and Curran revised background and workshop materials and conducted additional interviews with new Steering Committee members to obtain their perceptions and bring them up to speed. Further Covid demands delayed the virtual workshop which was ultimately rescheduled to a one-day, 8-hour, in-person event on October 6, 2021. The Workshop notice was posted to the Town website (https://www.pembroke-ma.gov/home/news/community-resilience-building-workshop), pinned to the Town Facebook page at "Town of Pembroke, MA Government", tweeted through Twitter at @PembrokeMA whereby it was retweeted by the MMA (Massachusetts Municipal Association) @massmunicipal and by the Patriot Ledger @PatriotLedger, who did an online feature about it. One-hundred (100) Stakeholders, including Pembroke's 8 neighboring municipalities, were invited to attend the workshop; 25 people participated. The full list of invitees is presented in **Appendix D**.

Table 3-1. Town of Pembroke MVP Steering Committee

Organization	Committee Member	Role
Town of Pembroke	Eugene Fulmine, Jr.	Director of Public Works
	Kenneth McCormick, Fire Chief	PEMA Co-Director
	Richard MacDonald, Interim Chief of Police	PEMA Co-Director
	Brian Phillips, AD/Facilities Director	Pembroke Public Schools
	William Chenard, Town Manager	MVP Project Manager
	Sabrina Chilcott, Assistant Town Manager	Assistant MVP Project Manager
	Lisa Cullity	PEMA, Health Agent
	Rose Campbell	Assistant to DPW Director
	Robert Clarke	Conservation Commission Agent
	Melissa Joyce	Assistant Conservation Commission Administrative Agent
Woodard & Curran	Scott Medeiros	Program Manager
	Dave White	MVP Certified Provider
	Scott Salvucci	Client Manager
	Laura Tessier	Senior Planner
	Eric Sneesby	GIS Specialist
Massachusetts MVP Program	Courtney Rocha	Southeast MA MVP Coordinator

The results of the CRB Workshop and related information are incorporated into the relevant sections of this MVHMP. **Appendix D** contains additional documentation related to the CRB Workshop. Below is a summary of the key findings for each of the CRB process steps.

- **Pre-Workshop Questionnaire**

As part of the Workshop invitation, Stakeholders were invited to complete a pre-Workshop Questionnaire to gauge perceptions about climate change and natural hazards, community strengths and vulnerabilities, and planning priorities to guide workshop discussions and preparation of the MVHMP. The compiled questionnaire responses are provided in **Appendix D**. Briefly summarized, respondents felt the most important characteristics of their Town to be its natural resources, particularly the size and number of water bodies, and community cohesiveness. The natural hazards of greatest concern were High Wind events, Flood/Extreme Rainfall, Winter Storms, and Extreme Temperatures; Pandemic also ranked high as a major concern. Respondents identified power outages, communications deficiencies, and elevated water levels in the ponds as the greatest community vulnerabilities, along with the utility infrastructure, over-development, and roads/walkways (impassability during hazard events due to flooding and downed trees). Respondents listed the Town's strong EMS (Pembroke residents), open space and ponds, and people as Pembroke's greatest strengths. In response to the categories most vulnerable to natural and/or climate hazards, respondents ranked infrastructure first, followed by environmental considerations and people. Economic concerns were ranked moderately susceptible with Governance and cultural/historic considerations perceived as least vulnerable. In general, respondents felt protecting critical facilities to be of greatest importance followed by preventing development in hazard

areas, enhancing function of natural assets (streams, wetlands etc.), strengthening emergency services, protecting private property, and promoting community cooperation.

- **CRB Workshop Facilitated Group Exercise**

During the Workshop, attendees were also given the opportunity to define and share with the group their perceptions regarding the top two hazard-related challenges facing the Town and to indicate what they hoped to take away from the Workshop. The responses are summarized in **Appendix D**.

- **CRB Workshop Identification of Top Hazards**

The CRB Workshop opened with a slide presentation by William Chenard, Town Manager, and Lisa Cullity, Town Health Agent, to provide participants with background on the findings of the 2015 Regional Hazard Mitigation Plan and to discuss hazard events that have impacted Pembroke in the recent past. Woodard and Curran, consultants to the Town, presented a second set of slides describing the purpose and tasks for the Workshop and provided background on natural hazards.

Participants were asked to identify the four top hazards (including climate change impacts) currently facing the community. The group readily agreed that the following five hazards were of greatest concern to the Town: (1) Extreme/High Wind Events, (2) Flood/Intense Rainfall, (3) Drought, (4) Snowstorms/Blizzards/Nor-easters, (5) Extreme Temperatures.

- **Community Vulnerabilities and Strengths - *Infrastructure***

Workshop participants were also tasked with identifying key infrastructure, assets, or locations in Pembroke most vulnerable to natural and climate change hazards, as well as those that serve to protect the community from impact. **Table 3-2** lists the participant findings.

Table 3-2. Town of Pembroke Infrastructural Vulnerabilities and Strengths

Infrastructure Vulnerabilities	Infrastructure Strengths
Groundwater Wells (aquifer), Water Towers, and Surface Water Supply that provides water to Pembroke and neighboring communities. Concern that Town is not sole user of the local aquifer and surface source.	**Town land acquisition** to protect aquifer and provide sites for new wells, including Andruck Bogs, Lage Property, Swanberg Property, Elmer Street (proposed Edgewood Bog Well), Zaniboni Bogs (Center Street), Zaniboni Bogs (Glenwood Bogs).
Roads and Culverts – emergency access and evacuation routes vulnerable to flooding and downed trees.	**New Community Center (in progress)**
Communications Systems – inadequate and/or unreliable cell phone coverage for all parts of Town, need for new towers and upgrades to existing infrastructure.	

Infrastructure Vulnerabilities	Infrastructure Strengths
Dams (Mill Pond and others) – lack of emergency overflow infrastructure and conditions**.**	
Septic Systems – Town-wide reliance on septic in the face of extreme precipitation and changing storm patterns.	
Public Safety / Municipal Buildings / Schools that serve as shelters in natural hazard and extreme weather events that need improved communications capability, HVAC and filtration systems to fully fulfill that function.	**Public Safety / Municipal Buildings / Schools** that serve as shelters in natural hazard and extreme weather events.

- **Community Vulnerabilities and Strengths – *Societal***

Workshop participants identified important sectors of the community particularly vulnerable to hazard impact as well as those that provide significant strength in terms of hazard adaptation and response. Participant determinations are presented in **Table 3-3**.

Table 3-3. Town of Pembroke Societal Vulnerabilities and Strengths

Societal Vulnerabilities	Societal Strengths
Pembroke Housing Authority at Macdonald Way (Federal), Mayflower Court (State), and Kilcommons Drive (State)	**Town Employees and Community Volunteers** including Town cohesiveness.
New England Villages at 664 School Street (intellectual and developmentally disabled – residential and day)	**Plymouth County Outreach** (collaboration of 27 municipal police departments in Plymouth County working to make substance use disorder treatment mor accessible)
Pembroke Hospital at 199 Oak Street (behavioral health facility)	
Bridges at 49 Cross Street (memory care facility)	
Schools, Daycare facilities – Hobomock Elementary, Bryantville Elementary, North Pembroke Elementary, Pembroke Community Middle School, Pembroke High School	
Societal Vulnerabilities	**Societal Strengths**

Residents without automobiles (Pembroke has no public transportation)	

- **Community Vulnerabilities and Strengths - *Environmental***

Environmental features, including natural resources and open space, composed the third category of the vulnerability and strength assessment addressed by Workshop participants. Their findings are presented in **Table 3-4**.

Table 3-4. Town of Pembroke Environmental Vulnerabilities and Strengths

Environmental Vulnerabilities	Environmental Strengths
Water Resources – Ponds, Lakes, Streams, Rivers, Wetlands including Water Supply vulnerable to nutrient loading, sedimentation, and contamination due to excess stormwater flows and Town-wide reliance on septic systems.	**Water Resources** – Significant ponds and streams, wetlands – provide stormwater management, water quality benefits, and significant wildlife habitat.
Community Trees / Forests – downed trees cause power outages.	**Community Trees / Forests** – Provide carbon capture and cooling, water quality renovation, erosion control.

- **Natural Hazard/Climate Change Mitigation Strategies & Community Priority Actions**

After determining priority hazards and community vulnerabilities and strengths in each of the three profile areas (infrastructure, societal, environmental), Workshop participants identified and prioritized mitigation actions for each area and established a timeframe for implementation. Actions were first identified in small work group discussions with the overall top priorities subsequently determined by large group consensus. It is important to note that the three breakout groups independently arrived at the same or similar conclusions indicating cohesive community perceptions and focus.

Table 3-5. Pembroke High, Medium, and Additional Priority Actions

HIGH Priority Actions & Timing (Short, Long, Ongoing)
Water Supply – Perform comprehensive water supply study to support construction of resiliency improvements to include pipe redundancy, distribution system upgrades, and development of new wells and sources to ensure adequate safe supply in future drought scenarios. Assess source quality threats and implement protections. Seek intermunicipal cooperation to assess intergovernmental reliance on Pembroke's supply. **(*Short-term).***
Water Supply – Construct new water storage tank at Oak Street to add system resiliency to address climate change-related drought. Currently, the well runs 24/7 to maintain adequate supply. (***Short-term****)*
HIGH Priority Actions & Timing (Short, Long, Ongoing)

Water Supply – Provide generators for High Street, West Elm, and Oak Street water towers. (***Short-term)***
Water Supply – Develop new water supply at the Swanberg Property (awaiting final DEP approval) to increase water security and resiliency to drought. ***(Short-term)***
Water Supply – Replace the Lowell Road 8-inch asbestos cement water main. ***(Short-term)***
Tree / Forest Management Study – Conduct a Town-wide inventory of trees to identify areas for pruning/ removal to mitigate power loss and areas for replating to increase community canopy cover and provide outdoor cooling to mitigate extreme temperatures. Include assessment of parks/playgrounds for shade infrastructure needs (e.g., Ford Park). (***Short-term)***
Culverts - Update the 15-year old Town-wide culvert assessment to identify and prioritize need for repair, replacement, upsizing. Specific areas to be addressed include enlarging the Birch Street at Duxbury Town Line (Pine Brook) to address flooding (carried forward from 2015), Dwelley Street at Hanson Town Line, Congress Street, Mill Street (Houses #54 and #36), Herring Run (design and permitting completed), Park Street (design underway), Taylor Street at the Ledges, Lorna Avenue in the Blake Ave and Burr Ave area, Woodbine and Shepard Avenues at the beach, Brenda Lane at Plymouth Street, Mill Pond off Hobomock Street, Indian Head River Dam at West Elm Street at Hanover Town Line, Valley Street at Duxbury Town Line – Upper Chandler Pond. The assessment will specifically include an evaluation of opportunities to incorporate green infrastructure and nature-based solutions to mitigate direct stormwater discharge into wetlands and the ponds. (***Short-term)***
Culverts/Flood Control – Install outfall control structures and address drainage from Hobomock Pond down Center Street to alleviate local flooding, in coordination with the Route 35 TIP project. (***Short-term)***
Stormwater – Upgrade or replace 2 failing detention basins and 6 leaching areas on Mill Pond Road. (Carried forward from 2015) **(Short-term)**

MEDIUM Priority Actions & Timing
Septic Systems - Prepare a Town-wide study to evaluate the impacts of septic systems on the Town's water resources and drinking water supply in the face of changing precipitation patterns due to climate change. Identify and evaluate areas most vulnerable to malfunction / failure under future conditions to determine the need for sewering of selected areas. (***Long-term)***
Dams - Conduct a Town-wide assessment of public dams to determine level of risk in relation to climate change, evaluate emergency overflow needs, and evaluate opportunities to increase stormwater management potential at Mill Pond/Furnace Pond Dam and Lower Chandler Pond Dam. Based on assessment results, develop and implement a local flood mitigation dam management program. (***Short-term)***
MEDIUM Priority Actions & Timing

Transportation/Roadways - Prepare a Town-wide assessment of areas of flooding to evaluate the need to elevate roadways and/or otherwise identify retrofits to manage stormwater, including direct discharges to wetlands. **(*Short-term)***
Public Buildings/Shelters - Retrofit public buildings that serve emergency management or emergency shelter functions during extreme temperatures and disaster events for HVAC and filters. **(*Short-term)***

Additional Priority Actions & Timing
Water Resources Quality - Assess the quality of the Town's ponds in relation to nutrient loading, stormwater impacts, and invasive species colonization due to increasing extreme weather events. Evaluate dredging and other alternatives to correct existing problems and mitigate future impacts with an emphasis on nature-based solutions (NBS). (***Long-term)***
Emergency Response – Maintain and improve emergency response plans. Ensure access routes and ability to maintain them for residential services and non-mobile (no car) residents. Coordinate with food pantries to ensure adequate provision of food to vulnerable populations during disaster events. (***Short-term & Ongoing)***
Public Buildings – Replace Public School parking lots with impervious pavement to remediate flooding; evaluate opportunities to install stormwater trees and raingardens in these locations. (***Long-term)***
Public Outreach - Develop and disseminate public information materials to educate the community on emergency response during natural disaster and extreme weather events. **(*Short-term & Ongoing)***
Snow/Flood Management – Assess Town-owned properties for retrofit opportunities to control and treat stormwater to reduce flooding and mitigation water quality impacts on Town wetlands, ponds, and watercourses. **(*Long-term)***

3.3 Public Listening Session #1

The Town of Pembroke held the first of two Public Listening sessions on October 18, 2021 to present the findings of the Community Resilience Building Workshop and gather information from the public to inform the Draft MVHMP. Preliminary information from the Draft MVHMP was posted to the Town's website and public comments invited. The public listening session was publicly noticed in the same manner as the CRB Workshop and was also publicized as part of the original Workshop noticing.

The Listening Session was attended by Steering Committee members and Town Planning Board staff, as well as the Town's consultant. No new community members or organizations attended, possibly due to the session following the CRB Workshop by two weeks. The Town Manager delivered a slide presentation summarizing the findings of the CRB Workshop held October 6th; the slide presentation was subsequently posted to the Town website for public viewing at will with the option for residents to provide comments and input to the Assistant Town Manager.

3.4 Public Listening Session #2

Public Listening Session #2 was held on _____ following release of the Draft Municipal Vulnerability and Hazard Mitigation Plan for the Town.

3.5 Continuing Public Engagement

Upon State and FEMA approval of the MVHMP, Pembroke will establish an Implementation Committee to monitor progress in implementing the priority actions and update the Plan as required, but at minimum every 5 years. All updates of the Plan will be added to the Town website and all meetings of the Committee will be noticed in accordance with State open meetings laws. The Implementation Committee will inform residents, businesses, neighbor communities and other stakeholders of plan status and provide them an opportunity to have input. **Table 3-6** lists members of the Implementation Committee.

Table 3-6. Pembroke MVHMP Implementation Committee

Member	Role
Eugene Fulmine, Jr., **DPW Director**	MVHMP Plan Coordinator
Kenneth McCormick, Fire Chief	PEMA Co-Director
Richard MacDonald, Interim Chief of Police	PEMA Co-Director
Brian Phillips, AD/Facilities Director	Pembroke Public Schools
William Chenard, Town Manager	MVP Project Manager
Sabrina Chilcott, Assistant Town Manager	Assistant MVP Project Manager
Lisa Cullity	PEMA, Health Agent
Rose Campbell	Assistant to DPW Director
Robert Clarke	Conservation Commission Agent
Melissa Joyce	Assistant Conservation Commission Administrative Agent

3.6 FEMA Hazard Mitigation Plan Requirements and the 2015 Hazard Mitigation Plan Update

Federal mitigation planning is prescribed by the Stafford Act and Title 44 Code of Federal Regulations Part 201. FEMA's *Local Mitigation Plan Review Guide* was used as to prepare this MVHMP and represents the Agency's interpretation of statute and defines the requirements for new and updated Local Mitigation Plans.

In 2015, the Town of Pembroke participated in the Old Colony Planning Council Regional Hazard Mitigation Plan (RHMP) along with 14 area communities; the regional plan expired in 2020. In 2019, the Town was awarded a Municipal Vulnerability Planning grant from the State of Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA) and opted to prepare a combined Municipal Vulnerability and Hazard Mitigation Plan to satisfy both State and Federal mitigation planning requirements. By updating and obtaining FEMA approval of this MVHMP, the Town will continue to be eligible for FEMA hazard mitigation project grant funding. (As noted previously, State approval of the combined plan ensures the Town designation as an MVP community and eligibility for Action Grant funding under that program.)

The FEMA Local Mitigation Plan Review Guide specifies that 44 CFR 201.6(d)(3) requires a local jurisdiction to review and revise its plan to reflect changes in development, progress in local mitigation efforts, and changes in priorities, and to resubmit the plan for approval within five years to be eligible for mitigation project funding. The update must include major disaster declarations that occurred since preparation of the prior plan.

Element A of the FEMA Regulation Checklist outlines components required as part of the Planning Process. These include:

1. An open public involvement process, including the opportunity for public comment both during drafting of the Plan and prior to its approval;
2. An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation and responsible for regulating development, businesses, academia and other private and nonprofit interests to be involved;
3. Review and incorporation of existing plans, studies, reports and technical information;
4. Plan maintenance including the method and schedule of monitoring, evaluation, and update within a 5-year cycle;
5. A discussion of continued public participation in the plan maintenance process.

Requirements (1) and (2) were met as described in the Section 3 preamble and subsections 3.1, 3.2, and 3.3. The MA MVP-required CRB process mandates broad stakeholder invitation to participate and one full-day public workshop (or 2 half-day sessions) as well as two Public Listening sessions (one during preparation of the Draft Plan and one on release of the Draft Plan for public comment). Requirement (3) is met specifically in Sections 1, 3.1, 4, and 5 of this Plan. Requirements (4) and (5) are discussed in subsections 3.4 and 10.2, 10.3, and 10.4.

3.7 Planning Timeline and 5-Year Update

Pembroke's MVHMP planning process began in February 2020 and proceeded according to the following schedule:

- January 2020 Identification of Pembroke Steering Committee members and Town plan liaison
- February 7, 2020 MVHMP Kickoff Meeting and CRB Workshop Planning
- March 26, 2020 CRB Workshop original target date and publicity

COVID postponement of activities

- June 2020 Pembroke requests and is granted MA MVP 1-year deadline extension
- May 2021 Pembroke requests and is granted an additional 1-year extension
- October 6, 2021 One-day, 8-hour CRB Workshop at the Pembroke Public Library
- October 18, 2021 Public Listening Session 1
- XXXX 2021 Public Listening Session 2
- Plan Adoption Pembroke Town Council
- Plan Approval MA EOEEA MVP Program
- Plan Approval MEMA and FEMA

The MVHMP will be updated at minimum every 5 years as outlined in Sections 3.5, 10.2, and 10.3.

4. HAZARD IDENTIFICATION

FEMA defines natural hazards as naturally occurring events that threaten lives, property, and other assets; because they are related to weather patterns and/or the physical characteristics of a land area, some hazards are more likely to occur, in particular, geographical locations and are relatively predictable, while others can only be assigned a general probability of occurrence. Types of natural hazards include floods, severe winter storms, hurricanes, tropical storms, high wind events, tornadoes, earthquakes, landslides, wildfires, extreme heat, and events restricted to specific locations, such as volcanoes, tsunamis, and coastal storms.

Many natural hazards – severe inland and coastal storms, heavy rainfall, extreme wind events (hurricanes, tropical storms, tornadoes), drought, wildfire, and landslides – will be significantly influenced by climate change and sea level rise. The impact of climate change is discussed in relation to each natural hazard.

This section reviews the natural hazards likely to affect the New England geography and the Town of Pembroke. Each hazard is characterized for frequency, magnitude/severity, and geographic extent using State, County, and local data sources. The vulnerability and risk to Pembroke residents and critical infrastructure associated with each hazard is discussed in Section 5.0.

4.1 Overview of Hazards

The natural hazards of greatest concern to the Town of Pembroke were first identified by the community as part of the intermunicipal planning process that developed the 2015 Old Colony Regional HMP. More recently, Town residents and stakeholders re-evaluated natural hazards of greatest concern as part of the Community Resilience Building Workshop held over a series of webinars in early May 2021; those findings are incorporated throughout this MVHMP. The MVHMP also assessed the following sources of extreme storm/climate data to ensure that all relevant hazards had been considered and to support the CRB Workshop findings:

- The 2015 Old Colony Planning Council Regional Hazard Mitigation Plan,
- The 2018 Massachusetts State Hazard Mitigation and Climate Action Plan (SHMCAP),
- Federal and State Disaster Declarations for the Pembroke region, and
- Federal, State, and other natural hazard databases, including but not limited to the USGS Unified Hazard Tool, NOAA Atlas 14 Precipitation-Frequency Atlas, NOAA Storm Events Database, Northeast States Emergency Consortium, Fourth National Climate Assessment (NCA4), and others referenced throughout the Section.

Hazard characterization for the Town of Pembroke follows the classification format used in the State Hazard Mitigation and Climate Action Plan as outlined in **Table 4-1.**

Table 4-1. Hazard Characterization ***(after MA SHMCAP 2018)***

GEOGRAPHIC EXTENT
Limited – Less than 10% of Town affected
Significant – 10-50% of Town affected
Extensive – 50-100% of Town affected
MAGNITUDE (SEVERITY)
Minor – Limited, scattered property damage; limited damage to public infrastructure; essential services not interrupted; limited injuries/fatalities.
Serious – Scattered major property damage; minor infrastructure damage; essential services briefly interrupted; some injuries/fatalities.
Extensive - Widespread major property damage; major public infrastructure damage (up to several days for repairs); essential services interrupted several hours to several days; many injuries and/or fatalities.
Catastrophic - Property and public infrastructure destroyed; essential services stopped; numerous injuries and fatalities.
FREQUENCY
Very Low – Occur < once in 100 years (< 1% per year)
Low Frequency – Occur from once in 50 years to once in 100 years (1 - 2% per year)
Medium Frequency – Occur from once in 5 years to once in 50 years (2-20% per year)
High Frequency – Occur more frequently than once in 5 years (> 20% per year)

4.1.1 Community Resilience Building Workshop Priority Hazards

As part of the CRB Workshop, participants discussed and identified the top hazards facing the Town of Pembroke. While this exercise was completed in Breakout Sessions, all groups identified the same top hazards which are:

Extreme/High Wind Events	Flood/Intense Rainfall	Drought
Snowstorms	Extreme Temperatures	

With the exception of Drought, the top hazards continue to be those identified by the Town in the 2015 OCPC Regional Hazard Mitigation Plan.

4.1.2 Old Colony Planning Council Regional Natural Hazard Mitigation Plan Hazard Identification

The 2015 Old Colony Planning Council Regional Natural Hazard Mitigation Plan (RHMP) for the Old Colony Region evaluated the vulnerability of Pembroke and 14 other communities to flood-related hazards, wind-related hazards (hurricanes, tropical storms, and tornadoes), winter storm and coastal hazards (shoreline change and erosion), fire-related hazards (wildfires), geologic-related hazards (earthquakes, tsunamis, landslides), and extreme temperatures. For ease of comparison between the 2015 and current hazard mitigation plans, this MVHMP uses the same general organization and list of hazards with some amendments and adds drought as a potential hazard associated with climate change.

In the 2015 RHMP, the Town assigned flooding, winter storms, hurricanes/tropical storms, and extreme temperatures the highest rankings as hazards of concern.[21] Flooding and winter storms were determined to represent a high frequency, seriously severe hazard for the Town, with hurricanes/tropical storms categorized as seriously severe events occurring with medium frequency. Extreme temperatures were noted to be high-frequency events of minor severity. Ranking lower in priority, wildfires were identified as medium-frequency events of minor severity, and tornadoes and earthquakes as low-frequency, serious events. Landslides were classified as very low frequency minor hazards and major urban fires, coastal erosion, and tsunamis were determined not relevant to the Town (**Table 4-2**). Ultimately, the Regional HMP assessed the relationship of 83 Critical Facilities in the Town to the FEMA Flood Zone, locally identified Flood Areas, 100-year Wind Event, Average Annual Snowfall, Wildfire Susceptibility, Landslide Risk, and Peak Ground Acceleration (Earthquakes).[22]

Table 4-2. 2015 OCPC Regional HMP Hazard Identification

HAZARD	FREQUENCY	SEVERITY	HAZARD RANKING
Flooding	High	Serious	6
Winter Storms	High	Serious	6
Hurricanes/Tropical Storms	Medium	Serious	5
Extreme Temperatures	High	Minor	5
Wildfires	Medium	Minor	4
Tornadoes	Very Low	Serious	3
Earthquakes	Very Low	Serious	3
Landslides	Very Low	Minor	2
Major Urban Fires	Not Applicable	Not Applicable	Not Applicable
Coastal Erosion/Shoreline Change	Not Applicable	Not Applicable	Not Applicable
Tsunamis	Not Applicable	Not Applicable	Not Applicable

Source: 2015 OCPC Regional HMP, p. 197.

[21] Old Colony Planning Council Natural Hazard Mitigation Plan for the Old Colony Region, 2015, p. 197.
[22] Ibid. pp. 192-196.

4.1.3 Massachusetts SHMCAP Hazards Identification

The Massachusetts 2018 State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) presents statewide risk assessment information under five major climate change/natural hazard headings:

- Changes in Precipitation - Inland flooding (including dam overtopping), Drought, and Landslide
- Sea Level Rise – Coastal flooding, Coastal erosion, Tsunami
- Rising Temperatures – Average/Extreme Temperature, Wildfires, Invasive Species
- Extreme Weather – Hurricanes/Tropical storms, Severe Winter Storm/Nor'easter, Tornadoes, Other
- Non-climate-influenced Hazards – Earthquakes

Table 4-3 summarizes a more recent assessment of the frequency and severity of natural hazards and climate vulnerabilities in the Commonwealth relative to the Town of Pembroke. Specific natural hazard information from the Massachusetts SHMCAP that relates to the Plymouth County region and/or the Town of Pembroke is detailed in sections 4.2 through 4.7.

Table 4-3. Massachusetts Hazard Summary Relative to the Town of Pembroke*

Hazard	Massachusetts		Pembroke	
	Frequency	**Severity**	**Frequency**	**Severity**
Flooding	High | 1 DR per 1.25 years over 28 yrs	Serious to Catastrophic	High | 19 serious events over 28 years+	Serious
Dam Failure	Very Low | 8 notable failures over 139 yrs	Extensive to Catastrophic	Very Low	Minor to Serious
High Wind	High | 10 events/yr from 2000-2020***	Minor to Extensive	Medium | 3.6/year***	Minor to Serious
Hurricane/Tropical Storm	High | 1 event/2 yrs	Serious to Catastrophic	Medium | 1 per 2.5 years ***	Serious
Tornadoes	High | 1.8-2.6/year	Minor to Extensive	Very Low | 7 since 1951	Serious
Thunderstorms	High | 20-30/year	Minor to Extensive	Medium | 3/year***	Minor to Serious
Nor'easters	High | 1-4/year	Minor to Extensive	High	Serious
Snow & Blizzard	High | 1/year	Minor to Extensive	High | 2.5 per year*** / 1 High-Impact event every other year (NESIS) / 1 Winter Storm DR every 6.5 years	Serious
Ice Storms	High | 1.5/year	Minor to Extensive	Low	Minor to Serious
Earthquakes	Very Low | 408 felt events over 348 yrs; damaging events in 1727(M5.6), and 1755(M6.2)**	Minor to Catastrophic	Very Low | 1 per 10 years; Lakeville 1982 M3.0, No. Pembroke 1993 M2.1, Plympton 2015 M1.8, No. Plymouth 2019 M2.1*	Serious
Landslides	Low | 1 per 2 years in W. Mass.	Minor to Extensive	Very Low	Minor

Hazard	Massachusetts		Pembroke	
Wild/Brush Fires	High | 1/year	Minor to Extensive	Very Low | 2 events in Plymouth in 1957 and 1964; 0 events in Pembroke	Minor
Extreme Temperatures	High | 1.5 cold and 2 hot weather events per year	Minor to Serious	High | 2.5 hot weather events per years^^^	Minor to Serious
Drought	High | 8% Chance Drought Watch/year	Minor to Serious	Medium | 2 severe droughts 2000-2020^^	Minor to Serious
Coastal Hazards	High | 6 per year last 10 years	Serious to Extensive	Not Applicable	Not Applicable
Tsunamis	Very Low | 1 per 39 years East Coast, none in MA	Extensive to Catastrophic	Not Applicable	Not Applicable

+Massachusetts State Hazard Mitigation and Climate Adaptation Plan Flood-related Declared Disasters. Note that the NOAA NCEI Storm Events database identifies 45 flood events between 1999-2019 for Plymouth County.
* Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Appendix B.
**Northeast States Emergency Consortium: Massachusetts Earthquakes.
***NOAA NCEI Storm Events Database.
^USGS Earthquake Hazards. https://Earthquake.usgs.gov
^^US Drought Monitor.
^^^ US Climate Resilience Toolkit ACIS Data Brockton Station USC00190860.

4.1.4 Previous Federal/State Disasters

The record of Presidential Declared Disasters for Plymouth County provides additional data regarding the frequency and type of hazard events that have impacted the Pembroke area over the past 30 years (**Table 4-4**).

Since 1991, 23 Emergency or Disaster Declarations have been issued that included Plymouth County.[23] Of these, 4 were hurricanes (Bob, Katrina, Earl, and Sandy) and 1 was a tropical storm (Irene). Ten involved heavy rain or severe storms and flooding that did not occur during winter months. An additional 9 entailed severe winter storms, blizzards, or snowstorms, most accompanied by flooding. This record indicates that severe rain, snow, and wind events pose significant hazard concerns for the Town of Pembroke.

[23] Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018, Appendix B.

Table 4-4. Presidential Disaster Declarations for Plymouth County, 1991-2020*

Disaster Name/Disaster Number	Event Date	Declared Counties
Hurricane Bob | FEMA-914-DR-MA	August 1991	Barnstable, Bristol, Dukes, Essex, Hampden, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk
Severe Coastal Storm | FEMA-920-DR-MA	October 1991	Barnstable, Bristol, Dukes, Essex, Middlesex, Plymouth, Nantucket, Norfolk, Suffolk
Winter Coastal Storm | FEMA-975-DR-MA	December 1992	Barnstable, Dukes, Essex, Plymouth, Suffolk
Blizzard | FEMA-3103-EM	March 1993	All 14 counties
Blizzard | FEMA-1090-EM	January 1996	All 14 counties
Severe Storms, Flood | FEMA-1142-DR-MA	October 1996	Essex, Middlesex, Plymouth, Norfolk, Suffolk
Heavy Rain, Flood | FEMA-1224-DR-MA	June 1998	Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Severe Storms and Flooding | FEMA-1364-DR-MA	March 2001	Bristol, Essex, Middlesex, Norfolk, Suffolk, Plymouth, Worcester
Snowstorm | FEMA-3175-EM	February 2003	All 14 counties
Snowstorm | FEMA-3191-EM	December 2003	Barnstable, Berkshire, Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, Plymouth, Suffolk, Worcester
Snow | FEMA-3201-EM	January 2005	All 14 counties
Hurricane Katrina | FEMA-3252-EM	August 2005	All 14 counties
Severe Storms and Flooding | FEMA-1614-DR-MA	October 2005	All 14 counties
Severe Storms and Flooding FEMA-1642-DR-MA	May 2006	All 14 counties
Severe Storms & Inland, Coastal Flooding | FEMA-1701-DR-MA	April 2007	All 14 counties

Disaster Name/Disaster Number	Event Date	Declared Counties
Severe Storms and Flooding | FEMA-1813-DR-MA	December 2008	All 14 counties
Severe Storms and Flooding | FEMA-1895-DR-MA	March-April 2010	Bristol, Essex, Middlesex, Norfolk, Plymouth, Suffolk, Worcester
Hurricane Earl | FEMA 3315-EM	September 2010	Worcester, Middlesex, Essex, Suffolk, Norfolk, Plymouth, Bristol, Barnstable, Dukes, Nantucket
Tropical Storm Irene | FEMA-4028-DR-MA	August 2011	Barnstable Berkshire, Bristol, Dukes, Franklin, Hampden, Hampshire, Norfolk, Plymouth
Hurricane Sandy | FEMA-4097-DR-MA	October – November 2012	Barnstable, Bristol, Dukes, Nantucket, Plymouth, Suffolk
Severe Winter Storm, Snowstorm and Flooding | FEMA-4110-DR-MA	April 2013	All 14 counties
Severe Winter Storm, Snowstorm and Flooding | FEMA-4214-DR-MA	April 2015	Barnstable, Bristol, Dukes, Essex, Middlesex, Nantucket, Norfolk, Plymouth, Suffolk, Worcester
Severe Winter Storm and Flooding | FEMA-4372-DR-MA	March 2018	Barnstable, Bristol, Essex, Nantucket, Norfolk, Plymouth

* Does not include 2020 COVID Disaster Declarations.
Source: MA SHMCAP 2018 and FEMA Declared Disasters https://www.fema.gov/disasters/disaster-declarations

4.2 Flood Hazards

Inland flooding can result from moderate precipitation over several days, intense precipitation over a short period, melting snowpack, or a combination of these factors. The magnitude of impact can be exacerbated if extreme rainfall occurs during prolonged wet periods when antecedent soil moisture is high. The Massachusetts 2018 SHMCAP notes that increasing precipitation and extreme storm events associated with climate change will increase inland flooding, including riverine overbank and flash flooding, and storm system surcharge.[24] These events can also cause overtopping when flood flows exceed the capacity of a dam, the spillway is blocked, or the dam crest has settled.

Massachusetts receives an average of 48 inches of rainfall per year with monthly means between 3-4 inches in all regions of the state. Heavy rainfall events occur regularly, rendering the majority of communities in the Commonwealth vulnerable to riverine flooding.[25] Between 1954 and 2017, Massachusetts had 22 major flood (or flood-related) events.

[24] Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018, p. 4-3.
[25] Ibid. p. 4-8.

Between 2007 and 2014 alone, the average annual cost of flood damages in Massachusetts exceeded $9 million,[26] with inland flooding caused by Nor'easters, ice jams, hurricanes/tropical storms, and other heavy precipitation events. **Figure 4-1** illustrates the number of FEMA-declared flood-related disasters over a 60-year period by Massachusetts county; Plymouth County, which includes Pembroke, experienced 15 flood-related disasters, the third highest number for all 14 counties in the State.[27]

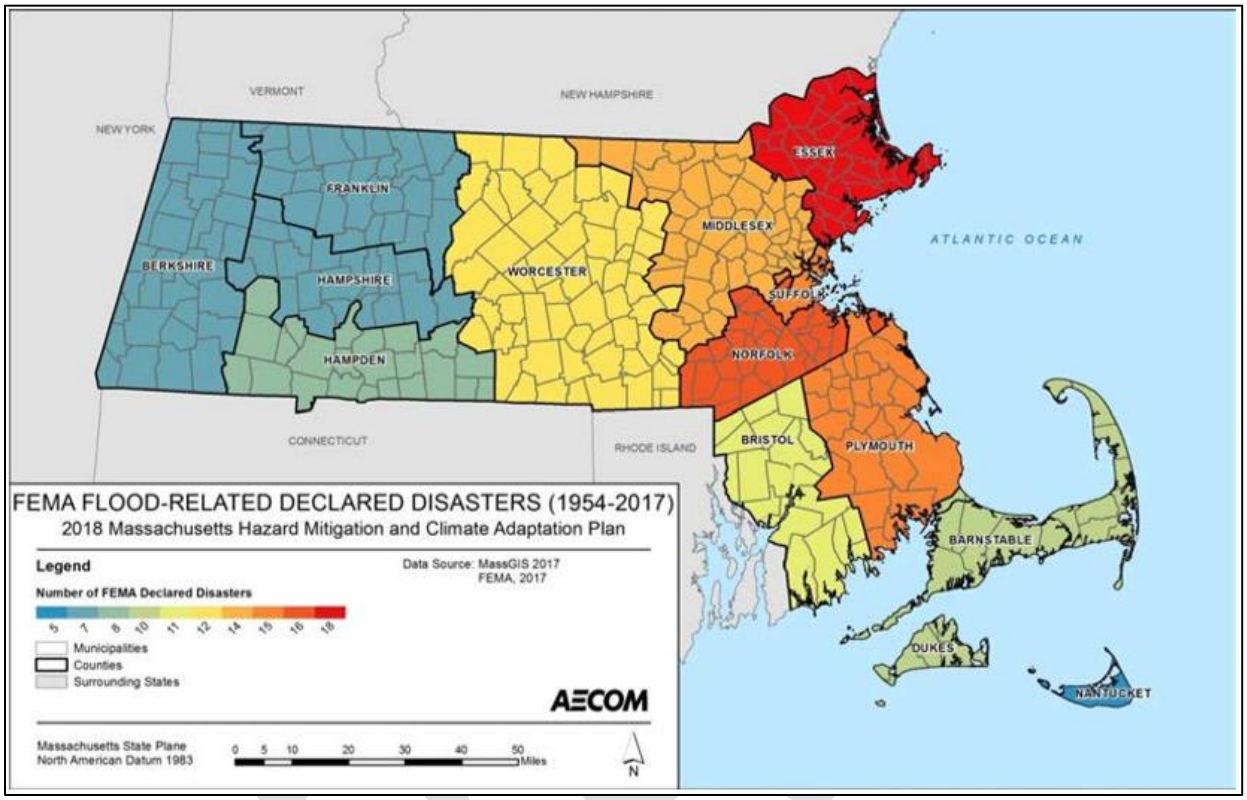
4.2.1 Regional Flood Events

The USGCRP Climate Resilience Toolkit identifies flooding and precipitation variability as growing challenges for the Northeast region. The NOAA NCEI State Climate Summary for Massachusetts notes that precipitation has increased during the last century with a record-setting number of extreme events occurring over the last decade. Winter and spring rain storms are projected to increase, with more expected to carry heavy rainfall.[28]

NOAA Atlas 14 is a Precipitation-Frequency Atlas of the United States; Volume 10, Version 3 pertains to the humid northeast, including CT, ME, MA, NH, NY, RI, and VT. In discussing the climatology of extreme precipitation for this region, the Atlas notes that mean annual amounts vary moderately as compared with the rest of the US, with minima in the northern and western interior lowlands and maxima along the coast and in higher elevations. Day-long extreme precipitation events occur throughout the year but are more common between spring and fall when strong cold fronts and other dynamic forces are prevalent. Areas along the coast, including the Town of Pembroke, have a slightly longer rainy season with extreme events into late fall and early winter. Hourly duration heavy precipitation is most likely to occur spring through fall with a maximum in summer. Heavy rainfall can also result from consecutive thunderstorms where one follows the path of another, leading to rainfall over an area for several hours. From October through April, Nor'easters that develop off the New England coast produce significant rain or snow; these extratropical cyclones can experience explosive development when cold polar air from Canada interacts with the warm Gulf Stream waters of the Atlantic. [29] The Atlas goes on to note that tropical cyclones – which include tropical depressions, tropical storms, and hurricanes – can also deliver heavy precipitation to the northeast during summer and fall. Notable examples include the "Long Island Express" Hurricane in 1938, the Great Atlantic Hurricane in 1944, hurricanes Carol and Edna in 1954, Hurricane Diane in 1955, Hurricane Donna in 1960, Hurricane Agnes in 1972, Hurricane Floyd in 1999, and Hurricane Irene in 2011.

[26] National Oceanic and Atmospheric Administration (NOAA). 2014. United States Flood Loss Report – Water Year 2014 in Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018, p. 4-1.
[27] Ibid. p. 4-9.
[28] NOAA National Centers for Environmental Information State Climate Summaries: Massachusetts, 2017.
[29] US Department of Commerce, NOAA, NWS *NOAA Atlas 14 Precipitation-Frequency Atlas of the United States, Vol. 10 v. 3.0: Northeastern States,* 2015 revised 2019, Silver Spring MD, pp. 6-7 of 265 pp.

Figure 4-1. FEMA Flood Declared Disasters by Massachusetts County



(Source: 2018 MA SHMCAP)

Seventeen significant regional storm events accompanied by flooding have occurred in Plymouth County between 1991 and 2018, as follows:[30]

Hurricane Bob	August 1991
Halloween Nor'easter	October 1991
Winter Storm	December 1992
Severe Storm (Rain)	October 1996
Heavy Rain, Flood	June 1998
Severe Storms, Flooding	March 2001
Winter Storm	January 2005
Hurricane Katrina	August 2005
Severe Storms, Flooding	October 2005
Severe Storms, Flooding	May 2006
Severe Storms, Flooding	April 2007
Severe Storms, Flooding	December 2008
Severe Storms, Flooding	March-April 2010
Tropical Storm Irene	August 2011

[30] Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018, Appendix B, pp. 1-13.

Severe Winter Storm, Snowstorm, Flooding	April 2013
Severe Winter Storm, Snowstorm, Flooding	April 2015
Severe Winter Storm, Flooding	March 2018

The NOAA National Centers for Environmental Information (NCEI) Storm Events Database records data for a range of storm types by State and County. Flood events recorded for Plymouth County (which includes the Town of Pembroke) from 12/1/99 to 12/31/19 are summarized in **Table 4-5**. It should be noted that the NCEI database contains multiple storm categories that are likely to include accessory flooding (e.g., Flash Flood, Coastal Flood, Heavy Rain, Hurricane, Tropical Depression, Winter Storm); only the events classified as "Flood" are presented in Table 4-5, suggesting that the actual regional flood hazard potential is somewhat higher.

Fifty-five events were reported over 45 days between 12/1/99 and 12/31/2019 with no loss of life or injury. The most notable event occurred in March 2010, when a low pressure system deposited 6 to 10 inches of rain across eastern Massachusetts, causing several streams to flood. These included the Taunton River at Bridgewater, the Jones River at Kingston, and the Indian Head River at Hanover. Several streets were closed throughout East Bridgewater, Bridgewater, and Whitman. In addition, collections at the Holmes Public Library in Halifax were damaged by floodwaters. Residents of John Dunn Drive in Rockland were evacuated from their homes and forty homes in Brockton were evacuated after power and gas were shut off to the houses. Just two weeks later, on March 29, 3 to 8 inches of rain fell across Plymouth County again causing several streams to rise above flood stage, including the Taunton River at Bridgewater (which set a record), the Indian Head River at Hanover, and the Jones River at Kingston. Several ponds in Lakeville overflowed their banks causing 35 families to evacuate their homes. Two buildings in the Ashley Place condominium complex in Middleborough were evacuated due to flooding, as well as a day care center on Route 28 and a multi-family dwelling on Ames Street in Brockton. Many streets flooded (and most were eventually closed) in Wareham, Mattapoisett, Scituate, Bridgewater, Brockton, East Bridgewater, Middleborough, Kingston, and Lakeville, including Route 105 in Middleborough where it passes under Interstate 495 at exit 4. This intersection was eventually closed, as were portions of Route 44 in Middleborough, and Route 18 in Whitman between routes 27 and 14. Several basements in Marion and Norwell were flooded with several feet of water, and West Bridgewater High School was closed due to flooding that threatened the electrical system. Several sewage treatment plants in the region also flooded, discharging raw sewage into rivers and other bodies of water.[31]

Table 4-5. Plymouth County, MA Flood Events 1999 – 2019[32]

Location	Report Date	Deaths	Injuries	Property Damage ($)
EASTERN PLYMOUTH (ZONE)	03/05/01	0	0	0
EASTERN PLYMOUTH / ALSO PART OF NORFOLK (ZONE)	03/28/05	0	0	0

[31] Ibid. https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=220249

[32] National Oceanic and Atmospheric Administration (NOAA). 2020. National Centers for Environmental Information, Storm events database. https://www.ncdc.noaa.gov/stormevents/listevents.jsp?eventType=%28Z%29+Flood&beginDate_mm=01&beginDate_dd=01&beginDate_yyyy=1999&endDate_mm=12&endDate_dd=31&endDate_yyyy=2019&county=PLYMOUTH%3A23&hailfilter=0.00&tornfilter=0&windfilter=000&sort=DT&submitbutton=Search&statefips=25%2CMASSACHUSETTS

Location	Report Date	Deaths	Injuries	Property Damage ($)
WESTERN PLYMOUTH (ZONE)	10/15/05	0	0	350K
EASTERN PLYMOUTH / ALSO PART OF NORFOLK (ZONE)	10/15/05	0	0	200K
WESTERN PLYMOUTH (ZONE)	10/15/05	0	0	50K
WESTERN PLYMOUTH (ZONE)	10/15/05	0	0	100K
EASTERN PLYMOUTH / ALSO PART OF NORFOLK (ZONE)	10/15/05	0	0	140K
EASTERN PLYMOUTH / ALSO PART OF NORFOLK (ZONE)	10/25/05	0	0	35K
SOUTHERN PLYMOUTH (ZONE)	12/09/05	0	0	40K
HINGHAM	05/13/06	0	0	500K
COUNTYWIDE	05/13/06	0	0	0
COUNTYWIDE	06/07/06	0	0	30K
HULL	06/23/06	0	0	2K
HINGHAM	08/20/06	0	0	5K
BROCKTON	10/28/06	0	0	10K
HINGHAM	03/02/07	0	0	10K
HINGHAM	03/17/07	0	0	8K
HINGHAM	04/15/07	0	0	25K
PLYMOUTH	02/13/08	0	0	0
WAREHAM	03/08/08	0	0	5K
ACCORD	03/08/08	0	0	0
PINEHURST BEACH	09/27/08	0	0	50K
WHITMAN	05/24/09	0	0	0
ANTASSAWAMOCK	08/29/09	0	0	0
HANOVER	03/14/10	0	0	16.15M
STANLEY	03/29/10	0	0	8.07M
STANLEY	04/01/10	0	0	0
WEST WAREHAM	07/13/11	0	0	5K
MONTELLO	08/10/12	0	0	30K
EAST WAREHAM	05/11/13	0	0	0
MARION	05/11/13	0	0	0
MARION	06/07/13	0	0	0

Location	Report Date	Deaths	Injuries	Property Damage ($)
EAST MARION	09/03/13	0	0	0
BROCKTON	03/30/14	0	0	0
HARBOR BEACH	03/30/14	0	0	0
MIDDLEBORO	10/22/14	0	0	0
MARION	11/17/14	0	0	0
PLYMOUTH ARPT	05/31/15	0	0	0
TREMONT	07/28/15	0	0	15K
MARION	09/10/15	0	0	0
PLYMOUTH	10/29/15	0	0	0
FIVE CORNERS	05/30/16	0	0	0
SCITUATE	04/01/17	0	0	5K
WHITMAN	04/06/17	0	0	5K
PARKWOOD BEACH	06/24/17	0	0	1K
STANLEY	10/25/17	0	0	0
EAST WEYMOUTH	10/25/17	0	0	0
KINGSTON	10/29/17	0	0	0
NAMELOC HGTS	01/12/18	0	0	0
KINGSTON	11/03/18	0	0	1K
WEST HINGHAM	04/15/19	0	0	0
KINGSTON	07/12/19	0	0	0
EAST MARION	07/22/19	0	0	0
BROCKTON HGTS	09/02/19	0	0	1K
MONTELLO	09/02/19	0	0	1K
TOTAL				**25.844M**

4.2.2 Local Areas of Flooding

Pembroke is principally located within the South Coastal Watershed. Only a small area in the southwest corner of the Town, around Stetson Pond, is tributary to the Taunton Watershed. Rivers and streams in the community include the tidally influenced North River and its headwaters, the Indian Head River, Robinson Creek, Swamp Brook, Pudding Brook and Little Pudding Brook, McFarland Brook, Rocky Run, and Herring Run. Pine Brook defines the Town's southeast border with neighboring Duxbury and the two communities share Lower Chandler Pond. The north extent of the 617-acre Silver Lake lies within the Town's south border and multiple ponds are scattered throughout the community: Oldham (231.9 acres), Furnace (102.7 acres), Great and Little Sandy Bottom (103 and 56 acres, respectively), Hobomock (12.7 acres), Upper and West Chandler (7.7 and 9.8 acres, respectively), and Stetson (88.2 acres). The eastern part of the Town also includes a non-potable reservoir fed by Pudding and McFarland brooks and the Town has five groundwater supply wells in the vicinity of Great and Little Sandy Bottom ponds and Tubbs Meadow. (**Figure 4-2**).

FEMA-designated flood zones are identified on the Flood Zones and SLOSH Hazard Map (**Appendix A**). Zones A, AE, and X-shaded are located primarily along the North River, Robinson Creek, and Cedar Swamp, Herring, Little Pudding, and Pudding brooks, and along the pond shorelines.

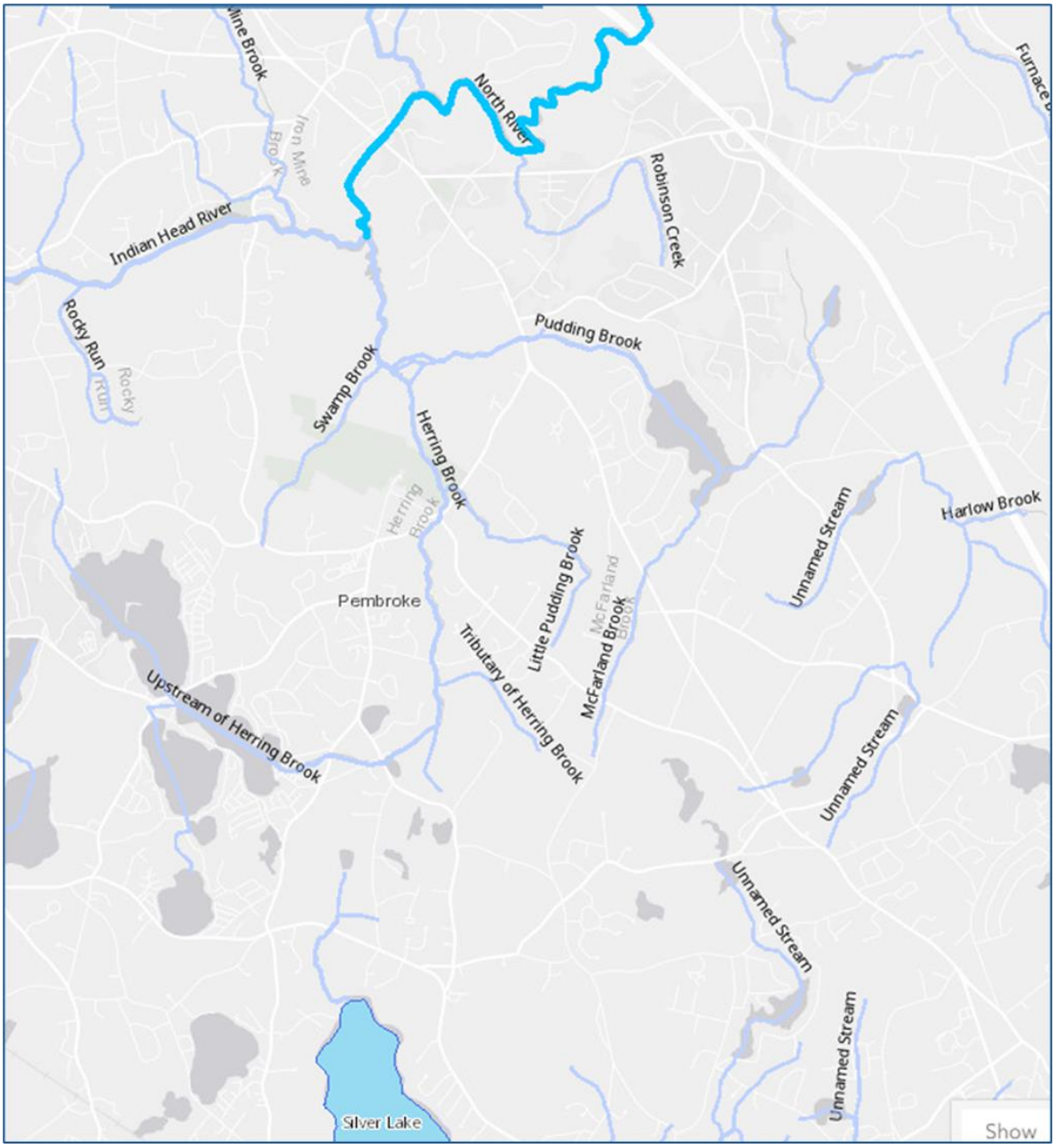
The 2015 OCPC RHMP identified local areas of flooding as Mill Pond Road, Glenwood Road, Center Street at Hobomock Street south to Herring Brook, Brenda Lane at Plymouth Street, Dwelley Street at the Hanson Town Line, Birch Street at the Duxbury Town Line, Mill Street at the low point (house numbers 54 and 66), Lake Shore Drive at the Lower Chandler Pond culvert, Mill Pond off Hobomock Street, Indian Head River dam at West Elm Street at the Hanover Town Line, and Valley Street at the Duxbury Town Line/Upper Chandler Pond.

Table 4-6 summarizes the areas of local flooding identified during the CRB Workshop and as part of this MVHMP. Areas addressed since the 2015 RHMP include Glenwood Road (pump chamber installed) and Lake Shore Drive at Lower Chandler Pond where the culvert was replaced by the Town working jointly with the Town of Duxbury. Additional mitigation underway includes evaluation of the culvert at Park Street, design of the culvert at Herring Run, and completion of a drainage and alternatives analysis for Taylor Street at the ledges and Lorna Avenue in the Blake/Burr roads area. Flooding in the low-lying areas that include the Memory Care Facility "Bridges" (Route 139 and Cross Street) were addressed by installing a drainage swale four years ago.

Table 4-6. Areas of Local Flooding

Area of Local Flooding	Flood Zone	Area of Local Flooding	Flood Zone
Mill Pond Road	A	Congress Street (undersized culvert)	
Center Street at Hobomock Street south to Herring Brook (Zone AE at Herring Brook)	AE at Herring Brook	Brenda Lane at Plymouth Street	No
Dwelley Street at the Hanson Town Line	No	Birch Street at the Duxbury Town Line	No
Mill Street (low point at house numbers 54 and 66)	No	Woodbine and Shepard avenues at the beach (high groundwater table)	Near X shaded
Mill Pond off Hobomock Street	AE	Indian Head River dam at West Elm Street at the Hanover Town Line	AE – Regulatory Floodway
Valley Street at the Duxbury Town Line	A	Low-lying areas	

Figure 4-2. Pembroke Water Features



Source: NOAA Water Resources Dashboard.

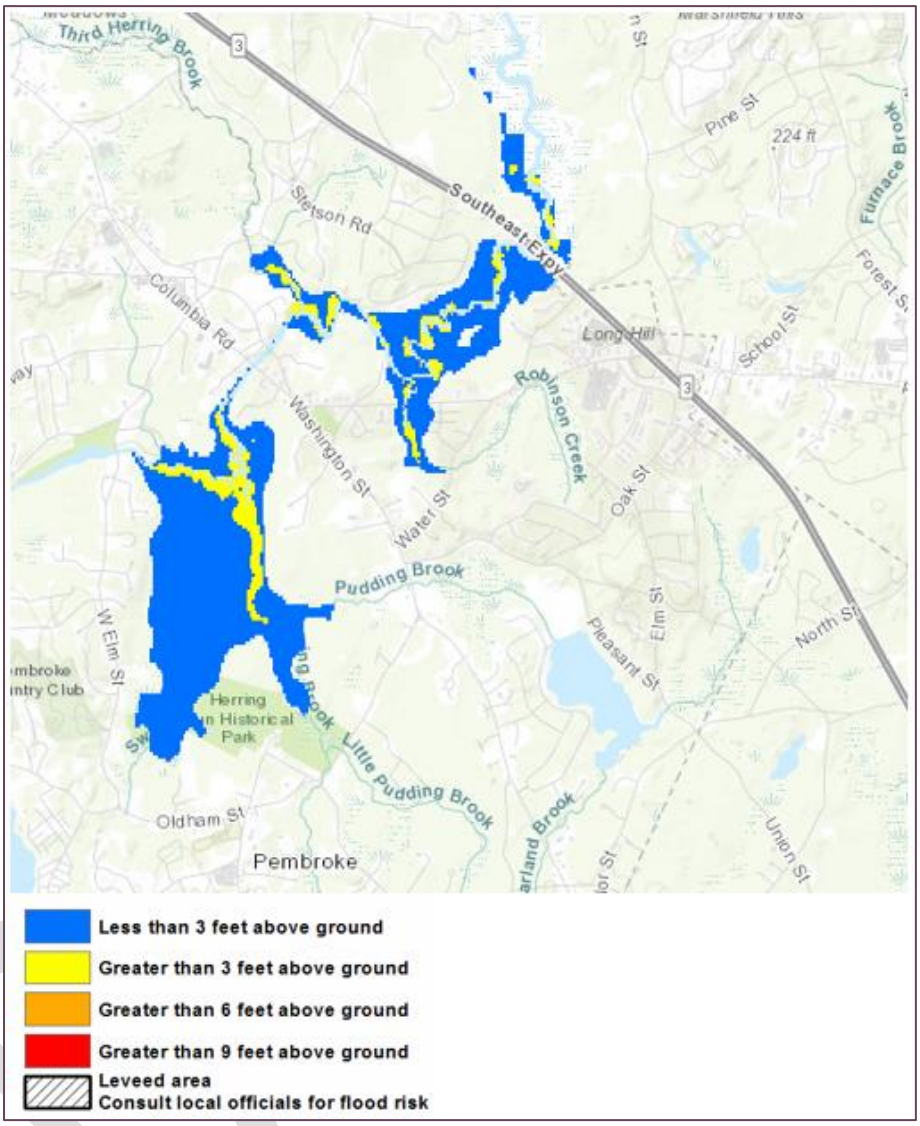
4.2.2.1 Hurricane Surge Inundation Zones (HSI)

In addition to high winds and heavy precipitation loads, hurricanes are capable of producing Sea, Land, and Overland Surges or Hurricane Surge Inundation (HSI). Coastal storm surge is an abnormal rise of water generated by storm winds blowing onshore; its height is determined by the approaching angle of the storm and coastline characteristics. SLOSH is the computer model utilized by NOAA to assess coastal inundation risk and predict storm surge. Although

the Town of Pembroke is approximately 5-7 miles from the coast of Massachusetts, its northern sections are subject to hurricane surge inundation along the North River as far inland as Herring Run Historical Park, Misty Meadow Conservation Area, the North Pembroke School Conservation Area, and the area bounded by the Indian Head River and North River north of Schoosett Street. **Figure 4-3** illustrates the depth of storm surge for a Category 1 Hurricane and **Figure 4-4** depicts the extent of storm surge for hurricane categories 1-4. The HSI inundated zones are depicted on the Flood and SLOSH Hazard Map in Appendix A. It is worth noting that only one hurricane affecting the Pembroke region – Bob, in 1991 - has exceeded Category 1.

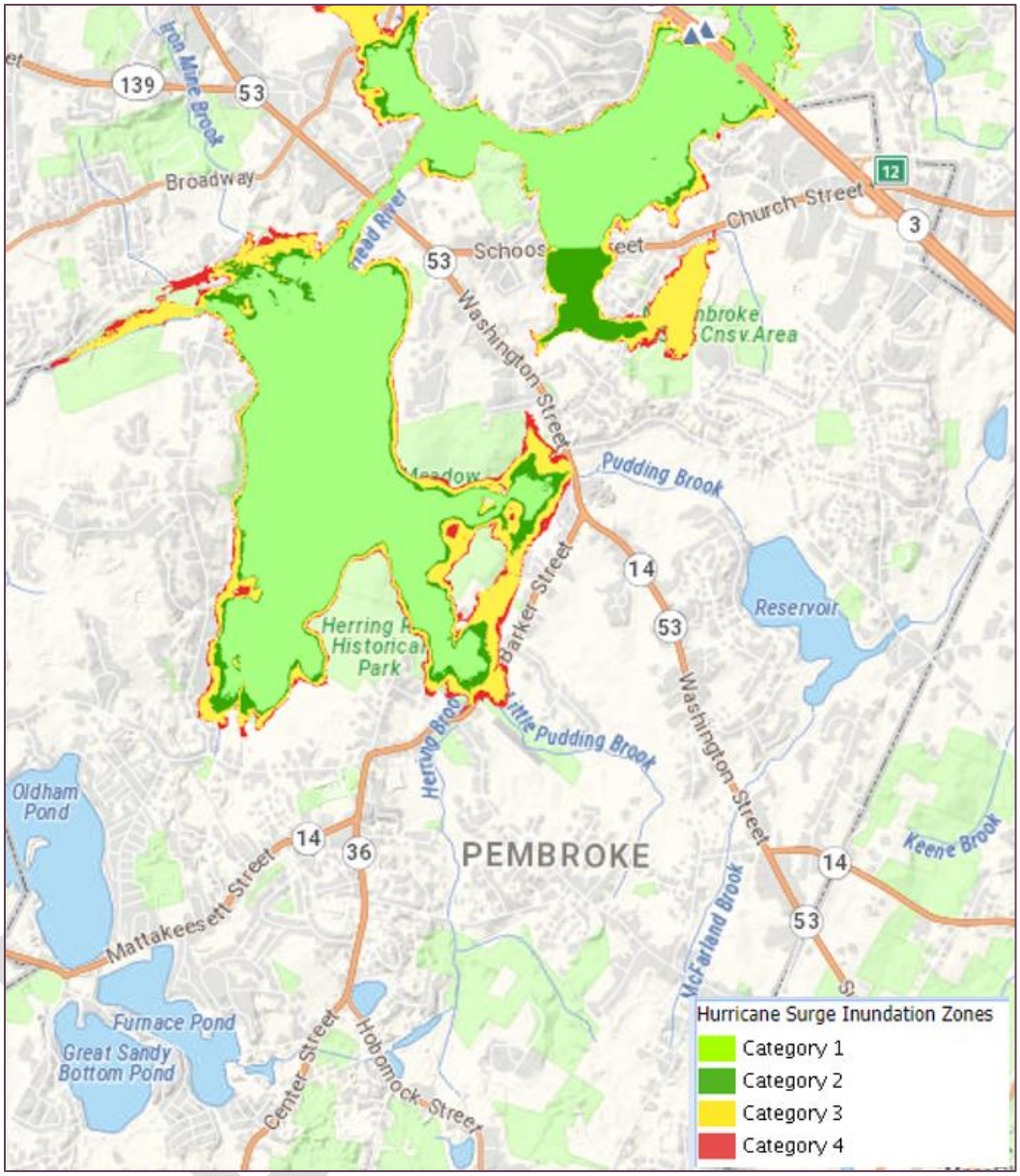
No Town structures are impacted by Hurricane Surge Inundation in a Category 1 storm. Structures potentially affected by HSI for Category 2, 3, and 4 storms in the Town of Pembroke include those east of West Elm Street, north of Oldham Street and Pleasant Lane, northeast of Allen Street, southeast of Barker Street at Little Pudding Brook, northwest of Barker Street, west of Red Barn Road, on Washington Street, Canoe Club Lane, Water Street, west of Lorna Avenue, on Burr Avenue at Lorna Avenue, and north of Schoosett Street. These are discussed in more detail in Section 5.0, Risk Assessment, and locations are generally indicated on the Flood and SLOSH Hazard Map (**Appendix A**). According to the Town, there is no history of any of the above areas being impacted by HSI.

Figure 4-3. Hurricane Surge Inundation Zone Category 1



. *National Storm Surge Hazard Maps, NOAA/NWS/NHC Storm Surge Unit.*

Figure 4-4. Hurricane Surge Inundation Zones, Town of Pembroke



Source: MassGIS Oliver.

4.2.2.2 2015 Old Colony Planning Council Regional HMP

The 2015 Natural Hazard Mitigation Plan for the Old Colony Region summarized hazard risks for Pembroke, characterizing flooding as a High frequency, Serious risk, the highest of the Town's hazard rankings.[33] The RHMP identified flooding as the most frequent hazard affecting Pembroke, the result of strong tropical storms, winter storms,

[33] Old Colony Planning Council, *Natural Hazard Mitigation Plan for the Old Colony Region*, May 2015, p. 197.

nor'easters, and periods of heavy rain during the spring and autumn months. Producing very high volumes of rain, these events cause rivers and streams to overflow their banks and overwhelm the community's stormwater infrastructure system, necessitating road closures and flooding recreational areas. According to the Town, there are no reports to their insurance carrier for any flood or storms or related damages to any structure in Pembroke within the past 30 years.

The characterization of flood risk as High frequency/Serious is continued for this MVHMP **(Table 4-3).**

4.2.2.3 2021 CRB Workshop Findings

The Town's Community Resilience Building Workshop was held as an 8-hour in-person session on October 6, 2021 and provided current community perceptions and information pertaining to flood hazards in Pembroke. Areas of local flooding concern are discussed in Chapter 2 and listed in Section 4.2.2.2.

4.2.2.4 Repetitive Loss and Severe Repetitive Loss Properties

There are no Repetitive Loss or Severe Repetitive Loss properties in the Town of Pembroke.[34] The Town NFIP Community Information System data is discussed in greater detail in Section 5.1.3.3.

4.2.3 Effect of Climate Change

The Fourth National Climate Assessment Volume II (NCA4), prepared by the US Global Change Research Program, considers the human welfare, societal, and environmental elements of climate change and variability for 10 regions and 18 national topics; it pays particular attention to observed and projected risks, impacts, consideration of risk reduction, and implications under different mitigation pathways.[35] For the Northeast Region, the Assessment finds that seasons are becoming less distinct, with milder winters and earlier spring conditions, altering ecosystems and environments to adversely impact tourism, farming, and forestry. Warmer ocean temperatures, sea level rise, and ocean acidification also threaten commerce, tourism, and recreation important to the Northeast regional economy. Major negative impacts on critical infrastructure, urban economies, and nationally significant historic sites are occurring and will become more common, threatening the ability of urban centers to function as regional and national hubs for cultural and economic activity. More extreme weather, warmer temperatures, degradation of air and water quality, and sea level rise are expected to lead to health-related impacts and costs, including additional deaths, emergency room visits, hospitalizations, and a lower quality of life. Health impacts are expected to vary by location, age, current health, and other characteristics of individuals and communities. The US Climate Resilience Toolkit notes that rising temperatures and altered precipitation patterns are significantly changing the quantity and quality of water available to humans and natural systems in the US; this impact is exacerbated by deteriorating flood control and water supply infrastructure.[36]

Throughout the Northeast, the recent dominant precipitation trend of increasing rainfall intensity exceeds the pattern for all other regions of the contiguous United States.[37] Rainfall intensity is projected to continue to increase with concomitant increases in total precipitation during winter and spring but little change in summer. Monthly precipitation

[34] J. Duperault, Director, Flood Hazard Management Program, MA DCR (personal communication, January 23, 2020).
[35] USGCRP, 2018, rev. 2019: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: Report-in-Brief [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 186 pp. doi: 10.7930/NCA4.2018.RiB
[36] US Climate Resilience Toolkit, Water. https://toolkit.climate.gov/topics/water
[37] Ibid, p. 117.

in the Northeast is projected to be about 1 inch greater for December through April by end of century (2070–2100) under the higher greenhouse gas emissions scenario (RCP8.5).

Average annual precipitation in Massachusetts varies from 40-50 inches across the State. According to the Northeast Regional Climate Center NCEI State Climate Summary for Massachusetts, precipitation statewide has increased during the last century with a record-setting number of extreme events in the last decade. Following the regional pattern, winter and spring precipitation and heavy rainfall events are projected to increase statewide.[38] **Figure 4-5** illustrates the projected mid-21st century spring precipitation associated with a higher emissions pathway across Massachusetts relative to recorded levels for the late 20th century.

The NRCC NCEI State summary for Massachusetts notes that precipitation is abundant but highly variable from year to year. The driest conditions were observed in the early 1900s and again in the 1960s, with wetter conditions occurring since the 1970s. The most recent 10 years have been the wettest period on record, averaging about 51 inches per year, well above the long-term average of about 45 inches per year (**Figure 4-6**). The driest 5-year period was 1962–1966 and the wettest 2005–2009. Since 2005, Massachusetts has experienced the largest number of extreme events, defined as days with more than 2 inches of precipitation, about 30% above the long-term average (**Figure 4-7**). In March of 2010 alone, three intense rainstorms led to extensive flooding throughout the state and southern New England with estimated damages of $2 billion. The heaviest rain fell in eastern Massachusetts with upwards of 7 to 10 inches falling in Methuen and Gloucester. Above average summer precipitation has been observed since 2000, with 12 of 16 summers during 2000–2015 exceeding the long-term average.[39]

Figure 4-5. MA Spring Precipitation Projection

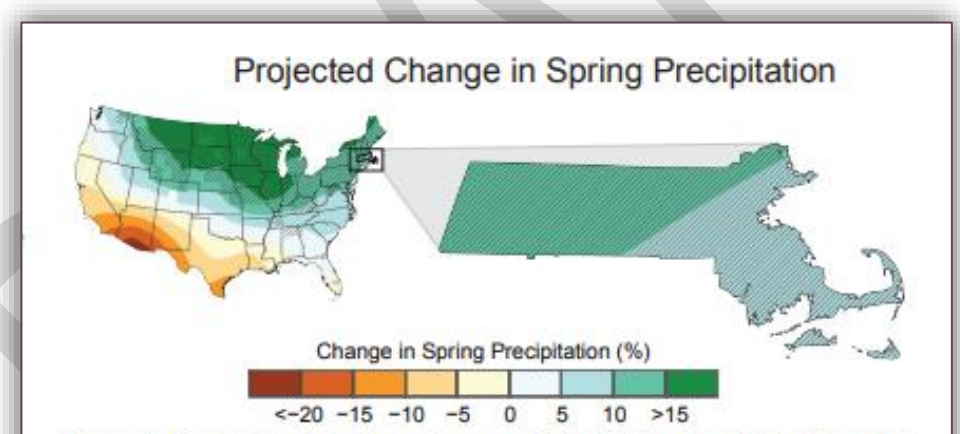
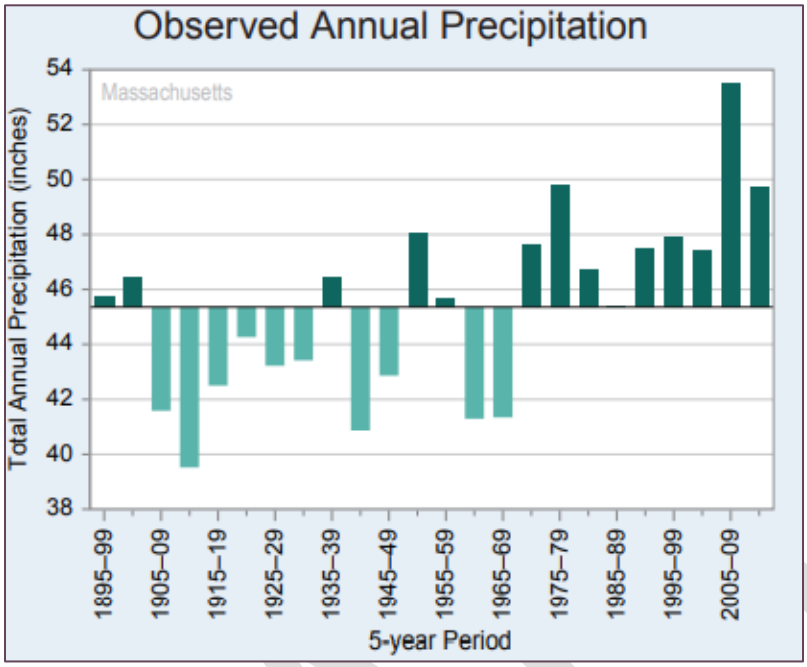


Figure 5: Projected change in spring precipitation (%) for the middle of the 21st century relative to the late 20th century under a higher emissions pathway. Hatching represents portions of the state where the majority of climate models indicate a statistically significant change. Precipitation in the spring is projected to increase in Massachusetts by mid-century. Source: CICS-NC and NOAA NCEI.

Source: NRCC NCEI State Climate Summaries: Massachusetts.

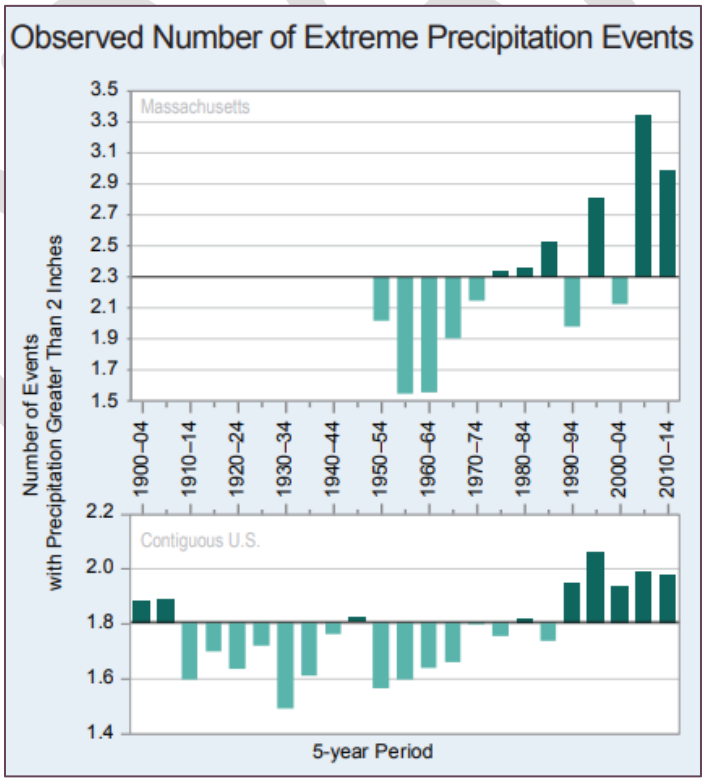
[38] Northeast Regional Climate Center, http://www.nrcc.cornell.edu/climate/resources/resources.html
[39] NOAA NCEI State Climate Summaries, Massachusetts. p. 5. https://statesummaries.ncics.org/chapter/ma/

Figure 4-6. Observed Annual Precipitation in Massachusetts 1895-2015



Source: NRCC NCEI State Summaries: Massachusetts.

Figure 4-7. Observed Extreme Precipitation Events Massachusetts and Contiguous US



Source: NRCC NCEI State Summaries: Massachusetts.

More specific to the Town of Pembroke, the US Climate Resilience Toolkit data for Hingham Station (USC00193624) indicates that from 1961 to 1980, there were nine 1-day precipitation events that exceeded 3 inches, well above the 2 inches that define extreme events. From 1981 to 2000, and again from 2001 to 2020, nearly double that number of events occurred.[40]

The climate change information for the Pembroke vicinity, the Northeast Region, and State of Massachusetts indicates that the flood hazard risk for the Town of Pembroke is likely to increase over the next decade and beyond.

4.3 Wind-related Hazards

Several natural hazards share selected characteristics and have the potential to cause common impacts. These include hurricanes, tropical storms, tornados, Nor'easters, and severe thunderstorms, all of which, while meteorologically distinct, can include high winds, heavy rain, and in some cases, snow. High wind events of all types have the potential to damage building structures and disrupt services when trees and power lines are downed. When combined with heavy rain or snow, these storms create hazardous driving conditions, impair or obstruct emergency access routes, and cause power outages, leaving residents vulnerable to extreme heat and cold depending on the season in which they occur. Outages can also disrupt critical infrastructure from functioning properly, or at all.

Resident perceptions expressed at the CRB Workshop and discussed further in the Breakout sessions identified Wind-related Hazards as one of, if not the most, significant threats facing the community. Participants indicated long periods of power outages associated with high winds as affecting the Town more than neighboring communities. Participants also indicated that such power outages, during periods of high heat or intense cold, pose a serious risk to vulnerable populations in the community including the elderly, individuals without transportation (the Town has no public option), and residents of memory care and medical facilities.

4.3.1 Hurricanes and Tropical Storms

Hurricanes begin as tropical storms over the warm moist waters of the Atlantic Ocean, off the coast of West Africa, and over the Pacific Ocean near the equator. As moisture evaporates, it rises until enormous amounts of heated, humid air are twisted high in the atmosphere. The winds begin to circle counterclockwise north of the equator (clockwise south of the equator), forming tropical cyclones (tropical depressions, tropical storms, and hurricanes) over the warm waters of the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. Tropical depressions carry sustained winds of 25-33 miles per hour, tropical storms of 34-73 mph, and hurricanes are declared when sustained winds[41] reach or exceed 74 mph. Hurricanes and their pre-cursors are rated for severity based on the Saffir-Simpson Scale which classifies hurricane-strength tropical cyclones into five categories (1-5) based on maximum sustained wind speed. Major hurricanes are considered categories 3, 4, and 5 on the Saffir-Simpson Scale (**Figure 4.8**).[42]

[40] US Climate Resilience Toolkit. https://crt-climate-explorer.nemac.org/historical-thresholds/?county=Plymouth%20County&city=Pembroke%2C%20MA&fips=25023&lat=42.07&lon=-70.81&zoom=9&nav=historical-thresholds%2F%3Fcounty&city=Pembroke%2C%20MA&fips=25023&lat=42.07&lon=-70.81&zoom=9&nav=historical-thresholds&threshold=2.1&window=1&thresholdVariable=precipitation&station=USC00193624&station-name=HINGHAM

[41] The highest wind sustained for 1 minute.

[42] Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018, p. 4-204.

Figure 4-8. Saffir-Simpson Scale of Hurricane Strength

Scale No. (Category)	Winds (mph)	Potential Damage
1	74 – 95	Minimal: Damage is primarily to shrubbery and trees, mobile homes, and some signs. No real damage is done to structures.
2	96 – 110	Moderate: Some trees topple; some roof coverings are damaged; and major damage is done to mobile homes.
3	111 – 130	Extensive: Large trees topple; some structural damage is done to roofs; mobile homes are destroyed; and structural damage is done to small homes and utility buildings.
4	131 – 155	Extreme: Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; and some curtain walls fail.
5	> 155	Catastrophic: Roof damage is considerable and widespread; window and door damage is severe; there are extensive glass failures; and entire buildings could fail.
Additional Classifications		
Tropical Storm	39-73	NA
Tropical Depression	< 38	NA

mph = miles per hour; NA = not applicable
Source: NOAA, n.d.

The Atlantic hurricane season runs from June 1 to November 30 of the year. In New England, these storms are most likely to occur in late summer and early fall, usually August through mid-October.

According to the Massachusetts SHMCAP, the entire Commonwealth is vulnerable to hurricanes and tropical storms, with areas of impact dependent on the storm track. Coastal areas are generally more susceptible to damage due to the combination of both high winds and tidal surge but inland areas are also at risk for wind damage and inland floodplains can sustain flooding due to heavy rain. According to the 2020 FEMA publication "Building Codes Save: A Nationwide Study," Plymouth County and the Town of Pembroke are within a hurricane-prone region as defined by ASCE 7-16.[43] On average, the State experiences 1 hurricane or tropical storm every 2 years with 63 events having occurred between 1842 and 2016; however storms severe enough to receive FEMA disaster declarations only occur every 9 years on average.[44] Notable events in the State since 2013 include Tropical Depression Hermine (2016) and Tropical Storm Andrea (2013). Massachusetts has not experienced any Category 4 or 5 hurricanes; however Category 3 storms have historically caused widespread flooding and wind damages have been sufficient to require individuals to be evacuated from their homes.[45]

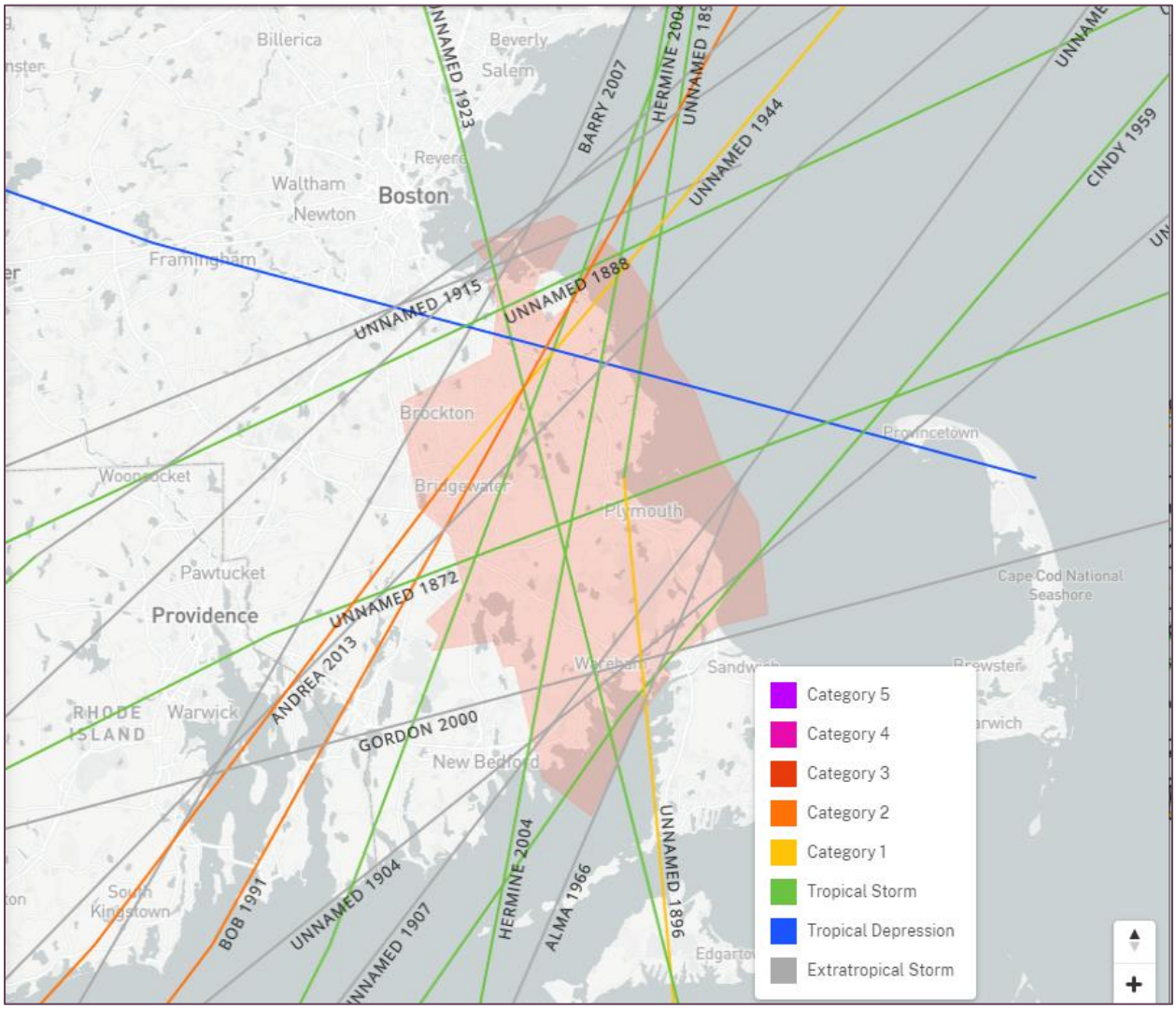
As illustrated by the Disaster Declarations for the Commonwealth, hurricanes and other severe storm systems need not track directly through a particular region or community to have a substantial impact. Nonetheless, hurricane tracks can be useful to indicate the relative frequency of tropical cyclone storms occurring in a particular location. The National Oceanic and Atmospheric Administration (NOAA) maintains a database of historical hurricane tracks for the United States. **Figure 4-9** presents the tracks for 19 storms that affected the Plymouth County area between 1872 and 2013. The characteristics of each event are presented in **Table 4-6**. Two storm tracks – Hermine and Andrea - passed directly through Pembroke in 2004 and 2013 and are depicted in **Figure 4-10**.

[43] FEMA, Building Codes Save: A Nationwide Study, p. 5-3.
[44] Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018, p. 4-205.
[45] Ibid, 4-208.

The 2015 OCPC Regional Hazard Mitigation Plan identified Hurricanes/Tropical Storms as a medium frequency, seriously severe hazard for the Town of Pembroke and noted summer and autumn as periods of greatest vulnerability.

Participants at the Pembroke CRB Workshop identified high winds as a significant hazard facing the community. Hurricanes and tropical storms were included with this category and the assessment of frequency and severity is unchanged from the 2015 RHMP.

Figure 4-9. Historical Hurricane Tracks, Plymouth County, MA



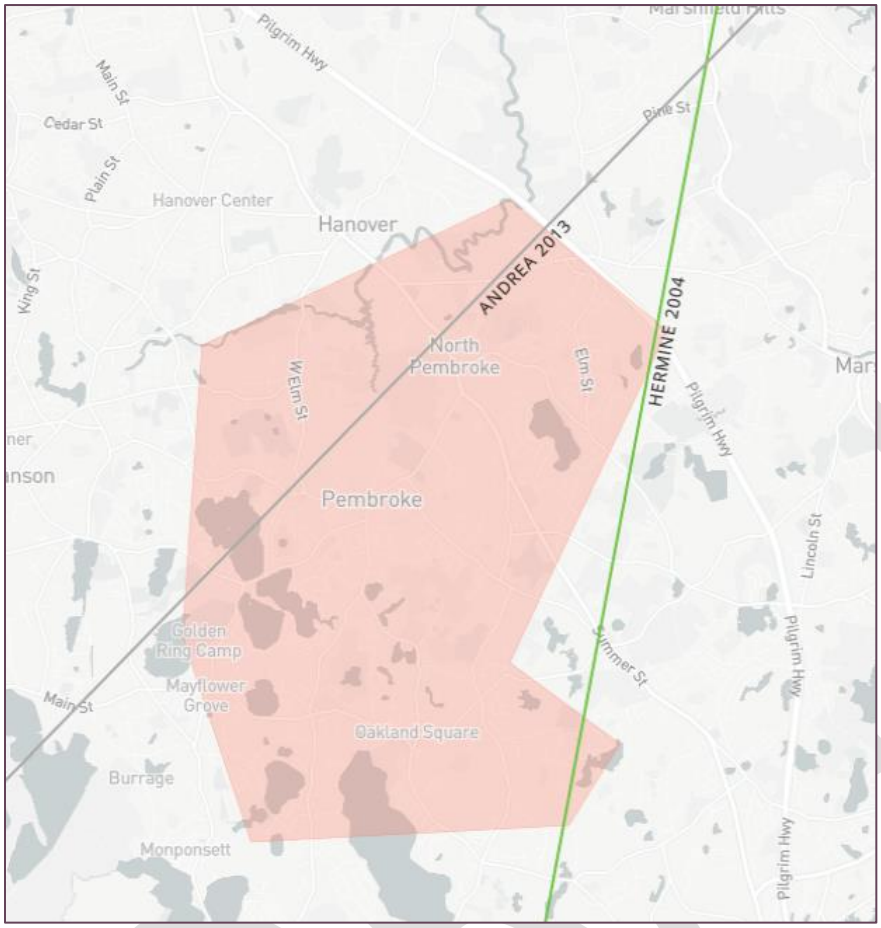
Source: NOAA Historical Hurricane Tracks.

Table 4-6. Historical Hurricanes, Tropical Storms, Plymouth County, MA

Event	Year	Maximum Wind Speed (mph) at Plymouth Co.	Category (at Plymouth Co.)
Tropical Storm Andrea	2013	46	Extratropical Storm
Hurricane Hanna	2008	52	Extratropical Storm
Barry (TS)	2007	40	Extratropical Storm
Hermine (TS)	2004	40	Tropical Storm
Gordon (H)	2000	20	Extratropical Storm
Bob (H)	1991	104	2
Alma	1966	46	Extratropical Storm
Cindy	1959	58	Tropical Storm
Unnamed	1944	75	1
Unnamed	1923	58	Tropical Storm
Unnamed	1916	52	Tropical Storm
Unnamed	1915	35	Extratropical Storm
Unnamed	1907	40	Extratropical Storm
Unnamed	1904	86	Extratropical Storm
Unnamed	1896	80	1
Unnamed	1888 (September)	40	Extratropical Storm
Unnamed	1888 (August)	46	Tropical Storm
Unnamed	1876	35	Tropical Depression
Unnamed	1872	46	Tropical Storm
Hurricane Irene*	2011	57	Tropical Storm

** Hurricane Irene did not track through Plymouth County but the County was affected and part of the Disaster Declaration.*
Source: NOAA Historical Hurricane Tracker.

Figure 4-10. Historical Hurricane Tracks Directly through Town of Pembroke



Tropical Storm ANDREA 2013
Maximum Winds 46 mph

Tropical Storm HERMINE 2004
Maximum Winds 58 mph

Source: NOAA Historical Hurricane Tracks.

4.3.2 Tornadoes

A tornado is a narrow, violently rotating column of air that extends from a thunderstorm to the ground. Because wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust, and debris.[46] Wind speeds in tornadoes range from values below weak hurricanes to more than 300 miles per hour. Unlike hurricanes, which produce wind speeds of generally lesser values over relatively widespread areas, the maximum winds in tornadoes are often confined to extremely small areas and can vary significantly over very short distances, even within the funnel itself. According to data from NOAA's Storm Prediction Center, during 2019 there were 1,520 preliminary tornado reports in the US, well above the 1991-2010 national average of 1,253 events.[47]

[46] NOAA NCEI, US Tornado Climatology. https://www.ncdc.noaa.gov/climate-information/extreme-events/us-tornado-climatology
[47] NOAA National Centers for Environmental Information, State of the Climate: Tornadoes for Annual 2019, published online January 2020, retrieved on October 19, 2020 from https://www.ncdc.noaa.gov/sotc/tornadoes/201913.

Historical records of tornadoes are complicated by the fact that these events are short-lived and unpredictable; if they occur in areas with few people, they are not likely to be documented. Many significant tornadoes may not appear in the historical record because they occurred in areas (e.g., Tornado Alley)[48] that were sparsely populated during the 20th century. Today, nearly all of the US is reasonably well populated, or at least covered by NOAA's Doppler weather radars; even if a tornado is not actually observed, modern damage assessments by the National Weather Service can discern if areas damaged by a tornado and the strength of the event. This disparity between past and current tornado records creates a great deal of uncertainty about the long-term behavior and patterns of their occurrence. Improved observational practices have led to a greater reporting of weaker tornadoes, and in recent years, EF-0 tornadoes have come to represent a larger proportion of the total events reported. Nonetheless, even today many small tornadoes may go undocumented in places with low populations or inconsistent communication facilities.[49]

Since 2007, the National Weather Service has used the Enhanced Fujita Scale, or EF Scale, to estimate the strength of a tornado; prior to 2007, the original Fujita Scale was used for this purpose.[50] The EF Scale takes into account more variables than the original Fujita Scale when assigning a wind speed rating to a tornado, incorporating 28 damage indicators such as building type, structures, and trees; however, the enhanced scale does not change the historical F scale database. For each of the 7 damage indicators in the EF Scale, there are 8 degrees of damage ranging from the beginning of visible damage to complete destruction of the damage indicator. An F5 tornado rated using the original scale is still an F5 under the EF scale, but the wind speed associated with the tornado may be slightly lower. A correlation between the original F Scale and the EF Scale has been developed. This makes it possible to express ratings in terms of one scale to the other and preserve the historical database.

EF0 and EF1 tornadoes are considered weak events, EF2 are strong/significant, EF3 are strong/significant/intense, and EF4 and EF5 are classified as violent events.

Table 4-7. The Enhanced Fujita Tornado Scale

Enhanced Fujita Scale		
EFU	Unknown	No surveyable damage
EF0	65–85 mph	Light damage
EF1	86–110 mph	Moderate damage
EF2	111–135 mph	Considerable damage
EF3	136–165 mph	Severe damage
EF4	166–200 mph	Devastating damage
EF5	>200 mph	Incredible damage

EF0 Minor Damage – Debris peeled off some roofs, basic damage to siding and gutters, broken tree branches broken, small shallow-rooted trees uprooted. Tornadoes with no damage are rated an EF0.

EF1 Moderate Damage – Roofs stripped off, mobile homes overturned, exterior door damage.

EF2 Considerable Damage – Roofs torn off well-constructed homes, foundation shifts, mobile homes completely destroyed, large trees snapped or uprooted, cars lifted.

EF3 Severe Damage – Well-constructed and framed homes destroyed, damage to large buildings, trains can overturn, trees can have bark torn off, heavy damage to weak foundations.

EF4 Devastating – Most homes completely destroyed, cars and car-sized objects thrown considerable distance, medium sized objects can become missiles.

EF5 Incredible Damage – Totally destroyed or severely damaged strong-framed homes and large structures. Train cars, cars, trucks can be thrown almost 1 mile.

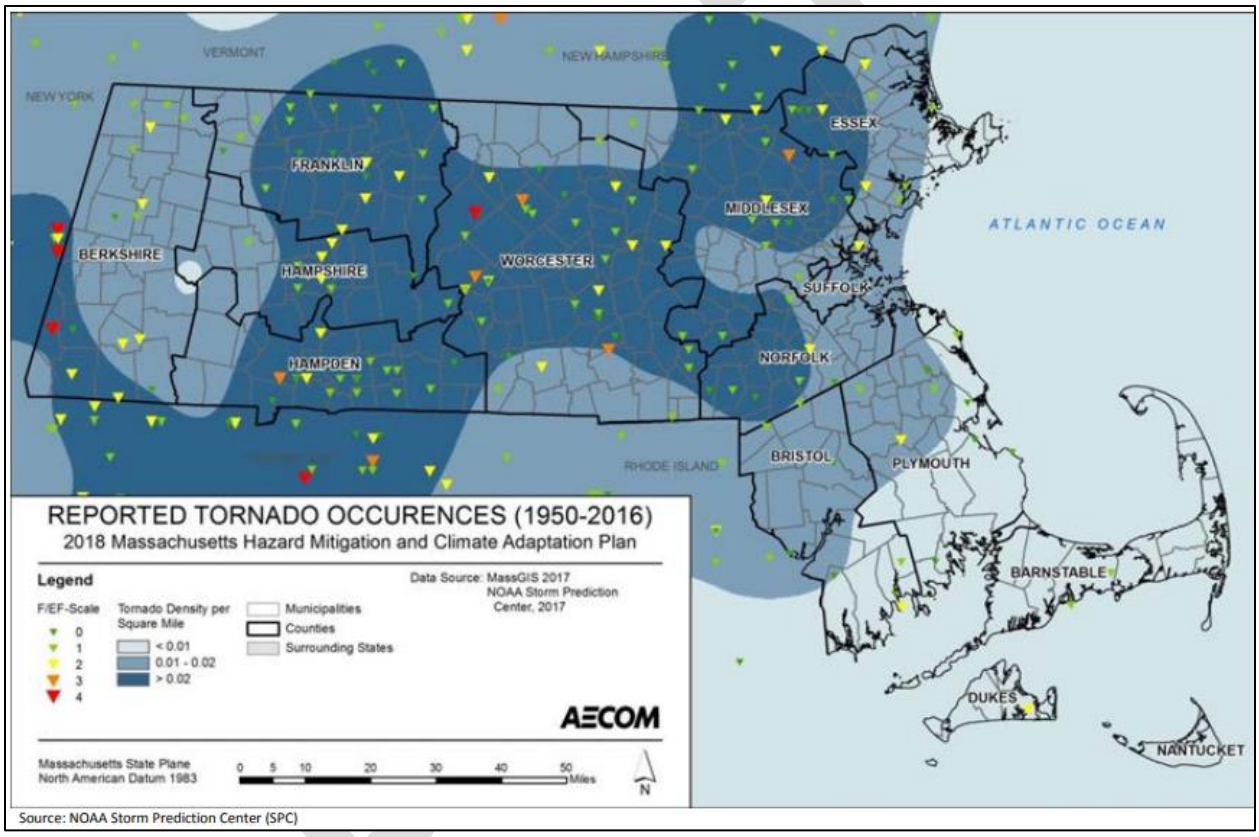
[48] Tornado Alley is a nickname given to an area in the southern plains of the central United States that consistently experiences a high frequency of tornadoes each year. Tornadoes in this region typically happen in late spring and occasionally the early fall.
[49] NOAA NCEI US Tornado Climatology, Historical Records and Trends. https://www.ncdc.noaa.gov/climate-information/extreme-events/us-tornado-climatology/trends
[50] "The Enhanced Fujita Tornado Scale", NOAA's National Climatic Data Center, Asheville, NC.

According to the 2018 MA SHMCAP, the Commonwealth experienced 171 tornadoes between 1950 and 2017, an average annual occurrence of 2.6 events per year; between 1998-2018 alone, these events averaged 1.7 per year.[51] Historically, the most tornado-prone portions of Massachusetts are the central counties (Franklin, Hampshire, Hampden, and Worcester) as well as portions of Middlesex and Norfolk counties.

In the Plymouth and Bristol county region of the State, which includes Pembroke, there have been at least 9 tornados reported since 1950; these have occurred in Duxbury, North Scituate, Plymouth, Brockton, and Fall River.[52] Five of the storms were EF1, four were EF0, one caused injury and none incurred fatalities. Five caused property damage.

The SHMCAP further notes that climate models project an increased frequency and intensity of severe thunderstorms, systems that can spawn tornados, although the confidence levels associated with these projections are low.[53]

Figure 4-11. Reported Tornado Occurrences, Massachusetts 1950-2016



The 2015 Old Colony Regional Hazard Mitigation Plan identified tornadoes as a very low frequency, serious severity hazard for Pembroke, noting that the Town has experienced only a single F1 tornado on July 4, 1964. According to the National Weather Service Storm Prediction Center, the tornado was approximately 10 feet wide, traveled 2.3 miles to

[51] 2018 Massachusetts State Hazard Mitigation and Climate Action Plan, p. 4-246.
[52] NOAA US Historical Tornado Tracks and Smithsonian Twister Dashboard.
[53] Ibid, p. 4-243.

the east, ending in Marshfield, caused no injuries or fatalities, and incurred moderate property damage[54] (**Figure 4-12**). There have been no reports of additional tornadoes in the Town since the Regional HMP was completed; therefore, the frequency and severity assessment for this hazard continues to be very low and serious, respectively **(Table 4-3).**

Figure 4-12. NOAA US Historical Tornado Tracks, Town of Pembroke

Source: NOAA US Historical Tornadoes – Tornado Tracks

The participants at the Town's CRB Workshop, identified high winds as a significant and frequent hazard event facing the community. While tornadoes are a wind-related hazard, residents did not express specific concern about tornadoes as a separate hazard event due to their relative infrequency.

4.3.3 Nor'easter

A Nor'easter is a storm along the East Coast of North America, so named because its coastal area winds are typically from the northeast. These storms can occur at any time of year but are most frequent and violent between September and April. In comparison with hurricanes, nor'easters typically last longer, with a duration of 12 hours to 3 days as

[54] NOAA Historical Tornado Tracks claims damages of $5M. The 2015 OCPC RHMP cites damages between $250,000 and $500,000 which are also cited in the NCEI Storm Events database. The SPC data layer for Figure 4-12 shows tornado touchdown points in the US from 1950-2006.

compared to hurricane surge and winds lasting 6-12 hours.[55] Some well-known Nor'easters include the notorious Blizzard of 1888, the "Ash Wednesday" storm of March 1962, the New England Blizzard of February 1978, the March 1993 "Superstorm" and the recent Boston snowstorms of January and February 2015. Past Nor'easters have been responsible for billions of dollars in damage, severe economic, transportation and human disruption, and in some cases, disastrous coastal flooding. Damage from the worst storms can exceed a billion dollars.[56]

Nor'easters typically develop between Georgia and New Jersey and within 100 miles east or west of the east coast. These storms trend northeastward, usually attaining maximum intensity near New England and the Maritime Provinces of Canada. They nearly always carry heavy rain or snow, winds of gale force, rough seas, and occasionally cause coastal flooding. The heavily populated I-95 corridor between Washington DC and Boston is particularly impacted by Nor'easters.[57]

The 2018 MA SHMCAP discusses Nor'easters under the category of Extreme Weather and notes that the east-facing coastal areas in the state are most affected; these include Salisbury Beach, Revere, Nahant, Scituate, Marshfield, and parts of the Cape and Nantucket. As coastal development increases and sea level rises, Nor'easters will cause more substantial damage. It is important to note that Nor'easters can also bring heavy snow that can paralyze inland cities or regions, and inland areas in the floodplain are at risk for flood and wind damage. Nor'easters are currently the most frequently occurring natural hazard in the State, with one per year at minimum and up to four events in some years.[58]

Nor'easters are not discussed as a separate category in the 2015 OCPC Regional HMP for the Town of Pembroke. The Plan does discuss winter storms and tropical storms, categories that typically include Nor'easters, classifying the former as a high frequency/seriously severe event and the latter as medium-frequency and seriously severe. Both storm categories were ranked in the top four natural hazards of concern to the community at that time.

Participants at the Pembroke CRB Workshop identified Wind-related hazards as one of the top events affecting the Town. The perceived frequency and severity of this hazard class which includes Nor'easters is unchanged from the 2015 OCPC RHMP.

4.3.4 Severe Thunderstorms and High Wind Events

Thunderstorms originate in cumulonimbus clouds that produce lightning, heating the air locally and creating an audible shock wave that we know as thunder. These storms form in the presence of moisture, rising unstable air, and a lifting mechanism (mountains or hills or contact with relatively colder air) and can produce secondary atmospheric hazards including hailstorms, intense downburst/microburst winds, lightning, and flash floods. Thunderstorms spawn as many as 1,000 tornadoes annually.[59]

Downburst winds - strong, concentrated, straight-line winds created by precipitation and sinking air, both of which can be present in a thunderstorm - can reach speeds of 125 mph while microbursts are more concentrated, with wind speeds up to 150 mph. Severe damage can result from the spreading of downbursts and microbursts which generally

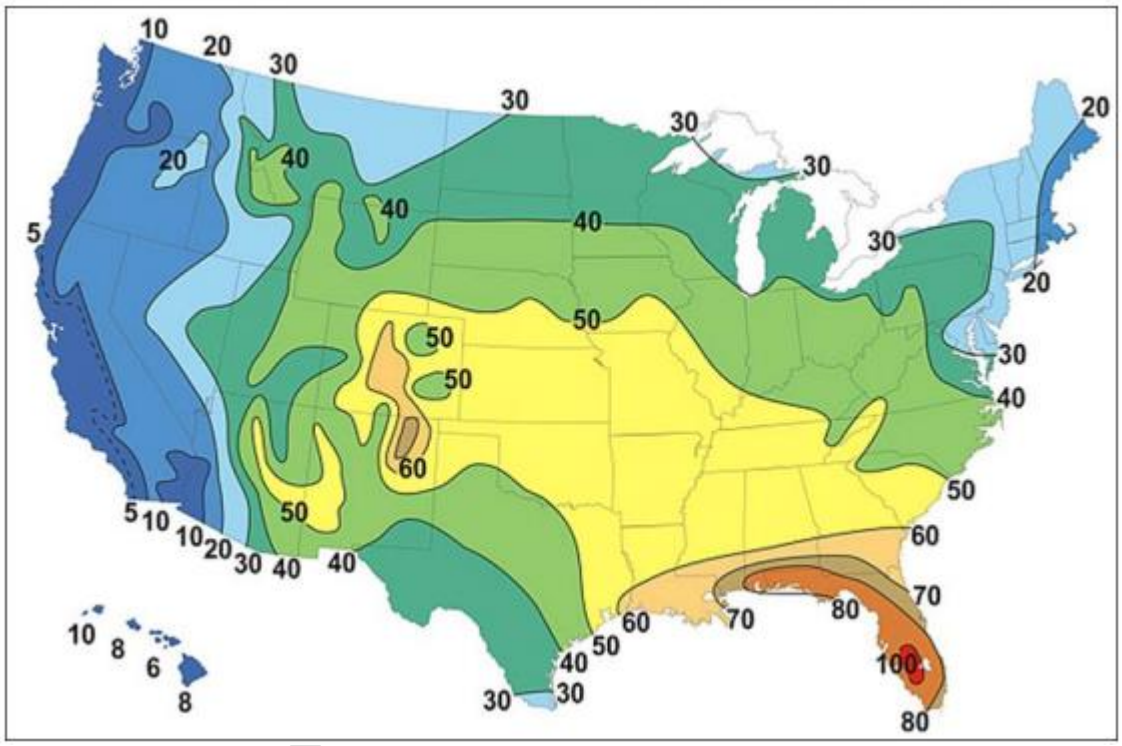
[55] 2018 Massachusetts State Hazard Mitigation and Climate Action Plan, p. 4-226.
[56] NOAA National Weather Service, https://www.weather.gov/safety/winter-noreaster
[57] Ibid.
[58] 2018 Massachusetts State Hazard Mitigation and Climate Action Plan, p. 4-224.
[59] FEMA Mitigation Directorate, Multi Hazard Identification and Risk Assessment, 2013, Part I, p. 30.

last 5-7 minutes.[60] An organized, fast-moving line of microbursts traveling across large areas is known as a derecho; these occasionally occur in Massachusetts and have been measured with wind speeds in excess of 100 mph.[61]

The National Weather Service has estimated that more than 100,000 thunderstorms occur each year on the US mainland, approximately 10% of which are severe. NWS classifies a thunderstorm as severe if its winds reach or exceed 58 mph, it produces a tornado, or it drops surface hail ≥ 0.75 inches in diameter. As compared with other atmospheric hazards, individual thunderstorms affect relatively small geographic areas and typically last less than 30 minutes at a single location. Despite their brief duration, severe thunderstorms were involved in 327 Federal disaster declarations between 1975 and 2013.[62]

According to NOAA, Massachusetts experiences between 20-30 thunderstorm days per year that vary widely in severity, ranging from ordinary short-term events to large-scale storms that cause direct flooding and/or intense lightning and high winds (**Figure 4-13**). The 2018 SHMCAP identified 7 FEMA Severe Storm Declared Disasters for Plymouth County between 1972 and 2017, the second highest total for the State, behind only Middlesex and Essex counties which each had 8 **(Figure 4-14**).

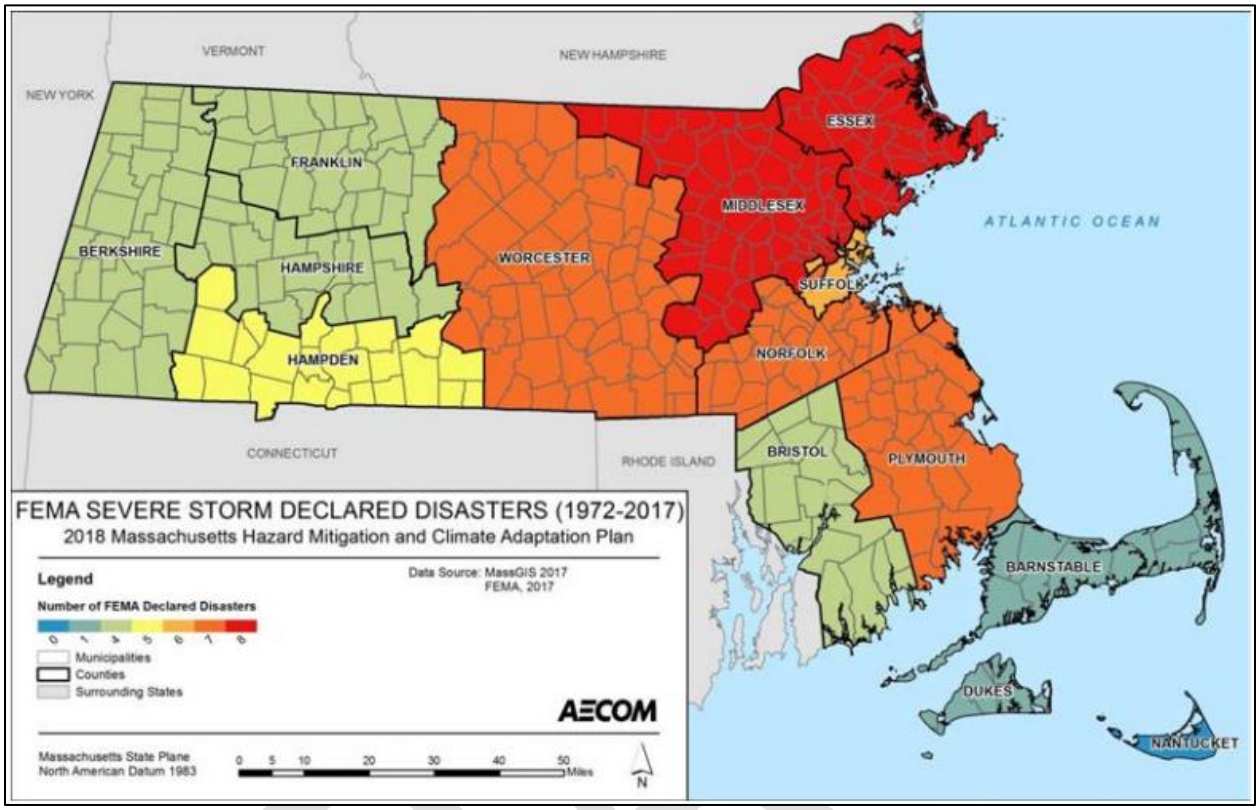
Figure 4-13. US Annual Average Number of Thunderstorm Days



Source: NOAA In Northeast States Emergency Consortium 2014.

[60] Ibid.
[61] Massachusetts State Hazard Mitigation and Climate Adaptation Plan, September 2018, p. 4-255.
[62] FEMA Mitigation Directorate, Multi Hazard Identification and Risk Assessment, 2013, Part I, p. 30.

Figure 4-14. FEMA Severe Storm Declared Disasters by County



Source: MA SHMCAP 2018.

The NOAA NCEI Storm Events Database was surveyed for **Thunderstorm Wind** events for the Plymouth County area. Between 2000 and 2020, there were 63 days of event occurrence, 51 of which included property damage. Fifty-three (53) event days involved thunderstorms with wind speeds in excess of 58 mph (50.4 kts), meeting the NWS criterion for Severe Thunderstorm and causing $1.029 million in property damage. Several of these severe events affected Pembroke, including July 6, 2007 which downed trees near Route 53: July 29, 2007 which downed wires on Stanford Hill Road; May 24, 2009 which carried hail up to two inches diameter, downed a tree and wires on Center Street, and caused $1000 property damage; and on June 29, 2019 when thunderstorms carrying large hail and damaging wind downed a tree and wires across Pleasant Street and caused $3000 property damage.[63]

High winds are defined by the National Weather Service as sustained non-convective winds of 35 knots (40 mph) or greater lasting 1 hour or more or gusts of 50 knots (58 mph) or greater for any duration[64]. Between 2008 and 2017, 435 high wind events occurred in Massachusetts on 124 days (an annual average of 43.5 events per year); however, since many high wind events are part of the same weather system, this total may overestimate the frequency of occurrence.[65]

[63] NOAA NCEI Storm Events Database for Plymouth County MA, Thunderstorm Wind.
[64] National Weather Service Watch/Warning/Advisory Definitions.
[65] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, p. 4-258.

The NOAA NCEI Storm Events Database was also surveyed for High Wind Events for the Plymouth County area. Between 2000 and 2020, there were 72 days with a high wind event (~3.6/year), 1 fatality in the Town of Plympton,[66] 2 injuries (November 2004 in Marshfield, and May 2005 in Brockton)[67], with property damages over the period totaling $3.48M.68 Wind speeds over the 72 events ranged from 38 to 70 knots (43.7 – 80.6 mph).

The 2015 OCPC Regional HMP assessed winter storms, hurricanes/tropical storms, and tornado hazards but did not separately characterize Thunderstorms or High Wind hazards for the Town of Pembroke. As previously discussed, the RHMP frequency and severity for Hurricanes/Tropical Storms were rated as medium and serious, respectively; the frequency and severity of tornadoes were rated as very low and serious, respectively. As noted in **Table 4-3,** the current assessment is that Pembroke has a medium frequency, minor to seriously severe risk for severe thunderstorms, and a medium frequency, minor to seriously severe risk for high winds.

Participants at the Pembroke CRB Workshop reaffirmed the frequency and severity of High Wind events as medium and serious, respectively, with power outages and blockage of roadways and emergency access routes as significant associated impacts.

4.3.5 Effect of Climate Change

With regard to wind-related hazards, the 2018 Massachusetts Hazard Mitigation and Climate Adaptation Plan notes that climate change is likely to drive larger, stronger storm systems due to increased fuel from warming oceans. Although no single storm can be directly attributed to climate change, both past events and modeled future conditions suggest that the intensity of tropical storms and hurricanes will increase as a result of climate change, while trends in storm frequency are less clear. Higher ocean temperatures may cause storm systems to increase in size and duration, and warmer global oceans could also expand the areas where conditions conducive to hurricane formation occur. Additionally, the rate of rainfall associated with these strong wind events is also likely to increase since warmer air can hold more water vapor. The SHMCAP notes one study which found that hurricane rainfall rates were projected to rise 7% for every degree Celsius increase in tropical sea surface temperature. Finally, as described for other hazards, sea level rise will exacerbate the impact of storm surge from storms of all severities.[69]

4.4 Winter Storms

According to the NOAA National Severe Storms Laboratory, a winter storm is a combination of heavy snow, blowing snow and/or dangerous wind chills and can be life-threatening. Three basic elements are necessary to cause a winter storm – cold air (below-temperatures in the clouds and near the ground), lift (to raise the moist air to form clouds and cause precipitation), and moisture. Winter storms include blizzards, ice storms, lake effect storms, and snow squalls. Most winter precipitation starts as snow because the top layer of a storm cloud is sufficiently cold to form ice crystals (snowflakes). Precipitation continues to fall as snow when the temperature remains at or below 0 Celsius from the base of the cloud to the ground. Snowfall events can range from light/short duration (snow flurries) to high winds with snow that reduce visibility (blizzards). Winter thunderstorms can also occur and there is some evidence that they carry

[66] In March 2018, a tree fell on a car in Plympton killing its occupant. Winds were estimated at 54 kts (62 mph). (https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=742954

[67] Ibid. Both injuries were due to trees falling on cars; wind speeds for both events were estimated to be 50 knots.

[68] Ibid.

[69] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, p. 4-258.

heavier snowfall; NSSL researchers have found that these events, although rare, occur most often in the Great Lakes, and in the central and eastern coastal areas of the US.[70]

While the category of Winter Storms is sufficiently broad to overlap with other natural hazard types (e.g., wind-related and flood hazards), this section focuses on heavy snow/blizzards and ice storms. Nor'easters and flooding associated with winter storms are discussed separately under those hazard headings.

Winter storms carry multiple risks from wind, ice, and snow, with most deaths due to traffic accidents, heart attacks from shoveling snow, and hypothermia associated with prolonged exposure to cold. Of injuries related to ice and snow, about 70% occur in automobiles, 25% are people caught out in the storm, and the majority involve males over 40 years of age. Of injuries related to cold exposure, 50% involve people over 60 years of age, over 75% are males, and about 20% occur in the home.[71]

Although there is no widely used scale to classify snowstorms, NOAA NCDC supports the Northeast Snowfall Impact Scale (NESIS) developed by the National Weather Service to characterize and rank Northeast snowstorms that have large areas of 10-inch snowfall accumulations and greater.[72] NESIS defines five categories - Extreme, Crippling, Major, Significant, and Notable – and differs from other meteorological indices in that it incorporates population information to indicate a storm's societal impacts.

NESIS scores are a function of the area affected by the snowstorm, the amount of snow, and the number of people living in the path of the storm. The aerial distribution of snowfall and population information are combined in an equation that calculates a NESIS score which varies from 1 for smaller storms to > 10 for extreme storms. The raw score is then converted into one of the 5 NESIS categories. The largest NESIS values result from storms producing heavy snowfall over large areas that include major metropolitan centers.[73]

Table 4-8. NOAA NCEI NESIS Categories

CATEGORY	NESIS VALUE	DESCRIPTION
1	1—2.499	Notable
2	2.5—3.99	Significant
3	4—5.99	Major
4	6—9.99	Crippling
5	10.0+	Extreme

NESIS ranks 64 high-impact snowstorms that affected the Northeast urban corridor between 1956 and 2016. These storms were further analyzed to determine the extent and severity of impact on the Town of Pembroke (**Table 4-9).** Of the 64 events, half deposited upwards of 10 inches of snow in the Pembroke vicinity and 9 of these carried snow accumulations between 20 and 30 inches. Of ten (10) Category 4 and 5 snowstorms that occurred during this period

[70] NOAA National Severe Storms Laboratory, Severe Weather, Winter Weather Basics. https://www.nssl.noaa.gov/education/svrwx101/winter/
[71] Ibid.
[72] Kocin, P. J. and L. W. Uccellini, 2004: A Snowfall Impact Scale Derived From Northeast Storm Snowfall Distributions. *Bull. Amer. Meteor. Soc.*, 85, 177-194..
[73] NOAA NCEI Regional Snowfall Index NESIS. https://www.ncdc.noaa.gov/snow-and-ice/rsi/nesis

(NESIS Value 6-10, Extreme or Crippling), 9 substantially affected the Town. Based on the NESIS historic database, high-impact snowstorms affect the Town of Pembroke at minimum every other year, on average.

Table 4-9. Northeast Snowfall Impact Scale 64 High-Impact Snowstorms Affecting the NE Urban Corridor

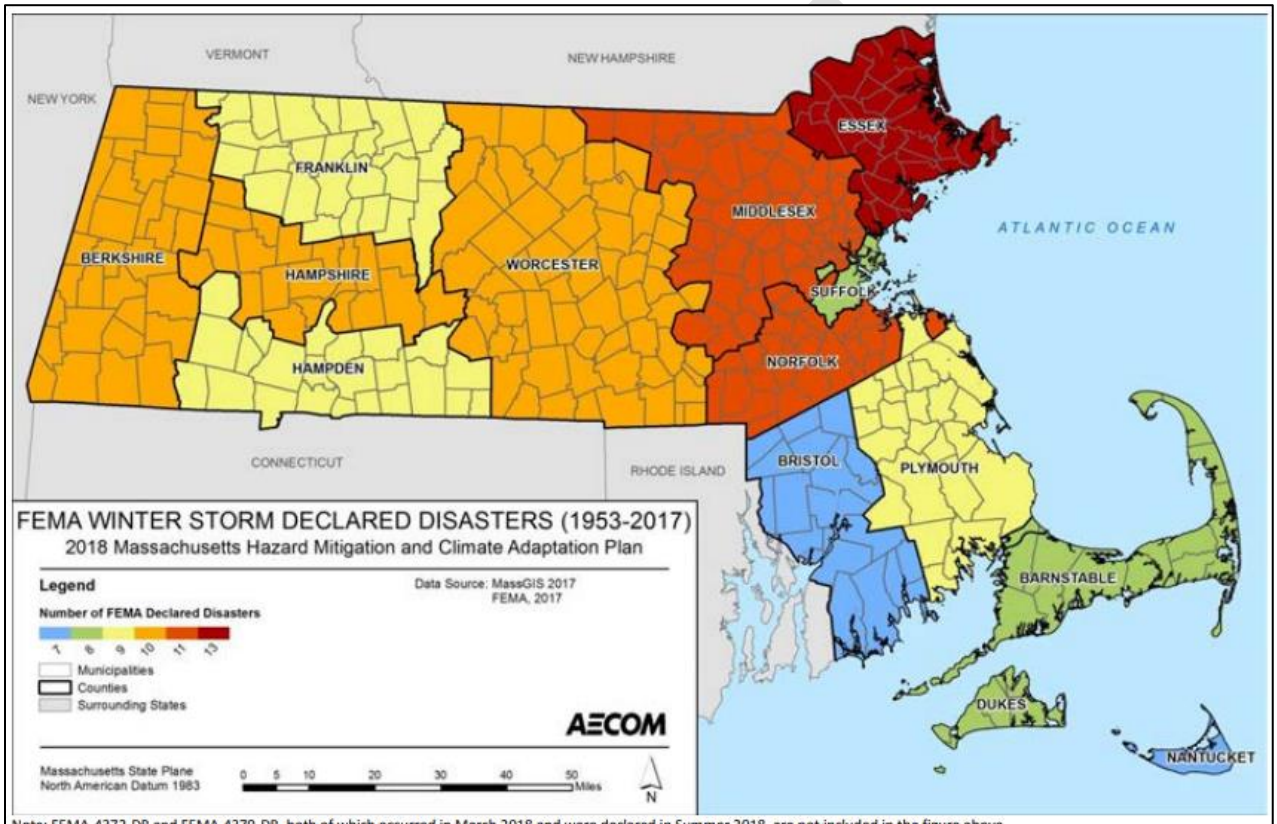
Rank	Date	NESIS Value	Category	Description	Pembroke Snowfall (inches)
1	1993-03-12	13.20	5	Extreme	10-20
2	1996-01-06	11.78	5	Extreme	20-30
3	1960-03-02	8.77	4	Crippling	20-30
4	2016-01-22	7.66	4	Crippling	4-10
5	2003-02-15	7.50	4	Crippling	20-30
6	1961-02-02	7.06	4	Crippling	10-20
7	1964-01-11	6.91	4	Crippling	10-20
8	2005-01-21	6.80	4	Crippling	20-30
9	1978-01-19	6.53	4	Crippling	10-20
10	1969-12-25	6.29	4	Crippling	4-10
11	1983-02-10	6.25	4	Crippling	10-20
12	1958-02-14	6.25	4	Crippling	10-20
13	1966-01-29	5.93	3	Major	4-10
14	1978-02-05	5.78	3	Major	20-30
15	2007-02-12	5.63	3	Major	1-4
16	2010-02-23	5.46	3	Major	1-4
17	2015-01-29	5.42	3	Major	10-20
18	1987-01-21	5.40	3	Major	4-10
19	1994-02-08	5.39	3	Major	20-30
20	2011-01-09	5.31	3	Major	10-20
21	2011-02-01	5.30	3	Major	4-10
22	2014-02-11	5.28	3	Major	<4
23	2017-03-12	5.03	3	Major	4-10
24	2010-12-24	4.92	3	Major	10-20
25	1979-02-17	4.77	3	Major	1-4
26	1972-02-18	4.77	3	Major	4-10
27	1960-12-11	4.53	3	Major	10-20
28	2010-02-04	4.38	3	Major	10-20
29	2013-02-07	4.35	3	Major	20-30
30	1969-02-22	4.29	3	Major	20-30

Rank	Date	NESIS Value	Category	Description	Pembroke Snowfall (inches)
31	2010-02-09	4.10	3	Major	4-10
32	2006-02-12	4.10	3	Major	10-20
33	2014-01-29	4.08	3	Major	4-10
34	1961-01-18	4.04	3	Major	4-10
35	2009-12-18	3.99	2	Significant	10-20
36	1966-12-23	3.81	2	Significant	1-4
37	1969-02-08	3.51	2	Significant	4-10
38	1958-03-18	3.51	2	Significant	4-10
39	1967-02-05	3.50	2	Significant	10-20
40	2018-03-05	3.45	2	Significant	4-10
41	1982-04-06	3.35	2	Significant	10-20
42	2013-12-30	3.31	2	Significant	10-20
43	2018-03-11	3.16	2	Significant	10-20
44	2013-03-04	3.05	2	Significant	10-20
45	2013-12-13	2.95	2	Significant	<4
46	2015-01-25	2.62	2	Significant	20-30
47	2007-03-15	2.54	2	Significant	4-10
48	2000-01-24	2.52	2	Significant	1-4
49	2000-12-30	2.37	1	Notable	1-4
50	1997-03-31	2.29	1	Notable	10-20
51	2018-01-03	2.27	1	Notable	10-20
52	2011-01-26	2.17	1	Notable	10-20
53	1956-03-18	1.87	1	Notable	4-10
54	2011-10-29	1.75	1	Notable	1-4
55	2018-03-01	1.65	1	Notable	4-10
56	2018-03-20	1.63	1	Notable	<4
57	2009-03-01	1.59	1	Notable	4-10
58	2014-11-26	1.56	1	Notable	<4
59	2014-12-09	1.49	1	Notable	0
60	1987-02-22	1.46	1	Notable	1-4
61	1995-02-02	1.43	1	Notable	4-10
62	2015-02-08	1.32	1	Notable	10-20
63	2014-01-20	1.26	1	Notable	10-20
64	1987-01-25	1.19	1	Notable	1-4

Note: Blue shading indicates storms that deposited 10 or more inches of snow.

The Massachusetts SHMCAP acknowledges the overlap between winter storms and other types of natural hazards and includes an overview of the number of winter storm disaster declarations by county between 1953 and 2017 (**Figure 4-15**); a winter storm March 2-3, 2018 (FEMA-4372-DR) also affected Plymouth County and is incorporated in the Plan by reference. According to the State data, Plymouth County has experienced 10 winter storm-related disaster events over a 65-year period, or 1 every 6.5 years on average.

Figure 4-15. FEMA Winter Storm-related Declared Disasters by County (1953-2017)



Note: FEMA-4372-DR and FEMA-4379-DR, both of which occurred in March 2018 and were declared in Summer 2018, are not included in the figure above.

The SHMCAP also identified 59 "notable" or more significant winter storms as affecting the Northeast urban corridor, which includes Massachusetts. Based on this historical record, high-impact snowstorms affecting the Commonwealth occur at approximately the rate of one per year, although there is significant interannual variability in their frequency and severity.

Additional data sources were examined to describe the frequency, extent, and severity of winter storms regionally, specifically in the Plymouth County area that includes the Town of Pembroke. NOAA National Centers for Environmental Information provides data for 1-, 2-, and 3-day snowfall extremes by County. The 1-Day extreme

snowfall for Plymouth County, MA was 24.0 inches on January 23, 2005; the 2-Day extreme is recorded as 30.1 inches on February 7, 1978; and the 3-Day extreme was 33.5 inches on March 19, 1995.[74]

The NOAA National Storm Events database also was queried for Winter Storms affecting the Plymouth County area between 1999 and 2020. During that period, 51 events were reported over 21 days, 8 of which incurred property damage (**Table 4-10**), and represent an approximate occurrence rate of 2.5 per year.

[74] NOAA NCEI Snowfall Extremes. https://www.ncdc.noaa.gov/snow-and-ice/snowfall-extremes/MA/3

Table 4-10. Plymouth County Winter Storm Events, 1999-2020

Date	Deaths	Injuries	Property Damage ($)
2/7/2003	0	0	0
2/7/2003	0	0	0
2/7/2003	0	0	0
2/17/2003	0	0	0
2/17/2003	0	0	0
2/17/2003	0	0	0
3/6/2003	0	0	50,000
3/6/2003	0	0	30,000
12/5/2003	0	0	0
12/5/2003	0	0	0
12/5/2003	0	0	0
12/26/2004	0	0	0
12/26/2004	0	0	0
12/26/2004	0	0	0
1/22/2005	0	0	0
1/22/2005	0	0	0
1/22/2005	0	0	0
3/1/2005	0	0	50,000
3/1/2005	0	0	75,000
3/1/2005	0	0	25,000
3/12/2005	0	0	0
2/12/2006	0	0	10,000
2/12/2006	0	0	10,000
2/12/2006	0	0	15,000
3/16/2007	0	0	0
3/16/2007	0	0	0
2/10/2010	0	0	10,000
2/10/2010	0	0	15,000
2/10/2010	0	0	5,000
12/26/2010	0	0	75,000
12/26/2010	0	0	75,000
1/12/2011	0	0	50,000
2/1/2011	0	0	180,000
1/7/2017	0	0	0
1/7/2017	0	0	0
1/7/2017	0	0	0
2/9/2017	0	0	0

Date	Deaths	Injuries	Property Damage ($)
2/9/2017	0	0	0
2/9/2017	0	0	0
3/10/2017	0	0	0
3/10/2017	0	0	0
1/4/2018	0	0	0
1/4/2018	0	0	6,000
1/4/2018	0	0	0
1/30/2018	0	0	0
1/30/2018	0	0	0
1/30/2018	0	0	0
2/18/2019	0	0	0
3/3/2019	0	0	0
3/3/2019	0	0	0
3/3/2019	0	0	0

Blizzards

NOAA's National Storm Events Database records Blizzards separately from Winter Storms and indicated that between 1999 and 2020, 13 events were reported over 9 days – 8 days with property damages. These events are summarized in **Table 4-11** and occur at an average rate of 0.65 or approximately one every other year.

Table 4-11. Plymouth County Blizzard Events, 1999-2020

Date	Deaths	Injuries	Property Damage ($)
2/12/2006	0	0	15,000
12/20/2009	0	0	100,000
2/8/2013	0	0	7,5000
2/8/2013	0	0	2,5000
2/8/2013	0	0	345,000
1/2/2014	0	0	5,000
1/26/2015	0	0	0
2/14/2015	0	0	10,000
1/23/2016	0	0	5,0000
2/8/2016	0	0	1,0000
3/13/2018	0	0	5,0000
3/13/2018	0	0	4,0000
3/13/2018	0	0	5,0000

The December 2009 blizzard (NESIS Event #35) dropped 18-20 inches of snow across southeastern Massachusetts, lowered visibility to 0, and carried wind gusts greater than 35 mph. Numerous trees and wires were downed by the combination of wind and heavy snow. The blizzard of February 2013 (NESIS Event #29) deposited 2 to 2.5 feet of snow in the region and produced a prolonged period of very strong winds with gusts of 68 mph near Scituate; trees

and wires were downed in Halifax. Combined wind and snow again downed wires in the January 2014 blizzard which also brought bitter cold and coastal flooding, and in the January 2015 event (NESIS Event #46), 24-31 inches of snow fell across Plymouth County. All of the regional blizzard events were accompanied by strong winds.

Ice Storms

In addition to blizzards, ice storms are a type of winter storm with potential to impact the Plymouth County/Town of Pembroke area. Ice storm conditions are defined by liquid rain falling and freezing on contact with cold objects, creating ice buildups of one-quarter inch or more.

Heavy accumulations of ice can bring down trees and topple utility poles and communication towers, disrupting communications and power supply for days. Even small accumulations of ice can be extremely dangerous to motorists and pedestrians. Bridges and overpasses are particularly hazardous because they freeze before other surfaces.[75] The National Weather Service will issue an Ice Storm Warning when freezing rain produces a significant and possibly damaging accumulation of ice. The criteria vary from state to state but a warning typically is triggered any time more than ¼ inch of ice is expected to accumulate in an area.[76]

From 1998 to 2017, the NOAA National Climatic Data Center reported 28 ice storm events for the State of Massachusetts. All of these storms occurred between November and February but were most frequent in late December and early January. The 2018 SHMCAP noted that ice storms of lesser magnitude impact the Commonwealth annually.[77] For Plymouth County, the NOAA NCEI Storm Events Database reported no Ice Storm events between 2000 and 2020; therefore, the frequency of this hazard for the Pembroke area is estimated to be low-very low.

The 2015 Old Colony Planning Council Regional HMP evaluated the frequency, extent and severity of winter storms for the Town of Pembroke as follows:

> *Winter storms represent a high frequency, serious severity hazard for Pembroke. Pembroke receives an average of 36"-48" of snow annually, with their being an approximately 48% chance of a NESIS ranked storm occurring annually. Winter storms are dangerous to the entire population, as the accumulation of snow and ice along with high winds can impact public safety as well as the local economy by disrupting transportation and commercial activities. The buildup on snow and ice on roadways also makes for dangerous travelling conditions. The accumulation of snow and ice on trees and power lines can cause them to sag and break, potentially closing roadways and cutting off electricity to homeowners and businesses. The accumulation of heavy snow over a long period of time can affect structures with flat roofs, as the weight of heavy snow can cause them to collapse. The entire community is vulnerable to the impacts of winter storms.*

NOAA's National Snowfall Analysis data were used to determine minimum and maximum snowfall averages for the Town of Pembroke for 2008 to 2019. During that period, Pembroke experienced an average annual snowfall of 42-47 inches per year. Four of the years – 2010-11, 2011-12, 2013-14, and 2014-15 – yielded snowfall in excess of 50 inches, with the 2014-2015 season showing the greatest accumulation, nearly 100 inches (**Appendix A,** Town of Pembroke Mean Annual Snowfall Hazard Map).

At the Town's 2021 CRB Workshop, participants identified Snowstorms as one of the top hazards facing the Town. While they noted that no severe events have occurred in the past 1 to 2 years, they recognized that the frequency

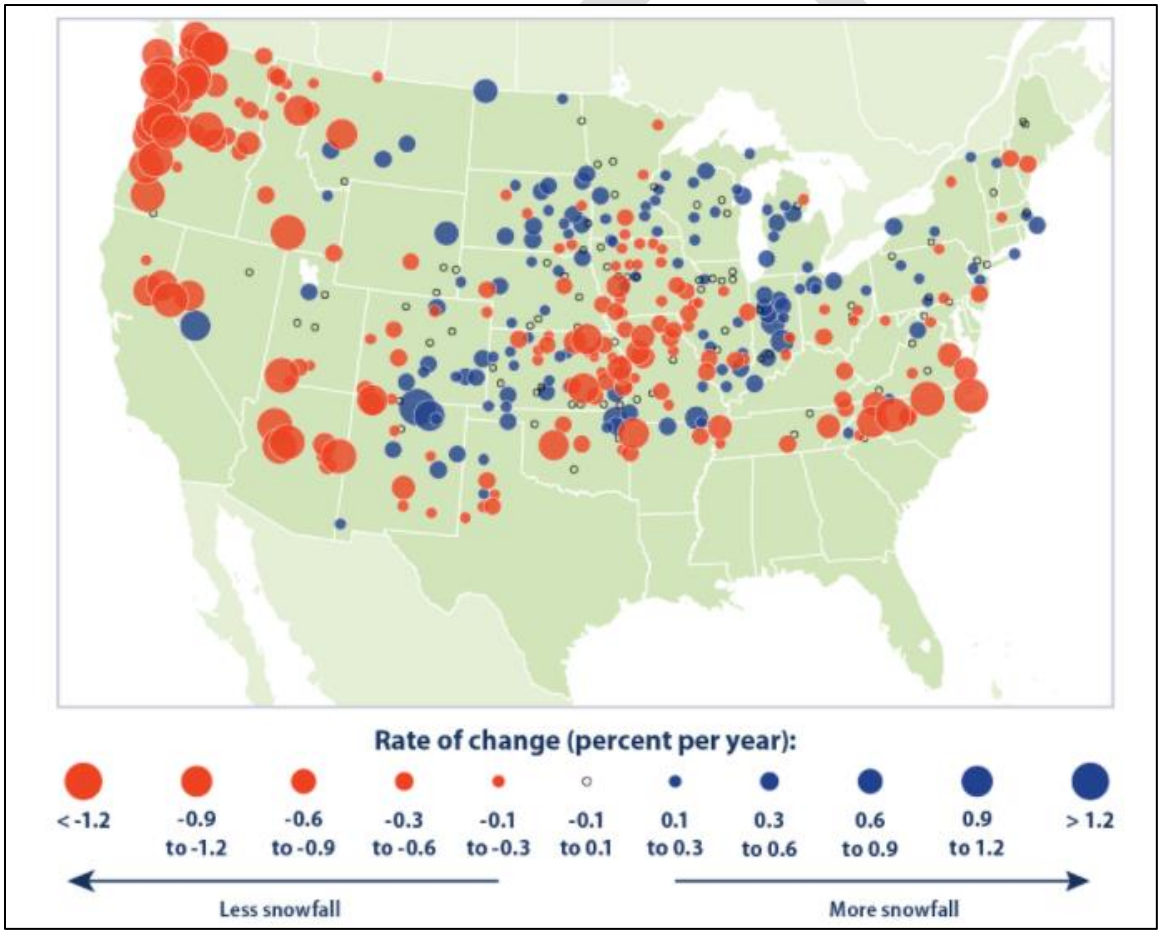
[75] National Weather Service, Ice Storms. https://www.weather.gov/safety/winter-ice-frost
[76] National Weather Service, Ice Storm Warning. https://w1.weather.gov/glossary/index.php?word=Ice%20Storm%20Warning
[77] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, p. 4-227.

has been high over the last 2 decades. As of 2021, winter storms continue to be a high frequency, seriously severe, Town-wide natural hazard for Pembroke.

4.4.1 Effect of Climate Change

Rising sea surface temperature in the Atlantic Ocean will increase the moisture content of air moving north over the ocean; when these fronts meet cold air from the north, greater amounts of snowfall can be expected. The Massachusetts SHMCAP notes that increasing water temperatures and reduced Arctic sea ice are causing atmospheric circulation patterns that favor winter storm development in the eastern US. There is also evidence to suggest that Nor'easters along the Atlantic coast are becoming more frequent and intense and may become more concentrated in the coldest winter months when temperatures are sufficiently low to produce significant snowfall.[78] The US EPA climate change indicators show a trend toward higher snowfall for the Plymouth-Pembroke area between 1930 and 2007, and a -2 to 2% change in snow to precipitation ratio from 1949-2016[79] (**Figures 4-16 and 4-17**).

Figure 4-16. Change in Total Snowfall in the Contiguous 48 States 1930-2007

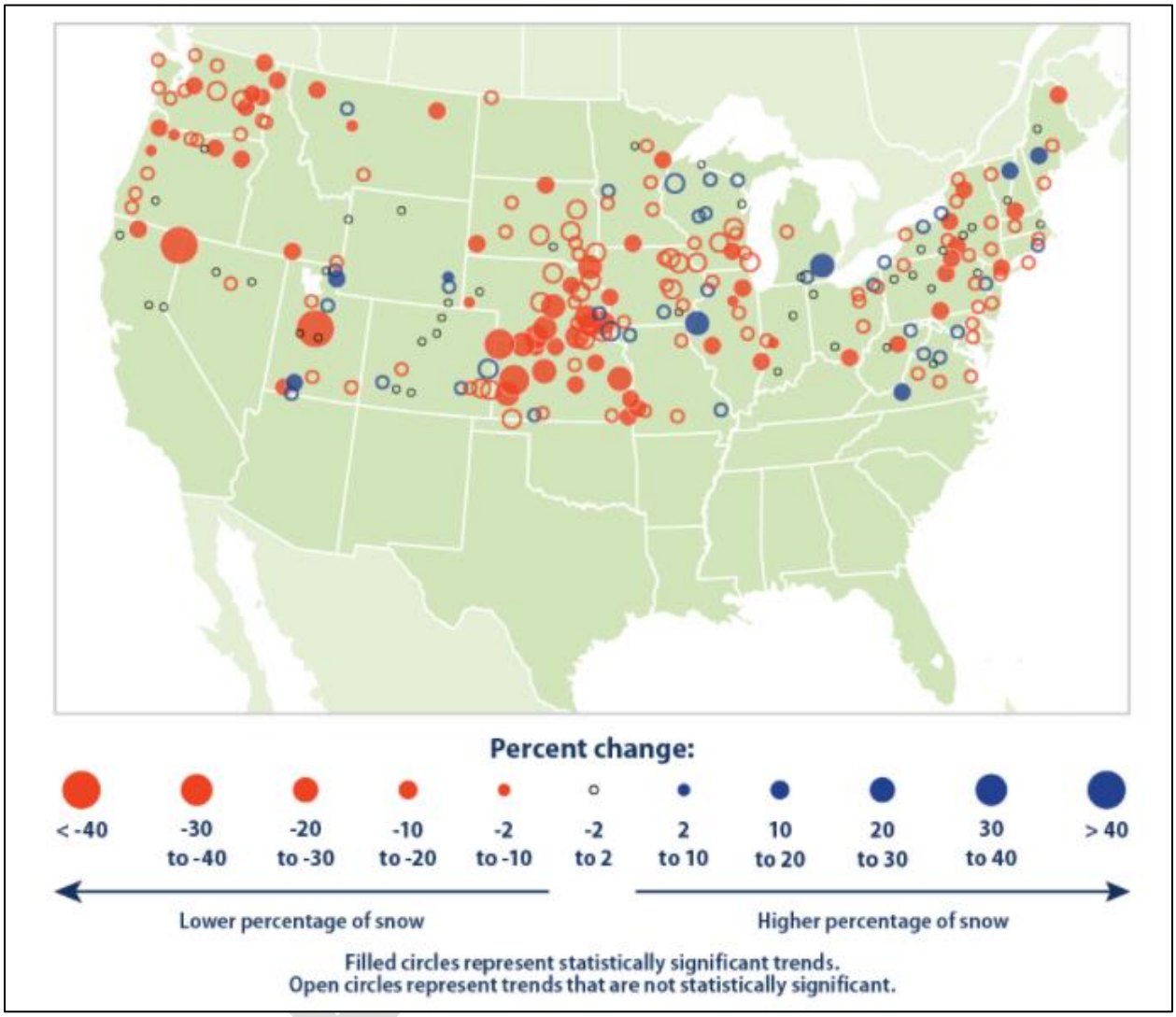


[78] Ibid, p. 4-224.

[79] The change in the snow to precipitation ratio for the Pembroke area is not statistically significant but indicates a moderating influence of higher temperatures on percent snowfall.

Source: US EPA (Kunkel KE et. al., 2009. Trends in 20th century US snowfall using a quality controlled dataset. J. Atmos. Ocean. Tech. 26:33-44.

Figure 4-17. Change in Snow to Precipitation Ratio in the Contiguous 48 States, 1949-2016[80]



The climate change projections for snowfall for the Plymouth-Pembroke area are not expected to alter the hazard characterization of severe, serious, and Town-wide over the next 5-year planning period.

[80] Kunkel, K.E., M. Palecki, L. Ensor, K.G. Hubbard, D. Robinson, K. Redmond, and D. Easterling. 2009. Trends in twentieth-century U.S. snowfall using a quality-controlled dataset. J. Atmos. Ocean. Tech. 26:33–44.

4.5 Geologic Hazards

Geologic hazards in the Northeast US typically include Earthquakes and Landslides. According to USGS, an earthquake is caused by a sudden slip, or displacement, on a fault. A fault is a fracture along which blocks of the earth's crust on either side have moved relative to one another parallel to the fracture. Tectonic plates -- large, thin, relatively rigid plates that move relative to one another on the outer surface of the earth -- are always slowly moving, but stick at the edges due to friction. When stress on the edge overcomes friction, an earthquake occurs, releasing energy in waves that travel through the earth's crust and cause the ground to shake. As a result, areas along fault lines experience earthquakes more often than areas remote from these lines.

Landslides involve the downward and outward movement of slope-forming material reacting under the force of gravity. The term includes mudflows, mudslides, debris flows, rock falls, rock slides, debris avalanches, debris slides, and earth flows. Landslides can comprise natural rock, soil, artificial fill or any combination of these materials and may be triggered by earthquakes or heavy and prolonged rains that create saturated conditions.[81]

4.5.1 Earthquakes

Ground shaking is the primary cause of earthquake damage to man-made structures which, in turn, pose the greatest threat to human life when they fail or fall; however, earthquakes can also trigger other devastating events such as landslides and fires and can damage dams, adding to flood risk. The significance of earthquake hazard depends on the magnitude and location of the earthquake, its frequency, and the properties of the rocks and sediments through which the seismic waves travel.

Seismic activity is described in terms of magnitude and intensity. **Magnitude** characterizes the total energy released, and Intensity subjectively describes effects at a particular location. While an earthquake has only one magnitude, its intensity can vary throughout an affected region. The Richter scale is a logarithmic scale expressed in whole numbers and decimals that is used to measure the magnitude of an earthquake; in qualitative terms, an earthquake of 5.0 is a moderate event, 6.0 is a strong event, 7.0 is a major quake, and 8.0 or higher is considered a great earthquake.

The effect of an earthquake on the earth's surface is its **Intensity**, most commonly measured by the Modified Mercalli Intensity Scale (MMI). This scale is composed of 12 increasing levels of intensity ranging from imperceptible to catastrophic and evaluates the severity of ground motion at a given location relative the effects of earthquakes on people and property.

Seismic hazards can also be described in terms of Peak Ground Acceleration. Peak acceleration is a measure of the maximum force experienced by a small mass located at the surface of the ground during an earthquake and is an index of hazard for short stiff structures, such as some buildings. **Peak ground acceleration** (**PGA**) is equal to the maximum ground acceleration (ground motion) that occurred during earthquake shaking at a particular location. Unlike the Richter scale, PGA is not a measure of the total energy (magnitude, or size) of an earthquake, but rather of how hard the earth shakes at a given geographic point.

In an earthquake, damage to buildings and infrastructure is related more closely to ground motion, of which PGA is a measure, rather than the magnitude of the earthquake itself.

Table 4-12 describes the relationship among earthquake magnitude (Richter Scale), intensity (Modified Mercalli Scale) and Peak Ground Acceleration (PGA).

[81] FEMA, 2013 Multi Hazard Identification and Risk Assessment, Subpart B, Geologic Hazards.

Table 4-12. Relationship among Modified Mercalli Intensity, Richter Magnitude, and Peak Ground Acceleration

MMI	Richter Scale Magnitude Equivalent	Felt Intensity	Peak Ground Acceleration (%g)
I		Not felt except by a very few under special conditions.	<0.17
II	<4.2	Felt by a few, especially on upper floors of buildings. Suspended objects may swing.	0.17 - 1.4
III		Felt noticeably indoors. Standing automobiles may rock slightly.	0.17 - 1.4
IV		Felt by many indoors, by a few outdoors. At night, some are awakened. Dishes, windows, and doors rattle.	1.4 -3.9
V	<4.8	Felt by nearly everyone. Many are awakened. Some dishes and windows are broken. Unstable objects are overturned.	3.9 – 9.2
VI	<5.4	Felt by everyone. Many become frightened and run outdoors. Some heavy furniture is moved. Some plaster falls.	9.2 - 18
VII	<6.1	Most are alarmed and run outside. Damage is negligible in buildings of good construction, considerable in buildings of poor construction.	18 - 34
VIII		Damage is slight in specially designed structures, considerable in ordinary buildings, great in poorly built structures. Heavy furniture is overturned.	34 - 65
IX	<6.9	Damage is considerable in specially designed buildings. Buildings shift from their foundations and partly collapse. Underground pipes are broken.	65 - 124
X	<7.3	Some well-built wooden structures are destroyed. Most masonry structures are destroyed. The ground is badly cracked. Considerable landslides occur on steep slopes.	>124
XI	<8.1	Few, if any, masonry structures remain standing. Rails are bent. Broad fissures appear in the ground.	>124
XII	>8.1	Virtually total destruction. Waves are seen on the ground surface. Objects are thrown in the air.	>124

Source: After MA SHMCAP 2018.

According to the 2018 SHMCAP, New England experiences intraplate earthquakes due to its location deep within the interior of the North American tectonic plate, and an average of 6 earthquakes are felt in the region each year.[82] Within the Commonwealth, earthquakes can occur anywhere, but Boston and areas in eastern Massachusetts are potentially vulnerable to the effects of events in Canada as well. The SHMCAP recognizes that earthquakes cannot be predicted and may occur at any time, noting research that has found a 10-15% probability of a magnitude 5.0 or greater event somewhere in greater New England in a 10-year period.[83] The Northeast States Emergency Consortium (NESEC)[84] has noted the November 1755 earthquake with an epicenter 30 miles east of Cape Ann, MA and moderate quakes centered in northeastern Massachusetts that caused no damage, including November 1852, December 1854, January 19 and April 1903, October 1907, and January 1925. In October 1963, another earthquake centered near Cape Ann had an estimated magnitude of 4.0. Other moderate earthquakes centered in southeast Massachusetts that cause no damage included events on August 1847, September 1876, April 1925, and January 1940. In total, over 400 earthquakes are known to have been centered in Massachusetts from 1668 through 2016, most in the northeast part of the state **(Figure 4-18**).

Figure 4-18. Number of Felt Earthquakes in Massachusetts 1668-2016

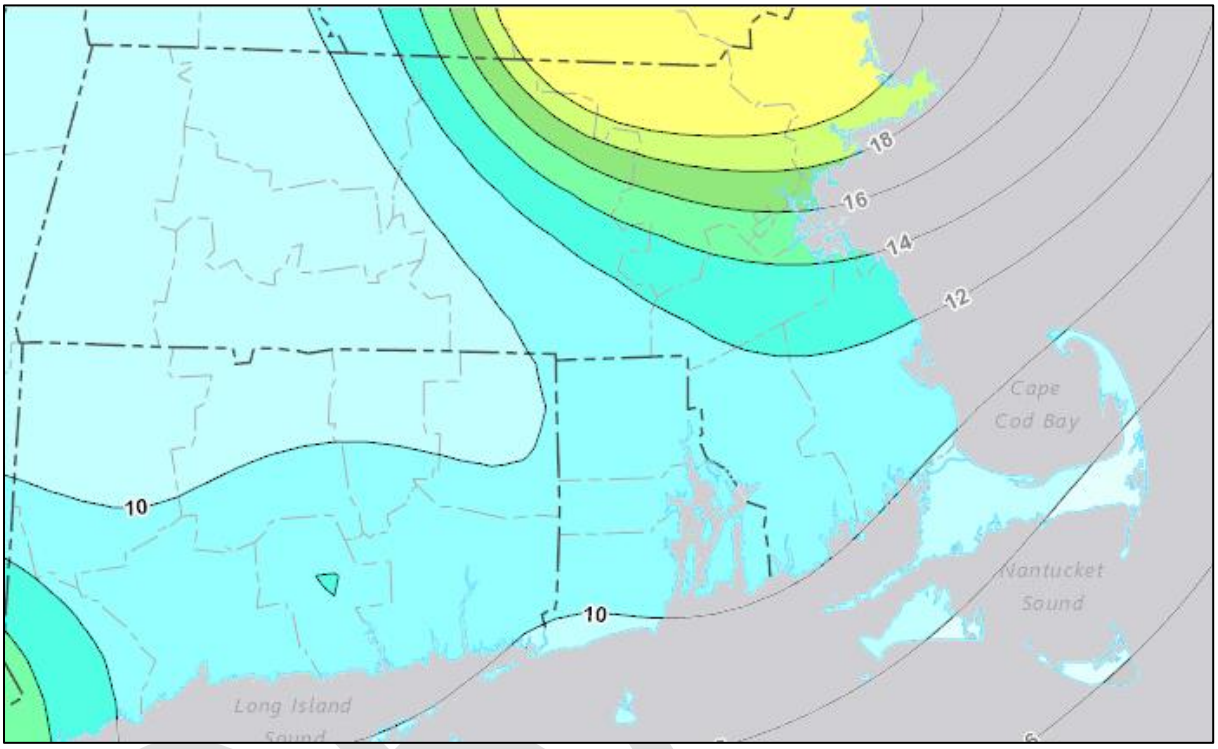
Number of Felt Earthquakes in the Northeast States			
State	**Years of Earthquake Record**	**Number of Felt Earthquakes**	**Years with Damaging Earthquakes**
Connecticut	1678-2016	115	1791
Maine	1766-2016	454	1973, 1904
Massachusetts	1668-2016	408	1727, 1755
New Hampshire	1638-2016	320	1638, 1940
New Jersey	1738-2016	98	1884
New York	1737-2016	551	1737, 1929, 1944, 1983, 2002
Rhode Island	1766-2016	34	
Vermont	1843-2016	50	
Total Number of Felt Earthquakes		2030	

Source: Northeast States Emergency Consortium. http://nesec.org/massachusetts-earthquakes/

[82] 2018 Massachusetts State Hazard and Climate Adaptation Plan, p. 4-274.
[83] Ibid. p. 4-275.
[84] The Northeast States Emergency Consortium, nesec.org.

The USGS Earthquake Hazards Program has developed the Unified Hazard Tool to provide earthquake hazard and probability mapping for the United States.[85] **Figure 4-19** presents the earthquake hazard and probability of the Peak Ground Acceleration that has a 2% chance of being exceeded in 50 years for the 760 m/s B/C boundary Site Class.

Figure 4-19. Massachusetts Earthquake Hazard and Probability Map - PGA 2% in 50 Years, 760 m/s[86]



Source: USGS Unified Hazard Tool.

The Town of Pembroke straddles two PGA zones – 10-12%g and 12-14%g. Additional analysis using the Unified Hazard Tool shows that for North Pembroke, the earthquake PGA that has a 2% chance of being exceeded in 50 years has a value of 12%g while for South Pembroke, the corresponding value is 11.47%g. These PGA values fall at the low end of the Modified Mercalli Intensity Scale level VI and roughly correspond to a 5.0 on the Richter Scale. The return interval associated with these values 2,475 years. Expressed differently, a 2% chance of exceedance equals a 98% chance that shaking will *not* exceed the value in any 50-year period.

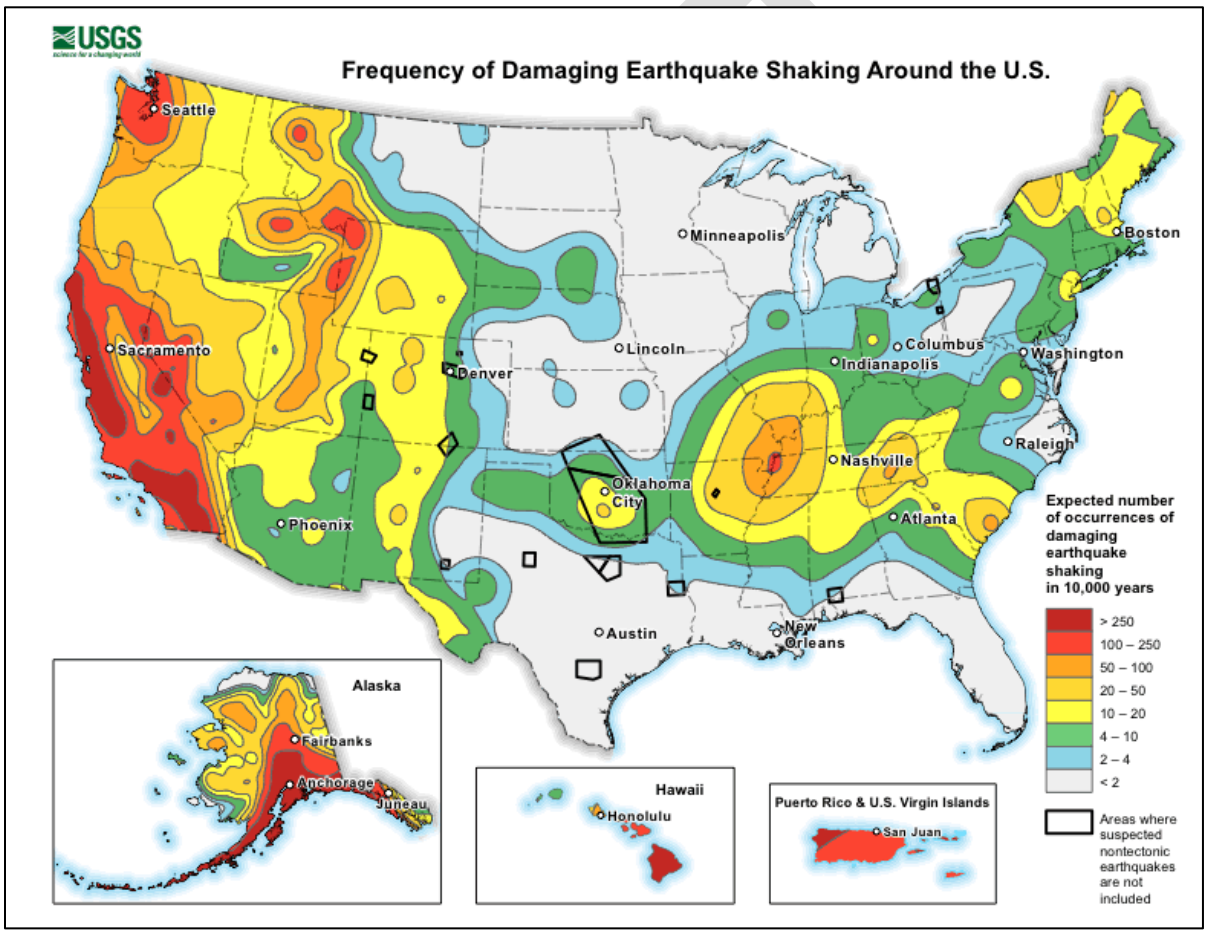
The USGS National Seismic Hazard Maps (NSHM) [87] show the distribution of earthquake shaking levels that have a certain probability of occurring in the United States. The NSHM compiles all known earthquake sources (and proxies for unknown sources), their distance from the site in question, and other seismological and geological information to project potential maximum expected ground motions at a site over a particular period of time and are updated every 6

[85] USGS Earthquake Hazards Program Unified Hazard Tool, https://earthquake.usgs.gov/hazards/interactive/index.php
[86] USGS NHSM 2014 Rev. 1
[87] USGS https://www.usgs.gov/natural-hazards/earthquake-hazards/science/introduction-national-seismic-hazard-maps?qt-science_center_objects=0#qt-science_center_objects

years. These maps are used to create and update public building codes and were created to provide the most accurate and detailed information possible to assist engineers in designing buildings, bridges, highways, and utilities to withstand shaking from earthquakes in the US. NSHM are also used by the insurance industry to set earthquake insurance premiums, by reinsurance companies to evaluate their risk to major disasters, by government officials, and land use managers.

Figure 4-19 illustrates how often scientists expect damaging earthquake shaking around the US. The map indicates the expected number of occurrences of damaging earthquake shaking in 10,000 years. According to this database, the expected number of occurrences of damaging earthquake shaking for the Town of Pembroke ranges from 4 to 20 over 10,000 years.

Figure 4-19. Frequency of Damaging Earthquake Shaking Around the US



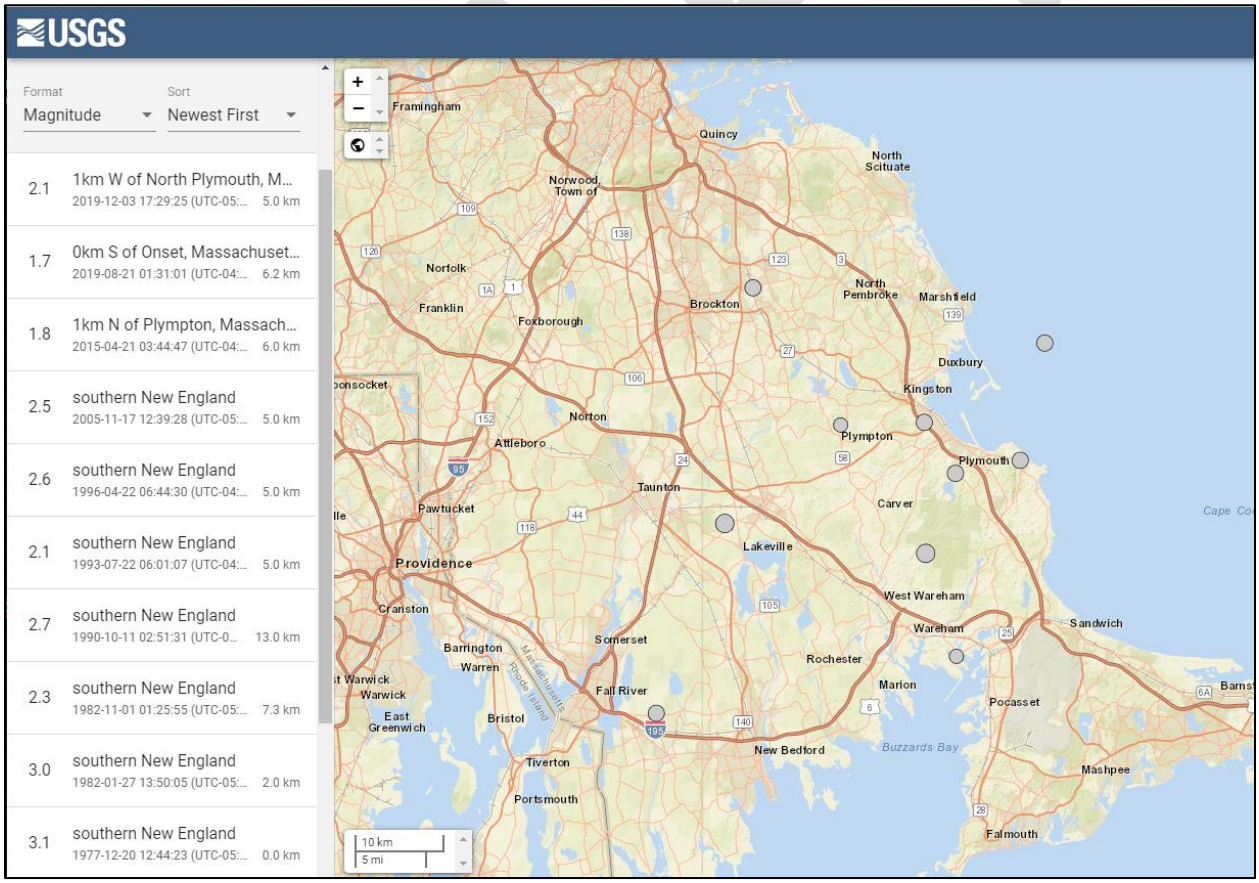
According to USGS, the Plymouth County region experienced 10 earthquakes between 1963 and 2020, ranging in magnitude 1.7 to 3.1. These events are presented in **Table 4-13** and **Figure 4-20.**

Table 4-13. Earthquakes in the Pembroke Vicinity 1963-2020

Date	Location	Magnitude
4/22/1964	East of Fall River	2.6
12/20/1977	West Wareham Vicinity	3.1
1/27/1982	Lakeville	3.0
11/1/1982	Off Duxbury Coast	2.3
10/11/1990	Plymouth Coast	2.7
7/22/1993	Abington-North Pembroke	2.1
11/17/2005	Plymouth	2.5
4/21/2015	1 km N of Plympton	1.8
8/21/19	Onset	1.7
12/3/2019	1 km W of North Plymouth	2.1

Source: USGS Latest Earthquakes.

Figure 4-20. Earthquakes in Pembroke Vicinity 1963-2020



Source: USGS Latest Earthquakes

The 2015 Old Colony Planning Council Regional Hazard Mitigation Plan assessed earthquake risk for the Town of Pembroke as a very low frequency, seriously severe hazard and noted that due to the historic nature of the Town, there is potential for a moderate earthquake to do damage, especially to older buildings.

The CRB Workshop participants did not list earthquakes as a significant risk to the Town. Based on the State, regional, and local data presented, the 2021 MVHMP assesses the earthquake hazard for the Town as Low-Very Low frequency, Serious magnitude, and Extensive (Town-wide) in extent.

4.5.2 Landslides

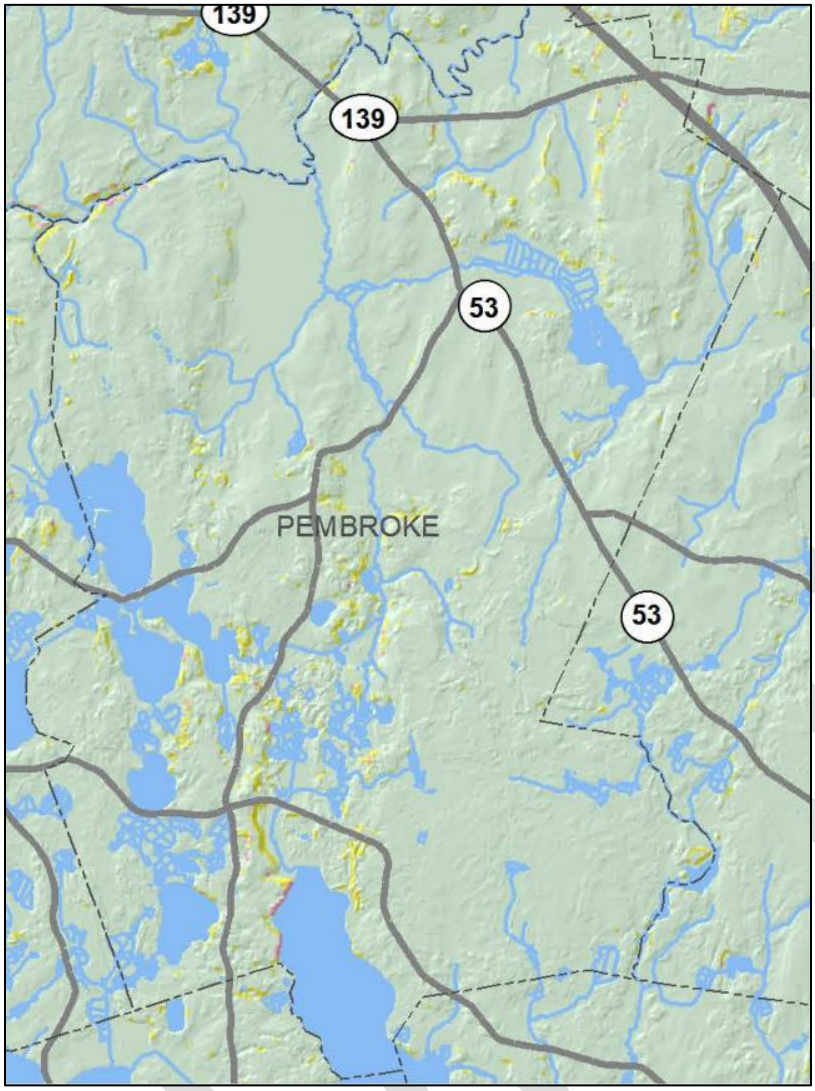
Landslides in the Commonwealth are most commonly caused by a combination of specific geologic conditions (glacial till or bedrock, both relatively impermeable in relation to the overburden), steep slopes, and/or excessive wetness leading to extreme pore pressures in the soil subsurface. Historical data suggest that most events in the

State are preceded by two or more months of higher than normal precipitation followed by a single, high-intensity rainfall of several inches or more that saturates slopes.[88]

In 2013, the Massachusetts Geological Survey prepared a map of potential landslide hazards for the Commonwealth to provide the public, local governments, and local and state emergency management agencies the location of areas where slope movements have occurred or may possibly occur in the future under the right conditions of prolonged antecedent moisture and high intensity rainfall. Three slope stability maps were prepared at a scale of 1:125,000; Sheet 3 covers southeastern Massachusetts, Cape Cod and the Islands. The section of Sheet 3 that relates to the Town of Pembroke is presented in **Figure 4-21**.[89]

[88] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, p. 4-59.
[89] Mabee, S.B. and C.C. Duncan. 2013. Slope stability map of Massachusetts. Massachusetts Geological Survey, Miscellaneous Map 13-01. Scale 1:125,000. 3 sheets. Adobe PDF and ESRI ArcGIS map data files. http://www.geo.umass.edu/stategeologist/Products/Landslide_Map/SSIM_Sheet3v2_print.pdf

Figure 4-21. Slope Stability Map



Map Color Code	Predicted Stability Zone	Relative Slide Ranking[1]
	Unstable	High
	Upper Threshold of Instability	
	Lower Threshold of Instability	Moderate
	Nominally Stable	Low
	Moderately Stable	
	Stable	Very Low

The Slope Stability Map assigns a Predicted Stability Zone from Stable to Unstable and a Relative Slide Ranking of Very Low, Low, Moderate, and High. The Relative Slide Ranking designates the relative hazard ranking for initiation of shallow slides on unmodified slopes.

Most of the Town of Pembroke is mapped as Stable and carries a Very Low Relative Slide Ranking. Several areas largely associated with surface water features are rated as Nominally to Moderately Stable with a Low Relative Slide Ranking. Still fewer areas, more visible on the Landslide Hazard Map (**Appendix A**), are at the Lower Threshold of Instability and carry a Moderate Relative Slide Ranking.

The USGS maintains a US Landslide Inventory that ranks landslide reports and locations as Possible, Probable, Likely, Confident, and High Confidence. The inventory identifies one high confidence landslide report for the greater Pembroke region, involving a Wal-Mart off Route 1 in Walpole, where three days of heavy rain caused a landslide in the hills next to the store, crushing part of a nearby storage facility; the event occurred on March 15, 2010. The next nearest reported

landslide occurred at the Good Shepard Church in Attleboro on November 4, 2014 when part of a hill collapsed putting the safety of the church at risk; the confidence level for this report was Likely.[90] No landslides were reported for the Town of Pembroke.

The 2015 Old Colony Regional HMP identified landslides as a very low frequency, minor hazard for Pembroke, noting that the Town has not experienced a recorded landslide and is not especially vulnerable to these events due to the lack of hills and generally flat topography.

The CRB Workshop Findings reaffirmed the findings of the 2015 RHMP.

The 2021 MVHMP assesses the landslide hazard potential for the Town of Pembroke as Very Low frequency, Minor magnitude, and Limited extent. This is supported by the FEMA National Risk Assessment data for this hazard as detailed in Section 5.

4.5.3 Effect of Climate Change

According to the 2018 SHMCAP, regional climate change models suggest that Massachusetts is likely to experience more frequent and intense storms throughout the year; this trend could increase the incidence of extreme soil saturation and conditions conducive to landslides. Landslide frequency could also increase due to the loss of vegetated slopes during prolonged droughts; denuded slopes are inherently less stable and depending on underlying geology and rainfall, could be vulnerable to slippage.[91]

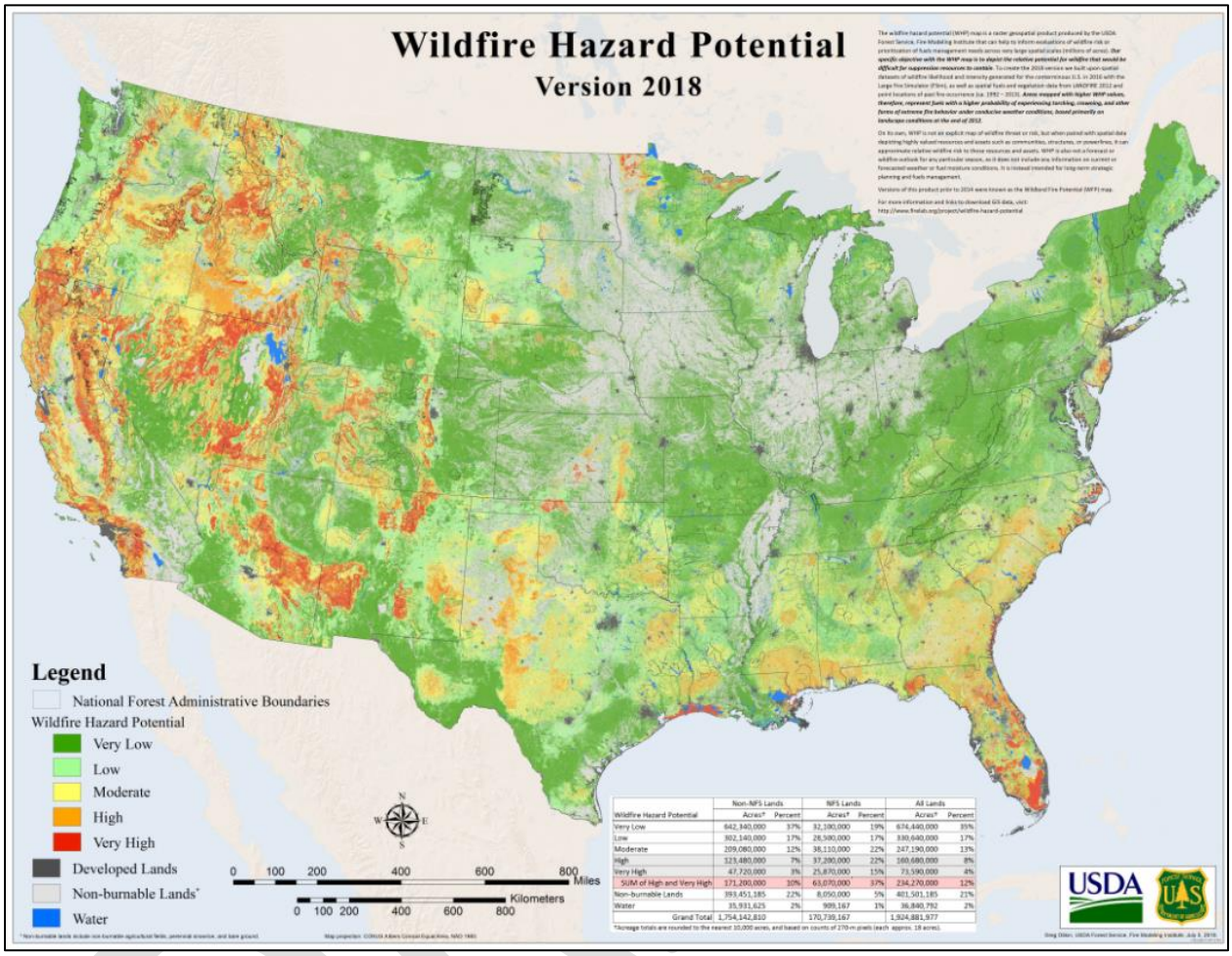
4.6 Wildfire Hazard

A wildfire is a non-structural, unauthorized human-caused fire that includes escaped fire use events (where appropriate management response to naturally ignited wildland fires escape), escaped prescribed fire projects, and all other unintended wildfires. Wildland fire occurs when vegetative fuel, such as grass, leaf litter, trees, or shrubs, is exposed to an ignition source and the conditions for combustion are met, resulting in fire growth and spread through adjacent combustible material. Wildfires are either ignited by lightning or a consequence of human activity and are a growing natural hazard in most regions of the United States, posing a threat to life and property, particularly where native ecosystems meet developed areas. The secondary effects of wildfires include erosion, landslides, introduction of invasive species, and changes in water quality, and are often more disastrous than the fire itself.[92]

The USDA US Forest Service prepares and regularly updates Wildfire Hazard Potential (WHP) maps for the continental US (**Figure 4-22**).[93] The stated objective of the WHP is to "…depict the relative potential for wildfire that would be difficult for suppression resources to contain."[94] The 2018 version of the WHP is based on spatial datasets of wildfire likelihood and intensity, with spatial fuels and vegetation data and point locations of past fire occurrence between 1992-2013. The map presents 5 wildfire hazard potential classes – Very Low, Low, Moderate, High, and Very High. The USFS qualifies that the WHP is not an explicit map of threat or risk but when paired with high value resource and community asset data (infrastructure, powerlines etc.), it can approximate relative wildfire risk to those elements.

[90] USGS US Landslide Inventory. https://www.usgs.gov/natural-hazards/landslide-hazards/maps
[91] 2018 MA State Hazard Mitigation and Climate Adaptation Plan, p. 4-60.
[92] USGS Fact Sheet, Wildfire Hazards – A National Threat, 2006.us for
[93] USDA USFS Fire, Fuel, Smoke Science Research Program. https://www.firelab.org/project/wildfire-hazard-potential
[94] Ibid.

Figure 4-22. Wildfire Hazard Potential Across the Coterminous US



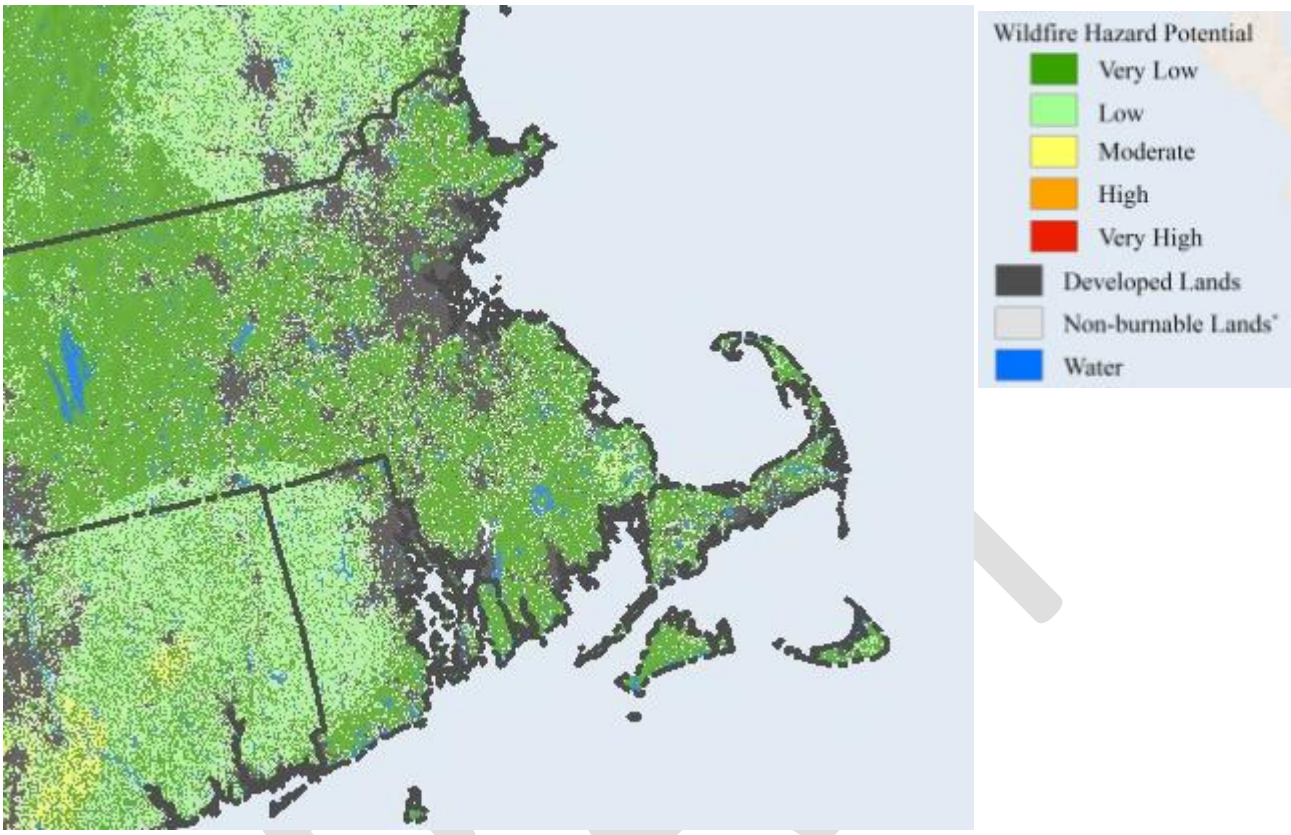
	Non-NFS Lands		NFS Lands		All Lands	
Wildfire Hazard Potential	Acres*	Percent	Acres*	Percent	Acres*	Percent
Very Low	642,340,000	37%	32,100,000	19%	674,440,000	35%
Low	302,140,000	17%	28,500,000	17%	330,640,000	17%
Moderate	209,080,000	12%	38,110,000	22%	247,190,000	13%
High	123,480,000	7%	37,200,000	22%	160,680,000	8%
Very High	47,720,000	3%	25,870,000	15%	73,590,000	4%
SUM of High and Very High	171,200,000	10%	63,070,000	37%	234,270,000	12%
Non-burnable Lands	393,451,185	22%	8,050,000	5%	401,501,185	21%
Water	35,931,625	2%	909,167	1%	36,840,792	2%
Grand Total	1,754,142,810		170,739,167		1,924,881,977	

*Acreage totals are rounded to the nearest 10,000 acres, and based on counts of 270-m pixels (each approx. 18 acres).

Source: USDA USFS Fire, Fuel, Smoke Science Program.

The most recent WHP mapping for the southeast Massachusetts area that includes the Town of Pembroke (**Figure 4-23**) is the basis for the Town of Pembroke Wildfire Hazard Map (**Appendix A**) which overlays the Town's critical infrastructure and provides a more detailed indication of WHP ratings throughout the community. In general, the Town has a Very Low to Low Wildfire Hazard Potential.

Figure 4-23. Wildfire Hazard Potential Southeastern Massachusetts.



Source: USDA USFS Fire, Fuel, Smoke Science Program.

The 2018 SHMCAP states that wildfires in Massachusetts are caused by natural events, human activity, or prescribed fire; the season typically runs from late March until June (with April the month of highest danger) and corresponds with the driest live fuel moisture period of the year.[95] The length of the fire season can be affected by related climate conditions, including drought, snowpack, and high winds. Ecosystems in the Commonwealth most vulnerable to fire are pitch pine, scrub oak, and oak forests, and the SHMCAP identifies Barnstable and Plymouth counties as the most fire-prone due to their vegetation, sandy soils, and drying winds. Additional areas susceptible to wildfire are those at the urban-wildland interface which is the zone where structures and development meet or intermix with undeveloped areas and vegetative fuels.

The SHMCAP lists several notable wildfires that have occurred in Massachusetts, noting that none resulted in a FEMA Disaster Declaration. These events included two events in the Plymouth area in 1957 and 1964, and 4 others – Dedham (April 2012), Brimfield (2012), Westfield (2016), and Joint Base, Cape Cod (2016). A fifth event in July 2002 involved smoke from wildfires in Quebec that affected air quality in Western Massachusetts.[96] The two Plymouth events are characterized in **Table 4-14**.

[95] 2018 MA State Hazard Mitigation and Climate Adaptation Plan, p. 4-171.
[96] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, Appendix B, Table B-6: Wildfire, p. 19.

Table 4-14. Notable Wildfire Occurrences, Plymouth County, Massachusetts

Date	Description
May 1957	Catastrophic wildfire in Plymouth burned 15,000 acres and destroyed approximately 40 structures.
1964	A large fire in the Plymouth area burned 5,500 acres and destroyed cottages on Charge Pond.

Source: 2018 MA SHMCAP Appendix B.

The 2015 OCPC HMP determined that the Town of Pembroke was not vulnerable to Major Urban Fires as there are no major urban areas in the Town; the Plan listed this hazard as "Not Applicable."

The Pembroke CRB Workshop participants did not consider Wildfire a significant potential hazard to the Town.

The 2021 MVHMP assesses the Wildfire hazard potential for the Town of Pembroke as Very Low frequency, Minor magnitude, and Limited in extent.

4.6.1 Effect of Climate Change

Over the last several decades, both the incidence of large wildfires and the duration of the wildfire season across much of the United States have increased. Future wildfire projections based on forecasted climate scenarios indicate both an increase in the expected severity of wildfires, and an expansion of wildfires over much of the northern hemisphere, particularly for western North America.[97]

The 2018 MA SHMCAP points out that seasonal drought risk is projected to increase during summer and fall in the Northeast as higher temperatures lead to greater evaporation and earlier winter and spring snowmelt; this is likely to be accompanied by more variable precipitation patterns. Drought and warmer temperatures may also heighten the risk of wildfire by causing forested areas to dry out and become more flammable. The Plan further notes that the frequency of lightning strikes could climb by approximately 12% for every degree Celsius warming, increasing the chance of wildfire.[98]

4.7 Climate Change Hazards

4.7.1 Extreme Temperatures

Extreme weather and climate events—such as drought, heavy rain, and heat waves—are a natural part of the Earth's climate system that can, nonetheless, have significant impacts on populations and the environment. In a stable climate, society and the environment are generally able to adapt to the historical range of extremes; however, as the climate changes, these extreme events may exceed their historical range to create societal and environmental vulnerabilities.[99] According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, scientists are increasingly confident that some weather events and extremes will become more frequent, widespread, or more intense

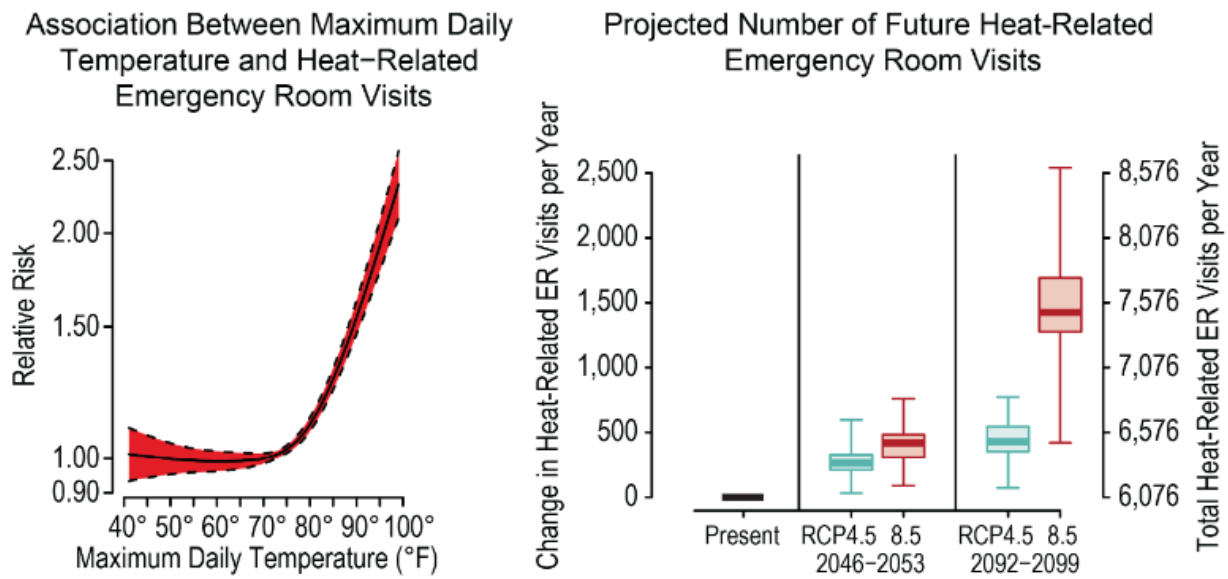
[97] USGS Wildfires and Climate.
[98] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, p. 4-172.
[99] NOAA North American Climate Extremes Monitoring.

in the 21st century. According to the US Climate Change Science Program, "…most of North America has been experiencing more unusually hot days and nights, fewer unusually cold days and nights, and fewer frost days."[100]

Extreme Heat

Cities in the northeast US tend to have higher temperatures than outlying areas due to large expanses of concrete and asphalt that absorb and hold short-wave radiation to create urban heat islands (UHI). Daytime temperatures in urban areas are about 1-7 degrees F higher and nighttime temperatures average 2-5 degrees F higher.[101] According to the US Global Change Research Program Fourth National Climate Assessment (NCA4) regional summary for the Northeast, nighttime temperatures remain high during extreme heat events, increasing risk of heat-related illness or death.[102] Since 1901, annual average temperature increases across the Northeast range from less than 1 degree F in West Virginia to about 3 degrees F (1.7 degrees C) in New England. The NCA4 notes that in 2013, there were 133 excess deaths in New York City due to extreme heat, and, for the region, projects approximately 650 additional premature deaths annually from extreme heat by the year 2050 under either a lower (RCP4.5) or higher (RCP8.5) emissions scenario.[103]

Figure 4-24. Extreme Heat and Emergency Room Visit Rate

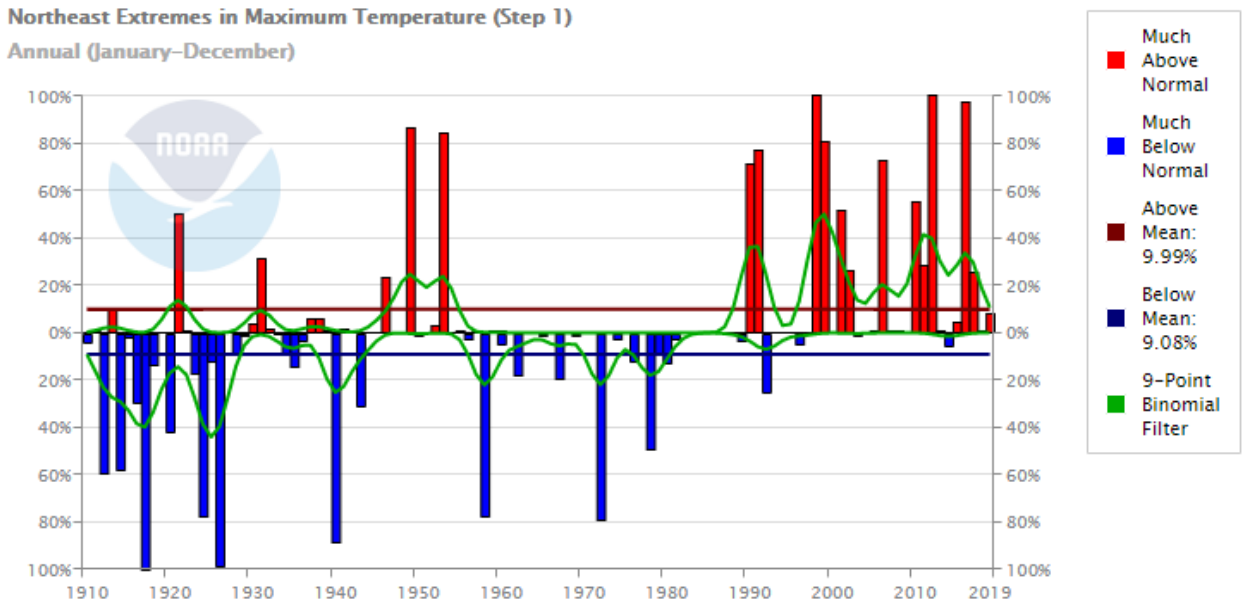


Source: USGCRP NCA4.

[100] In NOAA North American Climate Extremes Monitoring, https://www.ncdc.noaa.gov/extremes/nacem/introduction.
[101] US EPA Heat Island Effect.
[102] US Global Change Research Program Fourth National Climate Assessment, 2018, Vol. II, p. 118.
[103] RCP refers to a Representative Concentration Pathway, the greenhouse gas concentration trajectory adopted by the IPCC. RCP 4.5 is an intermediate scenario in which emissions peak around 2040 then decline; RCP 8.5 is a worst case scenario in which emissions continue to rise throughout the 21st century.

Over that past 100 years, the Northeast shows a trend of annual average temperatures much above normal, with the trend intensifying since 1990. **Figure 4-25** depicts the extremes in maximum temperature for the period of 1910 to 2019.[104]

Figure 4-25. National Annual Average Temperature Extremes 1910 – 2019



Source: NOAA NCDC US Climate Extremes Index.

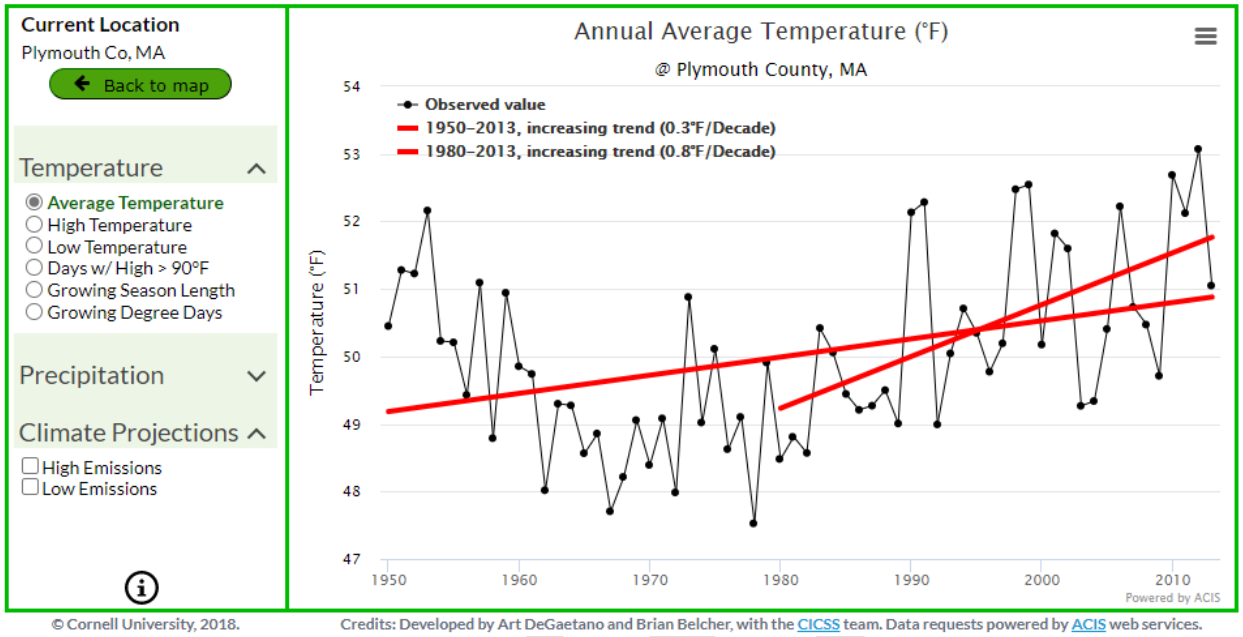
Cornell University Climate Smart Farming Program has developed a climate tool to show how the climate has changed in the Northeast since 1950 and to project change over the next century. For Plymouth County, MA, the annual average temperature data show an increasing trend of 0.3 degrees F per decade from 1950 to 2013 (63 years), and an increase of 0.8 degrees F per decade from 1980-2013 alone (**Figure 4-26**). Under a high emissions scenario, the CSC Tool projects an annual increase of 24 days with temperatures over 90 degrees F by mid-century and 60 days by end of century for the County. Under a low emissions scenario, the corresponding projections are 16 additional extreme heat days by mid-century and 27 by century's end. These figures approximate the projections by the Northeast Climate Service Center model that forecasts an increase of 10.23 days over 90 degrees F by mid-century and nearly 27 days by century's end.[105]

According to Resilient MA, the Commonwealth will face more heat waves in the future that will disproportionately affect sensitive and disadvantaged populations. Extreme heat, combined with high humidity, can create serious risk for individuals living in substandard quarters without adequate ventilation or cooling. Climate change may also cause increased periods of extreme cold due to shifts in the pathways of atmospheric air currents over Arctic northern regions.

[104] NOAA US Climate Extremes Index, Northeast Region. https://www.ncdc.noaa.gov/extremes/cei/graph/ne/01-12/1
[105] ResilientMA.

Extreme cold can threaten people without adequate shelter, or who live in poorly insulated homes, or who become stranded due to impaired travel conditions.

Figure 4-26. Annual Average Temperature Trend for Plymouth County MA 1950-2013



Source: Cornell University CSF Program.

Extreme heat for Massachusetts is generally defined as a period of 3 or more consecutive days above 90 degree F.[106] According to the 2018 SHMCAP, the average Massachusetts summer between 1971 and 2000 included 4 days of extreme heat (over 90 degrees F) and climate scientists project an additional 10-28 days annually over 90 degrees F by mid-century. By the end of the century, 13 to 56 additional extreme heat days could occur during summer months in the Commonwealth.

For the Pembroke area, data from the Brockton Station (USC00190860) records 11 occasions when temperatures exceeded 90 degrees F for a 3-day period between 1960 and 1980. The number of occurrences between 1981 and 2000 rose to 32, with 47 such events between 2001 and 2020.[107] This trend indicates an average occurrence rate increase from 1 event every other year to 2.5 events per year over the 60-year period.

The National Weather Service reports an excessive heat event whenever heat index values meet or exceed locally/regionally established excessive heat warning thresholds. Fatalities (directly-related) or major impacts to human health that occur during excessive heat warning conditions are reported using this event category.[108] The NOAA Storm Events Database reported only 2 Excessive Heat events for Plymouth County between 2000 and 2020. The first such event reported for Plymouth County occurred in July 2011 when a strong upper level ridge brought very hot temperatures to southern New England, accompanied by high humidity levels that drove heat index values to exceed

[106] 2018 Massachusetts State Hazard Mitigation and Climate Adaptation Plan, p. 4-143.
[107] NOAA US Climate Resilience Toolkit Applied Climate Information System Data. Climate Explorer (nemac.org)
[108] National Weather Service Instruction 10-1605, July 2018, Operations and Services Performance, NWSPD 10-16, Storm Data Preparation. https://www.nws.noaa.gov/directives/sym/pd01016005curr.pdf

105 degrees. The second event occurred in July 2018 when heat index values of 105-109 occurred in eastern Massachusetts, including Plymouth County. No injuries or deaths were reported for either event.

Extreme Cold

The National Weather Service defines extreme cold in the northern US as temperatures well below zero. Climate change may also contribute to the frequency of brief periods of extreme cold when temperatures drop well below normal, although the data are not clear. In recent years, extremely low temperatures have been triggered by shifts in the pathways of atmospheric air currents that pass over Arctic northern regions. The extended cold snap of 2015 was one such period.[109] Extreme cold can make it challenging for people to stay warm and safe, and can cause health emergencies for people without adequate shelter or living in homes that are poorly insulated, and people who become stranded due to poor travel conditions.

The CSC Tool for Plymouth County indicates that from 1950 to 2013, the annual average low temperature increased 0.4 degree F per decade (0.9 degrees F per decade from 1980 to 2013). Under a low emissions scenario, the annual average low temperature for the County will increase by 4 degrees F and under a high emissions scenario by nearly 9 degrees by the end of the century.

For the Town of Pembroke, Resilient MA projects an annual decrease of 0.72 days below 0 degrees F by 2030 under a High Emissions Scenario; the corresponding annual decrease associated with a Medium Emissions Scenario is 0.68 days.

The 2015 OCPC HMP identified Extreme Temperatures as a high frequency, minor severity, Town-wide hazard for Pembroke and noted the most vulnerable groups to be young children, the elderly, and people who are out-of-doors for extended lengths of time; this last group would include individuals without homes and outdoor workers.

The CRB Workshop participants listed Extreme Temperatures as one of the most significant hazards facing the Town. In addition to the vulnerable groups identified in the 2015 RHMP, participants also listed individuals in residential facilities and without personal transportation. These populations are at particular risk when extreme temperatures coincide with power outages caused by high winds, snowstorms, and intense rainstorms.

The 2021 MVHMP assesses the Extreme Temperatures hazard for Pembroke to be of high frequency, minor to serious in severity, and Town-wide.

4.7.2 Drought

A drought is a period of below-normal precipitation causing reduced soil moisture, a lowered water table, diminished stream flow, vegetation and crop damage, and a general water shortage. Droughts are the second-most costly weather events after hurricanes.[110] According to ResilientMA, a small projected decrease in average summer precipitation in Massachusetts could combine with higher temperatures to increase the frequency of episodic droughts. Droughts will create challenges for local water providers by reducing surface water storage and recharge of groundwater supplies, including private wells. More frequent droughts could also exacerbate the impacts of flood events by damaging vegetation critical to mitigating flood impacts. Droughts may also weaken tree root systems, making them more likely

[109] Resilient MA Climate Change Clearinghouse for the Commonwealth, Extreme Weather.
[110] National Geographic Society. https://www.nationalgeographic.org/encyclopedia/drought/

to uproot during high wind events and causing power outages.[111] The loss of vegetation due to drought, if significant over large areas, can also increase surface temperatures and heat island effects.

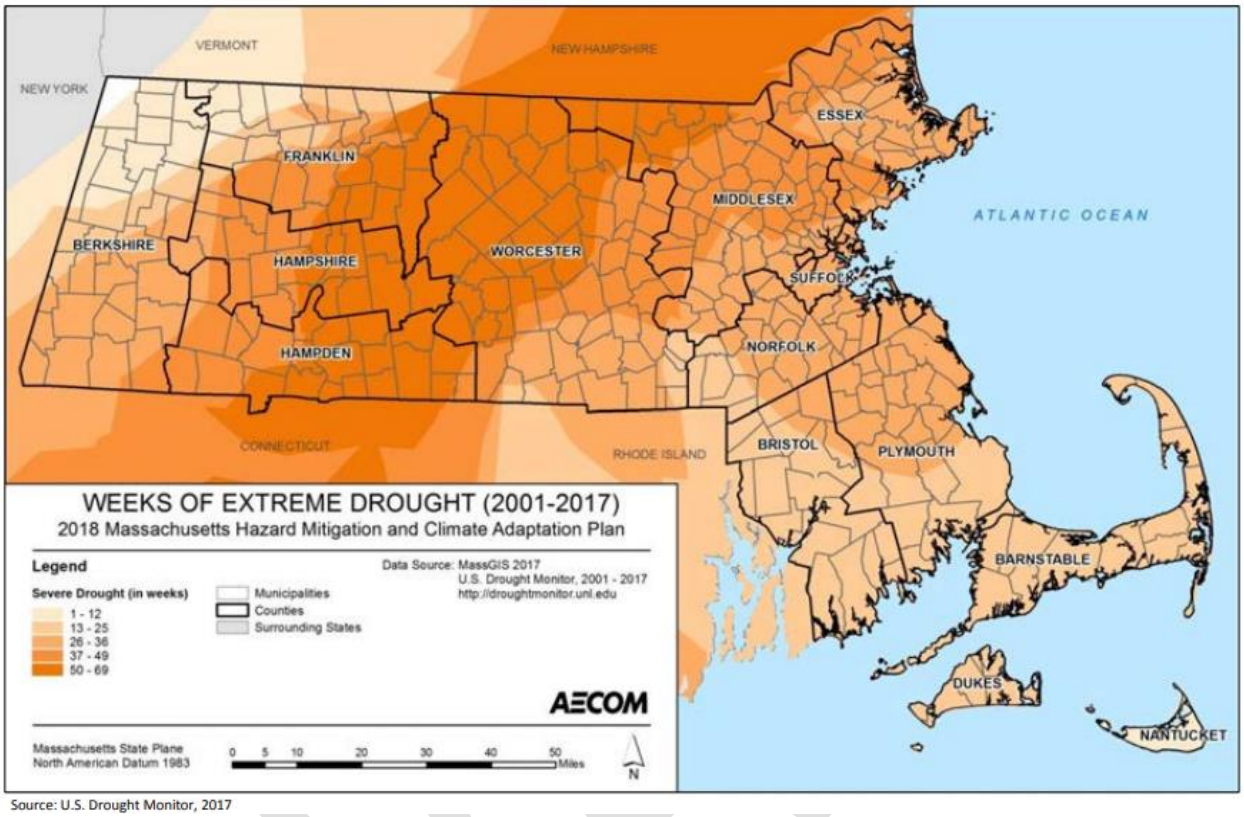
The entire Commonwealth is exposed to drought hazard, with each event affecting all or specific regions of the State. While the most recent emergency drought occurred in the 1960's, the drought of 2016 was of equal severity but shorter duration. Since the 1960's, there have been multiple severe events, including 2 warning and 4 watch events. Less severe events occur more often, with an approximately 8% chance of a Watch level drought occurring in any given month in the State.[112]

Both the frequency and intensity of droughts are expected to increase during summer and fall in the Northeast due to higher temperatures, greater evaporation, earlier snowmelt, and more variable and extreme rainfall patterns. Reduced snowfall due to higher temperatures translates to reduced snowpack and a shortened period for snowmelt to recharge the groundwater and base streamflow.

The Massachusetts Drought Management Plan assessed drought conditions in 6 regions, including the Southeast, Cape and Islands, and determined the number of weeks of Extreme Drought between 2001-2017 for each part of the State **(Figure 4-27).** The region that includes the Town of Pembroke experienced 26-36 weeks of severe drought over the 17-year period.

[111] ResilientMA. https://resilientma.org/changes/changes-in-precipitation#more_impacts_epsiodic_droughts
[112] 2018 State Hazard Mitigation and Climate Adaptation Plan, p. 4-39

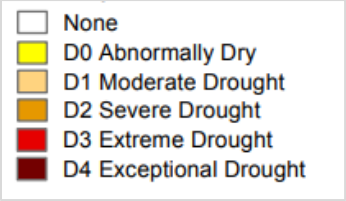
Figure 4-27. Weeks of Severe Drought 2001-2017



Source: 2018 MA SHMCAP.

The US Drought Monitor provides data for drought events nationwide and categorizes occurrences by progressive severity from Abnormally Dry (D0), Moderate Drought (D1), Severe Drought (D2), Extreme Drought (D3), and Exceptional Drought (D4) (**Figure 4-28**).

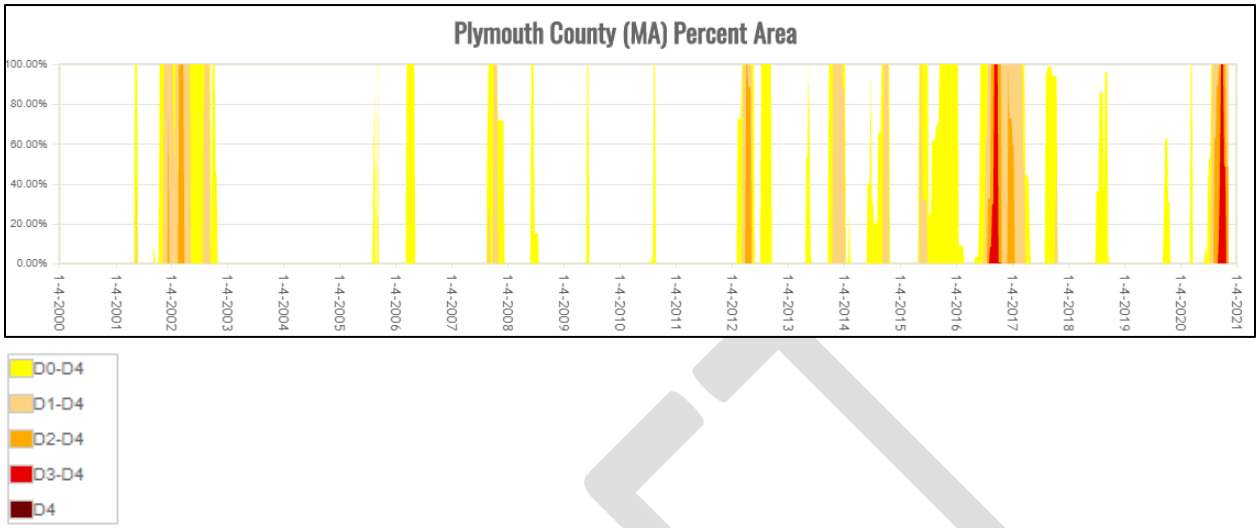
Figure 4-28. US Drought Monitor Intensity Scale



Source: US Drought Monitor.

According to the US Drought Monitor summary for 2000 to 2020, drought events for Plymouth County increased in frequency and intensity between 2010 and 2020 when compared to the previous 10 years (**Figure 4-29**). Over the 20-year period, the County experienced Severe Drought (D2-D4) between 2001-2002 and Extreme Droughts (D3-D4) between 2016-2017 and again in 2020.

Figure 4-29. Drought Events (D0-D4), Plymouth County MA, 2000-2020



Source: US Drought Monitor.

The 2015 Old Colony Planning Council Regional Hazard Mitigation Plan did not assess the Town of Pembroke's vulnerability to Drought.

The Pembroke CRB Workshop participants identified Drought as one of 5 top hazards facing the Town, of particular concern due to the fact that residents share their surface and groundwater supplies with several municipalities.

In light of the data presented in the State Drought Management Plan and the US Drought Monitor, Drought poses a Medium frequency, Minor to Serious, Town-wide risk to the Pembroke community.

4.8 2021 MVHMP Hazard Characterization Comparison with 2015 HMP

Table 4-15 summarizes the Natural Hazard characterization presented in the 2015 Old Colony Planning Council Regional Hazard Mitigation Plan and the current Natural Hazard and Climate Change for the 2021 MVHMP. The Top 4 Hazards for each planning period, as determined by the Town, are highlighted in orange.

Table 4-15. Natural / Climate Change Hazard Characterization Update from 2015

	Natural / Climate Change Hazard	2015 OCPC RHMP	2021 MVHMP
		Frequency / Severity / Ranking	
	Flood / Extreme Precipitation	High / Serious / 6	High / Serious / 2
Wind-Related	Hurricanes & Tropical Storms	Medium / Serious / 5	Medium / Serious / 1
	Tornadoes	Very Low / Serious / 3	Very Low / Serious / 1
	Nor'easters	(In Winter Storms)	High / Serious / 4
	Severe Thunderstorms / High Wind Events	Not Assessed	Medium / Minor-Serious / 1
	Winter Storms / Snowfall	High / Serious / 6	High / Serious / 4
	Earthquakes	Very Low / Serious / 3	Very Low / Serious / NA
	Landslides	Very Low / Minor / 2	Very Low / Minor / NA

	Natural / Climate Change Hazard	2015 OCPC RHMP	2021 MVHMP
	Wildfire	Medium / Minor / 4	Very Low / Minor / NA
Climate Change	**Extreme Temperatures**	High / Minor / 5	Very Low / Minor / 3
	Drought	Not Assessed	Medium / Minor-Serious / 5
	Major Urban Fires	Not Applicable	Not Applicable
	Coastal Erosion / Shoreline Change	Not Applicable	Not Applicable
	Tsunamis	Not Applicable	Not Applicable

5. RISK ASSESSMENT

Risk assessment is the process of measuring the potential loss of life, personal injury, economic injury, and property damage resulting from natural hazard events by assessing the vulnerability of people, buildings, and infrastructure. It answers the question of what would happen if a natural hazard and/or climate change-driven event occurred in a community, and is the foundation for the mitigation planning process.

This Section assesses the potential for personal and economic injury and property damage from the natural hazards identified in Section 4 as most likely to affect the Town of Pembroke. The general approach to the risk assessment is based on evaluation of the relevant hazard databases, input from Town staff and CRB Workshop participants, GIS-based vulnerability assessments for flood hazard, and the FEMA National Risk Index data for the three Town census tracts - 50801, 50802, and 508200. Each hazard assessment identifies changes, if any, since the 2015 OCPC RHMP.

5.1 Flood Hazards and Extreme Precipitation

The Town flood risk assessment is based on the FEMA NFIP Flood Insurance Rate Maps for Pembroke, the NOAA Hurricane Surge Inundation Data,[113] a GIS vulnerability assessment, information from Town staff, and accounts of past flood events provided by participants in the Community Resilience Building Workshop. As detailed in Section 4, the 2015 OCPC RHMP ranked Flooding as the most significant hazard facing the Town and rated is as a High Frequency, Serious risk. The results of the CRB Workshop ranked this hazard as one of the top 5 after High Winds.

5.1.1 Flood Hazard Areas

5.1.1.1 Riverine

Under the National Flood Insurance Program, the Federal Emergency Management Agency (FEMA) provides flood hazard data, maps, and other products as part of its Risk Mapping, Assessment, and Planning program (RISKMap) These products are intended to inform flood risk and vulnerability assessments in developing community hazard mitigation plans and include Flood Insurance Rate Maps (FIRMs) that designate Special Flood Hazard Areas, or flood zones. The FEMA-designated flood zones A, AE, and X (shaded) for the Town of Pembroke are delineated on the Flood and SLOSH Hazard Map in **Appendix A**. An explanation of each of the zones is provided below:[114]

FEMA Flood Insurance Rate Zones

Flood Zone A includes areas subject to inundation by the 1-percent-annual-chance flood event. Because no detailed hydraulic analyses have been performed for these areas, no Base Flood Elevations or depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Flood Zones AE and A1-A30 define areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods which allows Base Flood Elevations to be shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone X (shaded) defines areas of moderate flood hazard determined to be outside the Special Flood Hazard Area, between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood.

[113] *National Storm Surge Hazard Maps, NOAA/NWS/NHC Storm Surge Unit.*
[114] FEMA Flood Zones. https://www.fema.gov/glossary/flood-zones

The highest risk flood zones (A, AE) have a 1-percent chance of flooding in any given year and are often referred to as the 100-year floodplain; flood insurance is required for government-backed mortgages for homes in this zone. Moderate- to low-risk flood zones, referred to as the 500-year floodplain (X-shaded), do not require flood insurance.

It follows that the areas of the Town most vulnerable to flooding are those located within either or both the FEMA-designated flood zones and the Hurricane Surge Inundation zones (discussed separately in Section 5.1.1.2). These include lands along Cedar Swamp Brook (including Cedar Swamp), North River, Little Pudding and Pudding brooks, Herring Brook, Robinson Creek, a small segment of McFarland Brook, Tubbs Meadow Brook, Silver Lake, Great and Little Sandy Bottom ponds, Furnace Pond, and Oldham Pond. Notwithstanding, there are additional areas of the Town that have historically flooded but are not located within a FEMA Flood Zone (see Section 5.1.2).

5.1.1.2 Hurricane Surge Inundation Zones/SLOSH

Although the Town of Pembroke is approximately 5-7 miles from the coast of Massachusetts, its northern sections are subject to hurricane surge inundation (HSI) along the North River as far inland as Herring Run Historical Park, Misty Meadow Conservation Area, the North Pembroke School Conservation Area, and the area bounded by the Indian Head River and North River north of Schoosett Street (Flood and SLOSH Hazard Map, **Appendix A**). Section 5.1.3 presents the flood exposure analysis for these areas under hurricane categories 1 through 4.

5.1.2 Areas of Historical Local Flooding

Section 4.2.2 and Table 4-6 summarize the areas of historical local flooding from the 2015 OCPC Regional HMP and mitigation actions taken since that time, and updates the list of areas of concern for this MVHMP based on input from the CRB Workshop, Steering Committee, and public at large.

5.1.3 Flood Exposure Analysis

Both riverine and hurricane surge inundation flood hazard risk were evaluated for the Town of Pembroke. Riverine flood risk was assessed by combining the current effective (2017) FEMA Flood Insurance Rate Map data with Town property data. Pembroke's current tax parcel and property value data were used to estimate the number and assessed value of parcels (developed and undeveloped) and buildings located in identified flood hazard areas. Specifically, the tax parcel GIS dataset was joined to a Computer Assisted Mass Appraisal (*CAMA*) System database export provided by the Town; parcels were then overlaid with the FEMA Flood Zone layers defined in Section 5.1.1 (A, A/E, and X-shaded) and areas of intersection identified. A parcel or building was counted as affected if any portion of the land or structure fell within the designated flood zone. The derived GIS layer was then used to categorize parcels by flood zone designation and property type classification code following the MA Department of Revenue.[115] Using these new categorizations, acreages, structural units, yard values, land values, building values, and total values were aggregated and are summarized in **Table 5-1.** The individual Property Type Classification Codes and Parcel Type Categories used to develop Table 5-1 are presented in **Appendix B**. Table 5-1 indicates hazard vulnerability under existing conditions and the potential for additional vulnerability if currently vacant and potentially developable parcels are further developed or improved.

[115] Property Type Classification Codes, MA Department of Revenue/Division of Local Services Bureau of Local Assessment, April 2019.

Table 5-1. Exposure of Buildings in FEMA Flood Zones A, AE, and X-shaded by Parcel Type

Parcel Type Category & Property Type Classification Codes	Flood Zone	No. of Parcels Affected	No. of Units	Yard Value ($)	Land Value ($)	Building Value ($)	Total Value ($)	Total Parcel / Portion in Flood Zone (Acres)	% in Flood Zone
Commercial									
Industrial/Manufacturing/ Automotive (330, 400, 334, 316, 401)	A, AE	5	24	73,900	3,576,100	2,314,400	5,964,400	24.66 / 3.89	15.8
Office (340)	AE	2	1	0	0	2,789,600	2,789,600	8.67 / 3.83	44.2
Retail/Entertainment (323, 325, 326)	A, AE	7	22	462,400	16,543,100	21,888,000	38,893,500	57.90 / 18.81	32.4
Other/Unknown (31)	A, AE	3	9	203,600	909,400	952,600	2,065,600	6.28 / 1.73	27.5
		17	**56**	**739,900**	**21,028,600**	**27,944,600**	**49,713,100**	**97.51 / 28.26**	**28.9**
Land (Other)									
Conservation Land, Nature Study (61, 803, 930, 932, 936, 950, 982)	A, AE, X	72	1	265,139	23,221,998	100,100	23,596,298	2,770.18 / 1025.15	37.0
Recreation (87, 958)	AE	2	4	836,500	2,131,739	2,197,900	5,146,139	112.55 / 19.12	16.9
Other (Accessory Land, State Non-reimbursable) (106, 929)	A, AE, X	3	0	11,000	312,100	133,100	456,200	1.74 / 1.15	66.1
Religious (960)	A	1	4	0	2,086,800	5,040,100	7,126,900	126.49 / 0.20	0.16
Cranberry Bog (Ch 61A) (710)	A	1	0	0	25,751	0	25,751	35.85 / 17.44	48.6
		79	**9**	**1,112,639**	**27,778,388**	**7,471,200**	**36,351,288**	**3046.80 / 1063.06**	**34.9**
Public Service									
Improved Education, Municipal (934, 931)	A, AE, X	6	5	137,400	33,678,200	23,357,200	57,172,800	752.27 / 104.90	13.9
Residential									
Single Family (16, 17, 18, 101, 109)	A, AE, X	656	686	3,678,500	142,614,267	135,658,400	281,951,167	1499.29 / 426.80	28.5
Multifamily (102, 104, 105, 970)	A, AE, X	28	55	279,400	6,284,800	17,301,300	23,865,500	74.23 / 25.23	33.9
Other (959)	AE	2	2	900	403,700	372,900	777,500	1.76 / 0.17	9.6
		686	**743**	**3,958,800**	**149,302,767**	**153,332,600**	**306,594,167**	**1,575.28 / 452.20**	**28.7**

Vacant Land (Developable)									
Commercial, Industrial, Residential (130, 131, 390, 440)	A, AE	23	0	0	6,562,700	0	6,562,700	171.86 / 80.97	47.1
Vacant Land (Undevelopable)									
Accessory to Industrial, Residential (132, 442)	A, AE, X	91	0	600	1,651,800	0	1,652,400	1387.95 / 1153.65	83.1
Total			**813**	**5,949,339**	**240,002,455**	**212,105,600**	**458,046,455**	**7031.66 / 2882.97**	**41.0**

There are 933 parcels totaling $458,046,455 in property value located in the FEMA mapped flood zones; 114 of these parcels are undeveloped. A total of 813 buildings with a value of $212,105,600 are located within the three designated flood zones. Of the total property type classification acreage potentially vulnerable to flooding, approximately 41% is at risk to some degree of flooding (i.e., actual part of the parcels within a flood zone).

Under current conditions, 56 commercial structures assessed at $27,944,600 are vulnerable to some degree of flooding during the 100-year storm event; the bulk of the affected parcels are in industrial/automotive/manufacturing and retail/entertainment uses. Approximately 29% of the commercial property parcels classification that intersects the flood zones lies in whole or in part within the flood hazard area and is vulnerable to flood risk. Under current conditions, 743 residential structures with a value of $153,332,600, and 5 public service structures with a value of $23,357,200, are vulnerable to some degree of flooding during the 100- and 500-year storm events. Nine structures that include conservation, recreation, and religious facilities, with an assessed value of $7,471,200, are vulnerable to some degree of flooding in the 100- and 500-year storm events.

The Town of Pembroke currently has approximately 172 acres of vacant developable land and 1,388 acres of vacant undevelopable land within the 100-year flood zone. Any modification of the vacant developable land would be subject to the local land use, zoning, and overlay regulations designed to mitigate vulnerability (see Section 7, Capability Assessment).

5.1.3.1 Hurricane Surge Inundation/SLOSH

In addition to high winds and heavy precipitation loads, hurricanes are capable of producing Sea, Land, and Overland Surge (SLOSH) or Hurricane Surge Inundation (HSI) as described in Section 4.2.2.1. Although the Town of Pembroke is approximately 5-7 miles from the coast of Massachusetts, its northern sections are subject to hurricane surge inundation along the North River as far inland as Herring Run Historical Park, Misty Meadow Conservation Area, the North Pembroke School Conservation Area, and the area bounded by the Indian Head River and North River north of Schoosett Street.

HSI risk was assessed by joining the Town tax parcel GIS dataset to a Computer Assisted Mass Appraisal (*CAMA*) System database export provided by the Town Assessor; this layer was intersected with a Hurricane Surge Inundation Zones dataset obtained from MassGIS. The derived GIS layer was then used to categorize intersected parcels by both land use type following the MA Department of Revenue[116] and the surge inundation zone for hurricane categories 1 – 4. Using these new categorizations, acreages, structural units, yard values, land values, building values, and total values were aggregated (**Table 5-2)**. A parcel or building was counted as affected if any portion of the land or structure

[116] Ibid.

fell within the designated HSI flood zone. Table 5-2 indicates hazard vulnerability under existing conditions and the potential for additional vulnerability if currently vacant and potentially developable parcels are further developed or improved.

Table 5-2. Exposure of Buildings in HSI/SLOSH Zones by Hurricane Category and Parcel Type

Hurricane Category and Land Use	Parcels Affected by Category	Total Parcels Affected	No. Parcels with Structures Affected (Cum)*	No. Structures Affected (Cum)	Land Value	Yard Value	Building Value	Total Value	Acres	% of Affected Parcels in SLOSH Zone**
Category 1										
Commercial	5	5	0	0	1,395,600	34,600	0	1,430,200	14.6	55.1%
Residential	79	79	0	0	20,452,394	1,063,900	0	21,516,294	155.5	39.9%
Public Service	1	1	0	0	464,700	14,400	0	479,100	2.9	30.5%
Vacant Land (Developable)	3	3	0	0	920,100	0	0	920,100	48.9	60.7%
Category 2										
Commercial	2	7	1	2	4,119,600	58,600	12,300	4,190,500	8	18.3%
Residential	29	108	7	8	26,494,694	1,190,200	1,723,200	29,408,094	38.1	8.9%
Public Service	0	1	0	0	464,700	14,400	0	479,100	1.1	11.6%
Vacant Land (Developable)	1	4	0	0	1,160,500	0	0	1,160,500	5.5	6.7%
Category 3										
Commercial	3	10	3	5	5,481,100	99,900	833,900	6,414,900	4	7.9%
Residential	46	154	24	29	36,904,887	1,441,700	5,240,400	43,586,987	71.1	13.1%
Public Service	0	1	0	0	464,700	14,400	0	479,100	1.4	14.7%
Vacant Land (Developable)	1	5	0	0	1,418,500	0	0	1,418,500	13.8	14.7%
Category 4										
Commercial	3	13	3	5	6,530,400	124,700	833,900	7,489,000	1.5	2.8%
Residential	12	166	35	44	39,658,087	1,491,200	7,452,700	48,601,987	31.1	5.6%
Public Service	0	1	0	0	464,700	14,400	0	479,100	0.54	5.7%
Vacant Land (Developable)	1	6	0	0	2,234,800	0	0	2,234,800	4.5	3.6%

* Cum = cumulative totals, all category storms.

** Hurricane category 1 represents the least extensive flood zone; figures for categories 2-4 indicate the increment of total value and flooded area associated with each particular category.

No structures in the Town of Pembroke are impacted by HSI in a Category 1 storm. For a Category 2 event, a total of 10 structures would be affected representing a building value of $1,735,500. For a Category 3 event, an additional 24 structures are affected, raising the affected building value to $6,074,300. Fifteen additional structures are affected in a Category 4 hurricane (49 structures cumulatively) with a cumulative building value of $8,286,600. It is important to note that because a parcel or building was counted as affected if any portion of the land or structure fell within the designated HSI flood zone, the building values impact overestimates the actual level of risk.

It should also be noted that only one hurricane affecting the Pembroke region – Bob, in 1991 – has exceeded Category 1.

Structures potentially affected by HSI for Category 2, 3, and 4 storms in the Town include those east of West Elm Street, north of Oldham Street and Pleasant Lane, northeast of Allen Street, southeast of Barker Street at Little Pudding Brook, northwest of Barker Street, west of Red Barn Road, on Washington Street, Canoe Club Lane, Water Street, west of Lorna Avenue, on Burr Avenue at Lorna Avenue, and north of Schoosett Street; these locations are generally indicated on the SLOSH Hazard Map (**Appendix A**).

According to the Town, there is no history of any of the above areas being impacted from HSI.

5.1.3.2 Critical Facilities

Ninety-three (93) critical facilities were identified in the Town of Pembroke, the address and physical location of each confirmed, and the facilities mapped in GIS and overlain onto the Town hazard map series. Critical infrastructure located completely or partially within a FEMA-designated flood zone was determined to be exposed and potentially vulnerable to flood hazard. Of the 93 critical elements identified, four dams and 1 groundwater production well are located within the FEMA flood zone (**Table 5-3**). Groundwater Production Well #1, at 356 Center Street, lies just outside the mapped Zone AE but has not been used in recent decades and will be abandoned.

Table 5-3. Pembroke Critical Infrastructure in Flood Hazard Areas A, AE, X-shaded

Facility Type / Name	Address	FEMA Flood Zone
Dam / Mill Pond Upper Dam	NA	AE
Dam / Monroe Street Bog East Dam	NA	A
Dam / Stump Pond Dam	NA	A
Dam / Washington Street Pond Dam	NA	A
Well / GPW #5	100 Ridge Road	X-shaded (at margin)

5.1.3.3 Repetitive Loss Structures

FEMA defines a *repetitive loss property* as any insurable building for which the National Flood Insurance Program (NFIP) has paid two or more flood claims of $1000 or more in any 10-year period since 1978. S*evere repetitive loss* is defined as any NFIP-insured residential property that has met at least one of the following criteria since 1978 (in either case, 2 of the claims payments must have occurred within 10 years of each other):

- 4 or more separate claim payments of more than $5,000 each (including building and contents payments); or
- 2 or more separate claim payments (building payments only) where the total of the payments exceeds the current value of the property.

The Town of Pembroke has no Repetitive Loss or Severe Repetitive Loss properties as defined by FEMA.[117]

According to the FEMA Community Information System (CIS) database for the Town of Pembroke, there are 27 flood insurance policies totaling $7,981,000 in force. There have been 6 paid losses totaling $21,590 since 1978. The CIS data sheets for the Town are included in **Appendix C.**

5.1.3.4 Dams and Dam Failure

The Massachusetts Department of Conservation and Recreation Office of Dam Safety maintains records of dams throughout the state to ensure compliance with acceptable inspection and maintenance practices. The State regulations at 302 CMR 10.00 provide regulatory guidelines and classify dams greater than 6 feet in height or having a storage capacity equal to or greater than 15 ac-ft as having a High, Significant, or Low Hazard Potential **(Table 5-4).** High Hazard dams are those where failure would cause loss of life or serious damage to homes, commercial facilities, public utilities or main transportation routes. Significant Hazard dams are located where failure could cause such impacts. Low Hazard dams, if they failed, would cause minimal property damage with no loss of life.

Table 5-4. MA DCR Dam Hazard Potential Classification Table

HAZARD POTENTIAL CLASSIFICATION TABLE

High Hazard Potential (Class I)	Dams located where failure will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).
Significant Hazard Potential (Class II)	Dams located where failure may cause loss of life and damage to home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use or service of relatively important facilities.
Low Hazard Potential (Class III)	Dams located where failure may cause minimal property damage to others. Loss of life is not expected.

*302 CMR 10.00, Section 10.06(3).

According to MassGIS, there are 17 dams in the Town of Pembroke, 6 of which are classified by MA DCR as Low Hazard, 1 as Significant Hazard (Lower Chandler Pond Dam), and 10 as non-jurisdictional with no hazard classification (**Table 5-5**). Four of the dams – Monroe Street Bog East, Mill Pond Upper, Stump Pond, and Washington Street Pond are situated in FEMA flood zones A/AE. These structures are identified on the Critical Infrastructure Map in **Appendix A**.

[117] Personal communication with Joy Duperault, Director, Flood Hazard Management Program, State NFIP Coordinator, MA DCR, by email dated January 23, 2020.

Table 5-5. Town of Pembroke Dams

Dam / Impoundment	Waterway	Hazard Potential Code*	Owner	Flood Zone
Jurisdictional				
Lower Chandler Pond	Pine Brook	Significant	Town of Duxbury	No
Arnold Reservoir	Pudding Brook Tributary	Low	Private	No
Mill Pond	Dorchester Brook	Low	City of Brockton	No
Mill Pond Lower	Herring Brook	Low	Private	No
Monroe Street Bog East	NA	Low	Private	A
Trout Pond	Rocky Run	Low	Private	No
Upper Chandler Pond	Pine Brook Tributary	Low	Private	No
Non-jurisdictional				
Hill Pond	Jones River Tributary	NA	Unknown	No
Iabucci Dam	NA	NA	Unknown	No
Mill Pond Upper	Herring Brook	NA	Unknown	AE
Monroe Street Bog West	NA	NA	Unknown	No
Pleasant Street Pond	Pudding Brook	NA	Unknown	No
Randall Pond	NA	NA	Unknown	No
Stump Pond	Pudding Brook	NA	Unknown	A
Stumpy Pond Lower	Tubbs Meadow Brook	NA	Unknown	No
Stumpy Pond Upper	Tubbs Meadow Brook Tributary	NA	Unknown	No
Washington Street Pond	Pudding Brook	NA	Unknown	A

The 2015 OCPC Regional Hazard Mitigation Plan identified the 17 dams listed in Table 5-5 and noted that the Pembroke Highway Department reported only rarely having to adjust the boards at any of the small dams for flood control. The Plan further noted that the City of Brockton can operate the upper and lower gates of the Mill Pond Dam for flood control but can lower the pond more quickly by diverting flow to the Silver Lake Reservoir.[118]

The Lower Chandler Pond Dam, rated a Significant Hazard Potential, is co-owned by the towns of Pembroke and Duxbury. The towns split the inspection work load and equally shared the cost of replacement several years ago. According to the Pembroke Department of Public Works, there have been no storm-related problems associated with this structure.

All of the Breakout groups at the October 6th CRB Workshop identified Dams as significant infrastructure of concern. Participants listed emergency overflow, enhanced flood control and stormwater management potential, and growing vulnerability associated with climate change as elements for comprehensive study.

[118] Old Colony Planning Council Regional Hazard Mitigation Plan, 2015,, p. 198.

5.1.3.5 FEMA National Risk Index – Riverine and Coastal Flooding

In 2020, FEMA launched the National Risk Index, a collaboration of local, state, federal, and academic partners to help define the nation's communities most at risk from natural hazards.[119] The Index leverages best available source data to provide an overview of community-level risk by combining multiple hazards with socioeconomic and built environment factors. It calculates a baseline relative risk measurement for each census tract (and county) in the country for 18 natural hazards based on three component datasets: Expected Annual Loss (natural hazard component), Social Vulnerability (consequence-enhancing component), and Community Resilience (consequence-reducing component). The expected annual loss (EAL) incorporates data for hazard exposure (building, population, agriculture), frequency, and historic loss. The 18 assessed natural hazards are coastal flooding, cold wave, drought, earthquake, hail, heat wave, hurricane, ice storm, landslide, lightning, riverine flooding, strong wind, tornado, wildfire, winter weather, avalanche, tsunami, and volcanic activity; of these, the first 15 are relevant to the Town of Pembroke. The NRI only considers the main natural hazard event, not ancillary results or after-effects (e.g., air quality impacts due to wildfires).

The NRI calculates both an overall community Risk Index score that considers all 18 natural hazards, and an individual risk score for each individual natural hazard. The overall community Risk Index score for the Town of Pembroke is Very Low; the Expected Annual Loss is Relatively Low, Social Vulnerability is Very Low, and Community Resilience is Very High.

The Town of Pembroke comprises three census tracts – 508101 (North Pembroke), 508200 (East Pembroke), and 508102 (West Pembroke) as shown in **Figure 5-1**. The NRI Census Tract information and Risk Ratings Summary for each tract are presented in **Figure 5-2**.

[119] FEMA National Risk Index. https://www.fema.gov/flood-maps/products-tools/national-risk-index

Figure 5-1. Town of Pembroke Census Tracts and Population

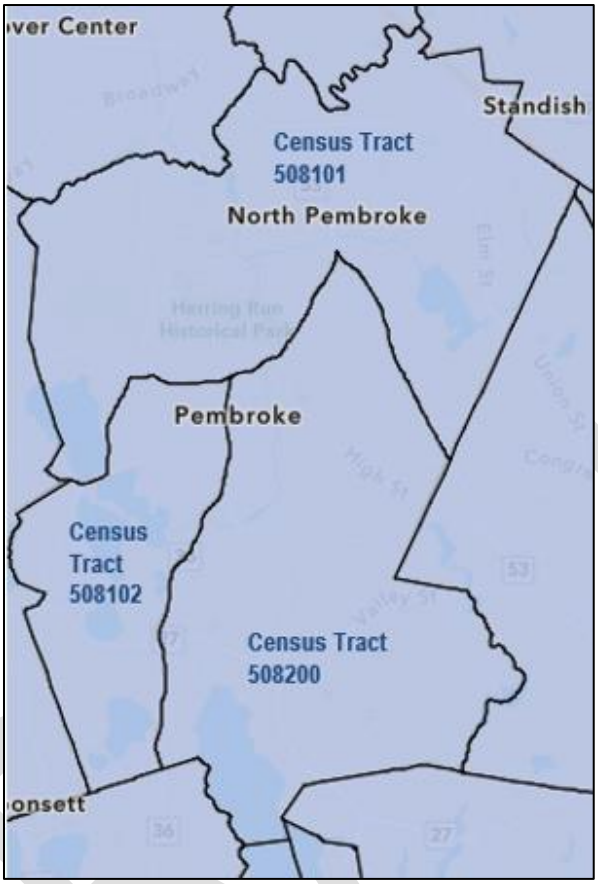


Figure 5-2. Pembroke NRI Census Tract Ratings Summaries (18 Hazards)

Census Tract 25023508200
Plymouth County, MA

Census Tract Info

Population (2016)	6,031
Building Value ($)	656,801,000
Agricultural Value ($)	520,690
Area (sq mi)	8

Ratings Summary

Risk Index	Very Low
Expected Annual Loss	Very Low
Social Vulnerability	Relatively Low
Community Resilience	Very High

Census Tract 25023508101
Plymouth County, MA

Census Tract Info

Population (2016)	6,708
Building Value ($)	951,697,000
Agricultural Value ($)	157,676
Area (sq mi)	10

Ratings Summary

Risk Index	Very Low
Expected Annual Loss	Very Low
Social Vulnerability	Very Low
Community Resilience	Very High

Census Tract 25023508102
Plymouth County, MA

Census Tract Info

Population (2016)	5,098
Building Value ($)	611,242,000
Agricultural Value ($)	590,951
Area (sq mi)	3

Ratings Summary

Risk Index	Very Low
Expected Annual Loss	Very Low
Social Vulnerability	Relatively Low
Community Resilience	Very High

The NRI scores for coastal and riverine flooding for the three census tracts are presented in Table 5-6. For all three census tracts, the expected annual loss rating for Coastal Flooding is Very Low to Relatively Low and the corresponding rating for Riverine Flooding for all three tracts is Relatively Low. The risk ratings for both coastal and riverine flooding are Very Low (CT 508102) or Relatively Low. A relatively low rating is proportional to the Town's total risk. There is no expected annual loss (EAL) of population for either hazard, and a low EAL for buildings.

Table 5-6. FEMA National Risk Index for Riverine and Coastal Flooding, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Historic Loss Ratio (Overall)	Exposure – Building Value ($)	Exposure – Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Coastal Flooding	2.86	Very Low	9,078,999.79	64	1489.87	0	Relatively Low	Relatively Low
	Riverine Flooding (45 events)	2.045	Very Low	14,519,917.16	94	4021.01	0	Relatively Low	Relatively Low
CT 508200	Coastal Flooding	0	No rating	0	0	0	0	No Expected Annual Losses	No Rating
	Riverine Flooding (45 events)	2.045	Very Low	8,277,765.14	71	2292.37	0	Relatively Low	Relatively Low
CT [illegible]	Coastal Flooding	.002	Very Low	6,960,510.61	58	0.796	0	Very Low	Very Low

	Riverine Flooding (45 events)	2.045	Very Low	9,920,406.36	64	2747.27	0	Relatively Low	Relatively Low

*NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

5.2 Wind-related Hazards

Wind-related hazards include hurricanes, tropical storms, tornadoes, nor'easters, severe thunderstorms, and high wind events, all of which are characterized in relation to the Town of Pembroke and discussed in detail in Section 4. **Table 5-7** summarizes the wind-related hazard assessment and indicates the geographic extent of each using the MA SHMCAP designations below. Table 5-7 also indicates the comparable hazard characterization presented in the 2015 Old Colony Planning Council Regional Hazard Mitigation Plan.

MA SHMCAP 2018 Geographic Extent Categories

Limited – Less than 10% of Town affected	**Significant** – 10-50% of Town affected	**Extensive** – 50-100% of Town affected

Table 5-7. Wind-related Hazard Characterization Summary, Town of Pembroke

Hazard	Frequency	Severity	Geographic Extent	2015 OCPC RHMP
Hurricanes/Tropical Storms	Medium | 1 per 2.5 years	Serious	Extensive	Medium | Serious | Town-wide
Tornadoes	Very Low | 7 since 1951	Serious	Extensive*	Very Low | Serious | Varies
Nor'easter	High**	Serious	Extensive	Not Assessed
Severe Thunderstorms	Medium | 3/year	Minor to Serious	Minor to Extensive	Not Assessed
High Wind Events	Medium | 3.6/year	Minor to Serious	Minor to Extensive	Not Assessed

* Dependent on storm track.
**MA SHMCAP 2018, p. 4-224.

Extreme high winds were identified by CRB Workshop participants as the top hazard facing the Town, causing extended power outages over large areas. Both residents and Town officials expressed concern with the impact of such outages on all citizens but particularly vulnerable populations, including the elderly, those without vehicle personal vehicles, and those residing in institutional facilities or reliant on electric-powered medical devices. When combined with extreme temperatures or snow/nor'easters, wind-caused power outages are significantly more serious and particularly affect those without air conditioning or access to cooling centers.

The entire Town of Pembroke is vulnerable to wind-related hazards with the location, type, and degree of impact dependent on storm track and other factors. The FEMA National Risk Index was used to evaluate risk to the Town for wind-related hazards, including hurricanes, strong winds, and tornadoes (Tables 5-8 and 5-9), returning a Very Low risk rating for Hurricanes and Tornadoes but a Relatively Low risk rating for Strong Winds. While the structural risk associated with these wind events may be low or relatively low, the increasing frequency of the events and the resultant power outages create an elevated perceived and actual risk.

Table 5-8. FEMA National Risk Index for Hurricanes, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Exposure – Building Value ($)	Exposure – Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Hurricane (16 events)	0.15	951,163,681	6707	1084.98	0	Very Low	Very Low
CT 508102	Hurricane (14 events)	0.16	610,428,689	5089	769.36	0	Very Low	Very Low
CT 508200	Hurricane (15 events)	0.16	656,643,667	6030	826.85	0	Very Low	Very Low

*NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

The 2015 OCPC RHMP assessed Hurricane risk as medium frequency, serious severity, and town-wide in extent, and this MVHMP carries forward that assessment. The FEMA NRI identifies a Hurricane building exposure value of $2,219,036,037 with an expected annual loss of $2,681.19; there is no expected annual loss of population and the NRI assigns a Very Low Annual Overall Loss Rating to this hazard.

The 2015 OCPC RHMP assessed Tornado risk to the Town as very low frequency, seriously severe, and variable in extent. This MVHMP carries forward the 2015 assessment but assesses the risk to be extensive; while the geographic effect is indeed dependent on storm track, presumably all areas of the Town are vulnerable.

The 2015 OCPC RHMP did not assess the Town risk associated with High Wind events. Based on the hazard characterization in Section 4, this MVHMP assesses High Wind risk as medium frequency, minor to serious, and minor to extensive. The FEMA NRI for Strong Wind events and Tornadoes identifies a building value exposure of $245,188,909 for Tornadoes and $2,219,740,000 for Strong Wind events. Neither hazard category carries any expected annual loss of population and the Index assigns a Relatively Low Expected Annual Loss Rating to strong wind events and a Very Low EAL to tornado events (Table 5-9).

Notwithstanding the foregoing and as stated previously, the increasing frequency of high wind events and the consequent extended and widespread power outages support categorization of this hazard as medium to high frequency, minor to serious, and minor to extensive.

Table 5-9. FEMA National Risk Index for Strong Wind and Tornadoes, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Exposure – Building Value ($)	Exposure – Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Strong Wind (111 events)	3.47	951,697,000	6708	5,067.73	0	Relatively Low	Relatively Low
	Tornado (0 events)	1.59	70,575,050	498	119,468.58	0	Very Low	Very Low
CT 508102	Strong Wind (120 events)	3.75	611,242,000	5098	3,538.38	0	Relatively Low	Relatively Low
	Tornado (0 events)	1.53	119,410,341	996	194,209.45	0	Very Low	Very Low
CT 508200	Strong Wind (119 events)	3.75	656,801,000	6031	3,799.17	0	Relatively Low	Relatively Low
	Tornado (0 events)	1.56	55,203,518	507	91,615.53	0	Very Low	Very Low

*NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

Additional wind-related hazards that affect the Town of Pembroke – Nor'easters and Severe Thunderstorms - were not assessed in the 2015 RHMP but are characterized in Section 4. The 2018 SHMCAP identified Nor'easters as the most frequently occurring natural hazard in the State, with 1 per year at minimum and up to 4 events in some years. Between 2000 and 2020, 53 Thunderstorm Wind events meeting the NWS criterion for Severe (winds > 58 mph) occurred in Plymouth County.

For purposes of this MVHMP, Nor'easters are considered High frequency, serious and extensive hazards and Severe Thunderstorms as Medium frequency, minor to serious, and minor to extensive hazards.

Because the Wind-related hazards are Town-wide, no particular Critical Infrastructure element is defined as being at greater risk than another.

5.3 Winter Storms

The Winter Storm hazard is characterized in Section 4.4 and includes discussion of blizzards and ice storms. The findings are summarized as follows:

- NESIS ranks 64 high-impact snowstorms that affected the Northeast urban corridor between 1956 and 2016. These storms were further analyzed to determine the extent and severity of impact on the Town of Pembroke

(Table 4-8). Of the 10 Category 4 and 5 snowstorms that occurred during this period (NESIS Value 6-10, Extreme or Crippling), 9 substantially affected the Town. Based on the NESIS historic database, high-impact snowstorms affect the Town of Pembroke every other year, on average.

- According to the State data, Plymouth County has experienced 10 winter storm-related disaster events over a 65-year period, or 1 every 6.5 years on average.
- The 1-Day extreme snowfall for Plymouth County, MA was 24.0 inches on January 23, 2005; the 2-Day extreme is recorded as 30.1 inches on February 7, 1978; and the 3-Day extreme was 33.5 inches on March 19, 1995.
- Between 1999 and 2020, 51 winter storms were reported over 21 days for Plymouth County.
- Between 1999 and 2020, 13 blizzards were reported over 9 days for Plymouth County, an average of a little more than one every other year.
- No ice storms were reported for Plymouth County between 2000 and 2020.

The 2015 OCPC RHMP categorized Winter Storms as high frequency, seriously severe events of Town-wide extent and assigned the highest hazard ranking of 6. The RHMP did not examine subcategories.

The Town of Pembroke CRB Workshop participants identified Winter Storms as one 5 top hazards while acknowledging that there have been none affecting the Town in the past two to three years. Nevertheless, residents felt these storms pose considerable risk to the community due to their ability to cause power outages and eliminate emergency access because of road closures from downed trees and power lines.

This MVHMP generally carries forward the 2015 hazard and risk characterization for the Town (high frequency, seriously severe) with the addition of blizzard and ice storm subcategories; the geographic extent for this hazard is Town-wide.

The FEMA National Risk Index winter storm hazard categories (hail, ice, winter weather) were used to assess the level of risk to the Town (**Table 5-10**).[120] For hail events, the Expected Annual Loss (EAL) for Building Value is very low for all three census tracts with no Population EAL; the overall risk rating for the Town for this category is Very Low. For winter weather, the Building Value EAL is Relatively Low with no expected annual loss of population; the overall risk rating for this category is Relatively Low. Out of the three winter weather-related NRI hazard categories, ice storms pose the highest risk to the Town of Pembroke with a somewhat higher Building Value EAL but no Population EAL; the overall risk rating for this category is Relatively Moderate.

[120] Hazard categories vary by data source and cannot be directly compared in all instances. NOAA NCEI uses one set of categories, FEMA NRI another, and so on. The closest categorical comparisons were applied to assess risk.

Table 5-10. FEMA National Risk Index for Hail, Ice, and Winter Weather Hazards, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Exposure – Building Value ($)	Exposure – Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Hail (195 events)	6.12	951,697,000	6708	156.36	0	Very Low	Very Low
	Ice Storm (24 events)	0.36	951,697,000	6708	18,325.70	0	Relatively Moderate	Relatively Moderate
	Winter Weather (122 events)	5.53	949971874.67	6708	214.22	0	Relatively Low	Relatively Low
CT 508102	Hail (185 events)	5.78	611,242,000	5098	94.53	0	Very Low	Very Low
	Ice Storm (33 events)	0.51	611,242,000	5098	1,5915.66	0	Relatively Moderate	Relatively Moderate
	Winter Weather (64 events)	5.27	611,242,000	5098	131.97	0	Relatively Low	Relatively Low
CT 508200	Hail (185 events)	5.78	656,801,000	6031	101.63	0	Very Low	Very Low
	Ice Storm (33 events)	0.50	656,801,000	6031	17,052.18	0	Relatively Moderate	Relatively Moderate
	Winter Weather (122 events)	5.36	655,589,838	6025	145.52	0	Relatively Low	Relatively Low

*NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

Because Winter Storm hazards apply Town-wide, all Critical Infrastructure elements share approximately equivalent risk.

5.4 Geologic Hazards

5.4.1 Earthquakes

The Earthquake hazard is characterized in detail for the Town of Pembroke in Section 4.5.1. The findings are summarized as follows:

- According to the 2018 SHMCAP, New England experiences an average of 6 felt earthquakes are in the region each year. Within the Commonwealth, earthquakes can occur anywhere, but Boston and areas in eastern Massachusetts are potentially vulnerable to the effect of events in Canada as well.
- There were 408 felt earthquakes in MA from 1668-2016 only two of which were damaging (1727, and 1755 with an epicenter 30 miles east of Cape Ann).
- The Town of Pembroke straddles two PGA zones – 10-12%g and 12-14%g. Analysis using the Unified Hazard Tool shows that for North Pembroke, the earthquake PGA that has a 2% chance of being exceeded in 50 years has a value of 12%g while for South Pembroke, the corresponding value is 11.47%g. These PGA values fall at the low end of the Modified Mercalli Intensity Scale level VI and roughly correspond to a 5.0 on the Richter Scale. The return interval associated with these values 2,475 years. A 2% chance of exceedance equals a 98% chance that shaking will not exceed the value in any 50-year period.
- According to USGS, the Plymouth County region experienced 10 earthquakes between 1963 and 2020, ranging in magnitude 1.7 to 3.1. The expected number of occurrences of damaging earthquake shaking for the Town of Pembroke ranges from 4 to 20 over 10,000 years.

The 2015 OCPC RHMP categorized Earthquakes as very low frequency, seriously severe events of Town-wide extent and assigned a moderate (3 of 6) hazard ranking.

Participants at the Town's CRB Workshop considered earthquake hazard but none of the Breakout groups identified this hazard to be of serious concern to the community.

Based on the State, regional, and local data presented, the 2021 MVHMP assesses the earthquake hazard for the Town as Low-Very Low frequency, Serious magnitude, and Extensive (Town-wide) in extent.

The FEMA National Risk Index earthquake hazard category was used to assess the level of risk to the Town (**Table 5-11)**. The entire town population is exposed but the Expected Annual Loss of residents is 0. The Building Value Exposure totals $2,219,740,000 with a Building Value EAL of $44,191. The Expected Annual Loss and Risk ratings for the Town are consequently Relatively Low.

Table 5-11. FEMA National Risk Index for Earthquake Hazard, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Exposure – Building Value ($)	Exposure - Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Earthquake	0	951,697,000	6708	24,917.1	0	Relatively Low	Rel. Low
CT 508102	Earthquake	0	611,242,000	5098	12,209.1	0	Relatively Low	Rel. Low
CT 508200	Earthquake	0	656,801,000	6031	7,064.80	0	Relatively Low	Very Low

*NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

Because the risk of earthquake is Town-wide, no particular Critical Infrastructure element is at higher risk than any other.

5.4.2 Landslides

The Landslide hazard is characterized in detail for the Town of Pembroke in Section 4.5.2. The findings are summarized as follows:

- The USGS US Landslide Inventory that ranks landslide reports identifies one high confidence report for the greater Pembroke region, involving a Wal-Mart off Route 1 in Walpole where three days of heavy rain caused a landslide in the hills next to the store, crushing part of a nearby storage facility; the event occurred on March 15, 2010. The next nearest reported landslide occurred at the Good Shepard Church in Attleboro on November 4, 2014 when part of a hill collapsed putting the safety of the church at risk; the confidence level for this report was Likely.[121] No landslides were reported for the Town of Pembroke.

Participants at the Town's CRB Workshop considered earthquake hazard but none of the Breakout groups identified this hazard to be of serious concern to the community.

The 2015 Old Colony Regional HMP identified landslides as a very low frequency, minor hazard for Pembroke, noting that the Town has not experienced a recorded landslide and is not especially vulnerable to these events due to the lack of hills and generally flat topography.

Based on the hazard characterization and the CRB Workshop findings, the 2021 MVHMP assesses the landslide hazard potential for the Town of Pembroke as Very Low frequency, Minor magnitude, and Limited in extent.

[121] USGS US Landslide Inventory. https://www.usgs.gov/natural-hazards/landslide-hazards/maps

The FEMA National Risk Index Landslide hazard category was used to assess the level of risk to the Town (**Table 5-12)**. The total Town population exposed to this risk is 11,279 with an Expected Annual Loss of 0. The total Building Value exposed is $1,366,586,062 with an EAL of $10,807.61. The Expected Annual Loss and Risk ratings for the Town are Relatively Low.

Table 5-12. FEMA National Risk Index for Landslide Hazard, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Exposure – Building Value ($)	Exposure – Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Landslide	0.02	546,200,558	3993	4,319.81	0	Relatively Low	Relatively Low
CT 508102	Landslide	0.02	410,921,143	3443	3,249.91	0	Relatively Low	Relatively Low
CT 508200	Landslide	0.02	409,464,361	3843	3,238.39	0	Relatively Low	Relatively Low

*NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

There are no Critical Infrastructure elements located in areas of moderate or high landslide risk.

5.5 Wildfire Hazards

The Wildfire hazard is characterized in detail for the Town of Pembroke in Section 4.6. The findings are summarized as follows:

- The most recent USDA Forest Service Wildfire Hazard Map for southeast Massachusetts is the basis for the Town Wildfire Hazard Map (**Appendix A**). With the exception of small portions of Herring Run Historical Park, all of the Town is mapped as having a Very Low or Low Wildfire Hazard Potential.
- The 2018 SHMCAP lists several notable wildfires that have occurred in Massachusetts, noting that none resulted in a FEMA Disaster Declaration. These events included two events in the Plymouth area in 1957 and 1964. The May 1957 event burned 15,000 acres in Plymouth and destroyed approximately 40 structures. The 1964 event burned 5,500 acres in Plymouth Town and destroyed cottages on Charge Pond.

The Town of Pembroke CRB Workshop participants did not consider Wildfire to be a significant risk to the community.

The 2015 OCPC HMP determined that the Town of Pembroke was not vulnerable to Major Urban Fires as there are no major urban areas in the Town; the Plan listed this hazard as “Not Applicable.”

Based on the hazard characterization and CRB Workshop findings, the 2021 MVHMP assesses the Wildfire hazard potential for the Town of Pembroke as Very Low frequency, Minor magnitude, and Limited in extent.

The FEMA National Risk Index Landslide hazard category was used to assess the level of risk to the Town (**Table 5-13)**. The total Town population exposed to this risk is 1,879 with an Expected Annual Loss of 0 individuals. The total Building Value exposed is $216,161,379 with an EAL of $3,769.45. The Expected Annual Loss and Risk ratings for the Town as a whole for this hazard are Very Low and Relatively Low.

Table 5-13. FEMA National Risk Index for Wildfire Hazard, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Exposure – Building Value ($)	Exposure – Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Wildfire	0	109,396,296	848	2085.66	0	Relatively Low	Relatively Low
CT 508102	Wildfire	0	11,254,372	93	92.54	0	Very Low	Very Low
CT 508200	Wildfire	0	95,510,711	938	1591.25	0	Relatively Low	Relatively Low

*NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

All Critical Infrastructure elements are located within Very Low or Low wildfire hazard potential areas or areas classified as unburnable.

5.6 Climate Change Impacts

5.6.1 Extreme Temperatures

Extreme Temperature hazard is characterized in detail for the Town of Pembroke in Section 4.7.1. The findings are summarized as follows:

- Since 1901, annual average temperature increases across the Northeast range from less than 1 degree F in West Virginia to about 3 degrees F (1.7 degrees C) in New England.
- Over the past 100 years, the Northeast shows a trend of annual average temperatures much above normal, with the trend intensifying since 1990.
- For Plymouth County, MA, the annual average temperature data show an increasing trend of 0.3 degrees F per decade from 1950 to 2013, and an increase of 0.8 degrees F per decade from 1980-2013 alone.
- The NOAA Storm Events Database reported only 2 Excessive Heat events for Plymouth County between 2000 and 2020.
- According to Resilient MA, the Commonwealth will face more heat waves in the future that will disproportionately affect sensitive and disadvantaged populations.

- The Northeast Climate Service Center model that forecasts an increase of 10.23 days over 90 degrees F by mid-century and nearly 27 days by century's end for Plymouth County.
- Cornell University's CSC Tool for Plymouth County indicates that from 1950 to 2013, the annual average low temperature increased 0.4 degree F per decade (0.9 degrees F per decade from 1980 to 2013). Under a low emissions scenario, the annual average low temperature for the County will increase by 4 degrees F and under a high emissions scenario by nearly 9 degrees by the end of the century.

Participants at the Town's CRB Workshop identified Extreme Temperatures as one of 5 top hazards affecting the community. The potential impact of this hazard was felt to be considerably exacerbated by the extended power outages that the Town experiences during high wind events.

The 2015 OCPC HMP assessed Extreme Temperatures as a High frequency, Minor severity, Town-wide hazard with a hazard ranking of 5 out of 6; it is listed as one of four top hazards for the Town.

The FEMA National Risk Index Heat Wave and Cold Wave hazard categories assess the level of risk to the Town as Relatively Low (Table 5-14). The entire Town population is exposed to the risk posed by Extreme temperatures, both heat and cold. The Expected Annual Loss of population associated with this risk is 0. The total Building Value exposed is approximately $2,216,706,793 with an EAL of $244.13 (Cold Wave) and $4.77 (Heat Wave). The Expected Annual Loss and Risk ratings for the Town as a whole for this hazard are Relatively Low.

Table 5-14. FEMA National Risk Index for Extreme Temperatures, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Exposure – Building Value ($)	Exposure – Population	Expected Annual Loss – Building Value ($)	Expected Annual Loss – Population*	Expected Annual Loss Rating	Risk Rating
CT 508101	Cold Wave (4 events)	0.1737	949,923,293	6708	106.53	0	Relatively Low	Relatively Low
	Heat Wave (11 events)	0.5946	950,192,700	6708	2.07	0	Relatively Low	Relatively Low
CT 508102	Cold Wave (2 events)	0.1647	611,242,000	5098	65.35	0	Relatively Low	Relatively Low
	Heat Wave (7 events)	0.5766	611,242,000	5098	1.29	0	Relatively Low	Relatively Low
CT 508200	Cold Wave (4 events)	0.1676	655,541,500	6025	72.25	0	Relatively Low	Relatively Low
	Heat Wave (11 events)	0.5824	655,809,556	6025	1.41	0	Relatively Low	Relatively Low

* NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

The 2021 MVHMP assesses the Extreme Temperature hazard potential for the Town of Pembroke as High frequency, Minor to Serious magnitude, and Extensive (Town-wide) based on the hazard characterization in Section 4.7 and the US Climate Resilience Toolkit data for Brockton Station (see Section 4.7.1).

5.6.2 Drought

Drought hazard is characterized in detail for the Town of Pembroke in Section 4.7.2. The findings are summarized as follows:

- The Massachusetts Drought Management Plan assessed drought conditions in 6 regions, including the Southeast, Cape and Islands, and determined the number of weeks of Extreme Drought between 2001-2017 for each region. The region that includes the Town of Pembroke experienced 26-36 weeks of severe drought over the 17-year period.
- According to the US Drought Monitor summary for 2000 to 2020, drought events for Plymouth County increased in frequency and intensity between 2010 and 2020 when compared to the previous 10 years. Over the 20-year period, the County experienced Severe Drought (D2-D4) between 2001-2002 and Extreme Droughts (D3-D4) between 2016-2017 and again in 2020.

The 2015 Old Colony Planning Council Regional Hazard Mitigation Plan did not assess the Town of Pembroke's vulnerability to Drought.

Participants at the Town's CRB Workshop identified Drought as one of 5 top hazards facing the community. Residents expressed concern with the adequacy of the local water supply in the face of increasing droughts due to the fact that both surface and ground water sources are shared by multiple other communities (see Section 2).

For this MVHMP, based on the data presented in the State Drought Management Plan and the US Drought Monitor, Drought is determined to pose a Medium frequency, Minor to Serious, Town-wide risk to the Pembroke community.

The FEMA National Risk Index Drought category was used to assess the level of risk to the Town (Table 5-15). The entire Town population is exposed to the risk posed by Drought but the NRI assesses only the historic loss, exposure, and expected annual loss for Agriculture. Additional drought risk to the community would be derived from its water supply which is provided by community groundwater wells; severe or prolonged periods of drought that depress the regional water table, and the occurrence of drought during summer months when water demand is high, could pose risks to the Town supply.

Table 5-15. FEMA National Risk Index for Drought, Town of Pembroke MA

	Hazard Type	Annualized Frequency	Historic Loss Ratio Agriculture	Exposure - Agriculture Value ($)	Expected Annual Loss Agriculture ($)	Expected Annual Loss Rating	Risk Rating
CT 508101	Drought (42 events)	2.33	0.00	105,117	676	Relatively Low	Very Low
CT 508102	Drought (42 events)	2.33	0.00	393,967	2535	Relatively Low	Relatively Low

CT 508200	Drought (28 events)	1.56	0.00	520,690	2233	Relatively Low	Relatively Low

* NRI estimates of Expected Annual Population Loss are shown as 0 for any figure that was smaller than 0.000. Population is 2016 ACS.

5.7 Development Since the 2015 Regional Hazard Mitigation Plan

Developments since completion of the 2015 Old Colony Planning Council Regional Hazard Mitigation Plan are listed in Table 5-16 and assessed for Flood and Wildfire Risk. The risk to these developments posed by the other hazards evaluated in this Plan are the same as for properties Town-wide.

Table 5-16. Risk Assessment for Significant Pembroke Development Projects Approved or Pending Since 2014

Project	Status	Project Type	# Housing Units	Commercial SF Current / As-Built	Year Proposed	FEMA Flood Zone	Wildfire Risk
43 Mattakeesett Street	Proposed	Commercial (boat storage)		10,300 / Not Available	2020	No	Low
50 Mattakeesett Street	Approved	Commercial (storage)		4,968 / Not Available	2020	No	Low / Non-burnable
Old Cart Path Lane Extension (70 Old Cart Path Lane)	Approved	Single-Family Subdivision	3		2020	No	Low / Non-burnable
Camp Pembroke (306 Oldham Street)	Approved	Institutional (overnight camp)			2019	No	Very Low / Non-burnable
Herring Brook Solar Project (~ 132 Hobomock Street)	Approved	Solar Power Array		Solar Array	2019	No	Low / Non-burnable
171 Mattakeesett Street	Approved	Light Industrial		Not Available	2019	No	Low
345 Oak Street	Approved	Commercial (office)		Not Available	2019	No	Non-burnable
Urgent Care Facility (296 Old Oak Street)	Complete	Medical		25,360	2018	No	Very Low / Non-burnable
Lisa's Lane (79 Taylor Street)	Under Construction	Single-Family Subdivision	5		2018	No	Low
Brigham & Women's Medical Building (15 Corporate Park Drive)	Complete	Medical		30,000 GSF	2018	No	Very Low / Non-burnable
Irving Oil Gas Station (92 Washington Street)	Complete	Commercial (gas station)		1755	2018	No	Very Low / Non-burnable

Project	Status	Project Type	# Housing Units	Commercial SF Current / As-Built	Year Proposed	FEMA Flood Zone	Wildfire Risk
Dominic's Way (56 Gorham Avenue)	Approved	Single-Family Subdivision	2		2018	No	Low
Magical Years Preschool (212 Schoosett Street)	Under Construction	Educational (child care)		5950	2018	No	Low
204 Center Street (Pembroke Village)	Approved/ Litigation	Mixed-Use (mostly multifamily)	6		2018	No	Non-burnable
260-280 Oak Street	Complete	Light Industrial		Not Available	2017	No	Non-burnable
River Marsh Village (40b) (~274 Water Street)	Proposed	Multifamily (40b)	57		2017	Site Plan Dependent	Low
Bristol Estates (73 Taylor Street)	Under Construction	Single-Family Subdivision	7		2017	No	Low
56 Pembroke Woods Drive (Warehouse Expansion)	Complete	Light Industrial		55,750	2016	No	Non-burnable
220 Center Street	Complete	Mixed-Use (multifamily)	14	3000	2016	No	Low
Hobomock Solar Project (~158 Hobomock Street)	Complete	Solar Power Array		Solar Array	2016	No	Low
Bridges at Pembroke (49 Cross Street)	Complete	Medical (assisted living)	48		2016	No	Non-burnable
Brisan Way Extension (~ 25 Old Washington Street)	Under Construction	Single-Family Subdivision	12		2016	No	Low / Non-burnable
Shell Gas Station (223 Church Street)	Complete	Commercial (gas station)		3600	2015	No	Non-burnable
Copperwood Circle (40b) (Copperwood and Ironwood Rds.)	Under Construction	Single-Family Subdivision (40b)	36		2015	No	Low / Very Low
590 Washington Street	Complete	Multifamily	9		2015	No	Non-burnable
South Paws Doggie Day Care (275 Oak Street.)	Complete	Commercial (kennel)		9625	2014	No	Non-burnable
593-595 Washington Street	Complete	Multifamily	12		2014	No	Non-burnable
Panera & Taco Bell (156-166 Church Street)	Complete	Commercial (restaurants)		6354 and 11772	2014	No	Non-burnable
599 Washington Street	Complete	Multifamily	18		2014	No	Non-burnable
TOTAL			**229**	**168,434**			

Source: M. Heins, Town of Pembroke Planning Commission.

6. HAZARD MITIGATION GOALS

Hazard mitigation goals set forth the framework within which hazard mitigation actions are defined. Hazard mitigation goals for the Town of Pembroke were discussed and developed by the Steering Committee and based on the information obtained from the public and other stakeholders during the Community Resilience Building Workshop. Specifically, the Steering Committee reviewed the CRB and MVHMP Section 5 risk assessment problem statements as well as existing Town plans and policies to ensure consistency of purpose. The Steering Committee also sought to align its hazard mitigation goals with those identified in the Massachusetts State Hazard Mitigation and Climate Adaptation Plan **(Table 6-1).**

Table 6-1. MA State Hazard Mitigation and Climate Adaptation Strategy Goals

1. Enhance the Commonwealth's resiliency to natural hazards and climate change by integrating programs and building institutional capacity.
2. Reduce the impacts of natural hazards and climate change with forward-looking policies, plans, and regulations.
3. Understand our vulnerabilities and risks and develop immediate and long-term risk reduction strategies for current and future conditions using the best available science.
4. Increase the resilience of State and local government, people, natural systems, the built environment, and the economy by investing in performance-based solutions.
5. Support implementation of this plan through increased education, awareness, and incentives for action for state agencies, local governments, private industry, non-profits, and the general public.

The Town of Pembroke Hazard Mitigation Goals are as follows:

Town of Pembroke Hazard Mitigation Goals

1. Prevent or minimize loss of life, injury, public health impacts, and damage to property, the economy, and the environment from natural hazards and climate change.
2. Prevent or minimize damage to public and private infrastructure, buildings, and utilities from natural hazards and climate change.
3. Seek to use nature-based solutions as hazard mitigation whenever possible to reduce and minimize damage while accomplishing the accessory goals of environmental restoration and resource protection.

4. Ensure that future development within the Town meets federal, state, and local standards for climate resiliency and natural hazard mitigation.
5. Incorporate climate change resiliency and hazard mitigation policies, guidance, and requirements into relevant Town plans and policies.
6. Identify and seek funding to implement priority hazard mitigation projects identified in the MVHMP.
7. Collaborate with surrounding communities and state, regional, and federal agencies to ensure broad cooperation to maximize mitigation cost and effectiveness across multiple communities.
8. Promote awareness of hazard mitigation, priority project implementation, and MVHMP maintenance among municipal departments, committees, boards, and the public at large, with emphasis on vulnerable and isolated populations.
9. Maximize community participation in the development, implementation, and update of the MVHMP. Invite the business community, public institutions, educational sector, and non-profits, particularly those that work with sensitive or vulnerable populations, to review, implement, and contribute to development and maintenance of the Plan.

7. CAPABILITY ASSESSMENT

The following capability assessment evaluates the Town's current authorities, policies, programs, and resources to reduce long-term vulnerability and accomplish the mitigation actions outlined in this Plan.

7.1 Flood Hazard Mitigation Capabilities

The Town of Pembroke has participated in the National Flood Insurance Program (NFIP) since 1974 with 6 policies in force as of September 30, 2019. Community Information System data for the Town were obtained from the Massachusetts Department of Conservation and Recreation, Office of Water Resources and are summarized in **Table 7.2**; the CIS data sheets are provided as **Appendix C**. All of the flood policies cover residential buildings; most (26) are for single-family structures. There are no Repetitive or Severe Repetitive Loss properties in the Town.

Table 7.1. National Flood Insurance Program Summary, Town of Pembroke

Flood insurance policies in force as of 9.30.19	**27**
Insurance coverage in force	$7,981,000
Total premiums	$21,200
Total Losses	6
Closed Losses	6
Open Losses	0
Repetitive Loss and Severe Repetitive Loss Properties	0
Value of Closed Paid Losses	$21,590

The Town plans to continue to participate in the NFIP in compliance with all requirements. Although it does not participate in the Community Rating System program, the MVHMP Implementation Committee will consider future participation. In addition, Pembroke has enacted the following planning and regulatory tools that address flood mitigation as well as other natural hazards:

- *Zoning Bylaws (revised through May 2019)* - These bylaws were enacted to lessen congestion in the streets; conserve health; secure safety from fire, flood, panic and other dangers; provide adequate light and air; prevent overcrowding of land; avoid undue concentration of population; provide housing for persons of all income levels; facilitate the adequate provision of transportation, water, water supply, drainage, schools, parks, open spaces and other public requirements; conserve the value of land and buildings, including the conservation of natural resources and the prevention of blight and pollution of the environment; encourage the most appropriate use of land throughout the town, including consideration of the recommendations of the master plan adopted by the planning board and the comprehensive plan of a regional planning agency; preserve and increase amenities; enhance the visual environment of the town; protect and preserve from despoliation significant environmental features and resources, such as salt marshes, lakes, ponds, rivers, brooks and other water bodies by reducing the sources and possibilities of pollution, sedimentation or other destruction of water bodies; protect wetlands; and protect and promote the natural scenic and aesthetic qualities of the town.

- *Site Plan Approval Rules and Regulations* - The regulations require drainage system design for no net increase in the pre- versus post-development peak rates of stormwater discharge for the 2-, 10-, and 100-year storm events, and to comply with all Town, State, and Federal agencies. Systems are required to promote on-site infiltration, minimize pollutant discharge, and provide emergency overflow for the 100-year storm and 1 foot of freeboard for all detention/retention structures.
- *Town of Pembroke Drainage Commission (Town Bylaws, Article XIII)* - The Drainage Commission maintains a Master Drainage Plan and recommends to the Planning Board the need for changes to proposed drainage work in connection with subdivision plans. The Commission also approves all drainage for municipal projects.
- *Floodplain & Watershed Protection District (Pembroke Zoning Bylaws, Section V, revised through May 2019)* - The purpose of the floodplain overlay district is to protect the health and safety of persons from the hazards of flooding, conserve the value of land and buildings, facilitate adequate water supply by preserving groundwater and wetlands, and protecting significant environmental features by reducing sources of pollution. The overlay prohibits encroachments in the regulatory floodway, controls construction in the A and AE flood zones in compliance with the NFIP, and requires that all proposals minimize flood damage and comply with Chapter 131, Section 40 of the Massachusetts General Laws, State Building Code, MA DEP wetlands restrictions (310 CMR 10) and septic regulations (310 CMR 15, Title 5). The Town Planning Board is responsible for implementing the overlay requirements.
- *Water Resources & Groundwater Protection District (Pembroke Zoning Bylaws, Section IV, revised through May 2019)* - This overlay district map is appended to the Town Zoning Bylaws, includes specifically designated areas that include Zone II and IWPAs, and applies to all new construction, reconstruction, or expansion of buildings and new or expanded uses. This overlay district serves to preserve/protect the Town drinking water resources and minimize public health risks.
- *Stormwater Management Bylaw (Town Bylaws updated to Town Meeting of May 14, 2019, Article XXXV)* - This bylaw regulations illicit connections and discharges to storm drain systems to protect Town waterbodies and groundwater and safeguard public health, safety, welfare, and the environment. The bylaw addresses illicit discharge and detection, construction site runoff, and post-construction site runoff.
- *Drainage Improvements* - The Highway Division of the Department of Public Works routinely repairs or replaces aging drainage structures. Since 2014, the Town has completed drainage improvements as part of the Route 14 Corridor Project.
- *Wetlands Protection Bylaw (Town Bylaws updated to Town Meeting of May 14, 2019, Article XXXVI)* - The Pembroke Wetlands Protection Bylaw is more protective than the State Wetlands Protection Act. The bylaw requires a permit to remove, fill, dredge, alter or build upon or within 200 feet of a riverfront area along most perennial streams or within 100 feet of any bank, fresh water wetland, coastal wetland, beach, dune flat, marsh, meadow, bog, swamp or upon or within 100 feet of any estuary, creek, river, stream, pond or lake, or within 100 feet of any land under said waters or upon or within 100 feet of any land subject to tidal action, coastal storm flowage, flooding or inundation, or within 100 feet of the 100-year storm line.
- *Street Sweeping, Catch Basin Cleaning and Repair* - The Town Highway Division of the Department of Public Works annually contracts for street sweeping and catch basin maintenance in compliance with the Town stormwater regulations.
- *Pembroke Open Space and Recreation Plan (2019)* - The Plan articulates 5 goals and recommends 12 actions that include protecting the Town groundwater and surface water resources, exploring smart growth strategies to focus growth away from valued resources, and extending and connecting protected natural areas to create contiguous corridors. The Town Open Space Committee evaluates opportunities for acquisition and protection of open space parcels to protect Pembroke's water resources and achieve related goals.

- *Town of Pembroke Comprehensive Emergency Management Plan* – The CEMP follows the Massachusetts Emergency Management Agency template. It charges the Emergency Co-directors with coordinating the development and implementation of a hazard mitigation plan and strategies which is reflected by the membership of the MVHMP Steering Committee. Under the CEMP, the Public Works Department is charged with inspecting public and private water impoundment sites and maintaining roads, bridges, waterways, and water and sewer systems and services.

- The Town Water Department has acted with foresight to purchase properties important for aquifer protection and as potential future sites for drinking water wells. These include the Swanberg Property on Pleasant Street, the Edgewood/Elmer Street Bogs, the Zanaboni/Glenwood Bogs, and the Zanaboni/Center Street Bogs.

- The Town of Pembroke enforces the *Massachusetts State Building Code (Ninth Edition CMR 780)* Section 1612 provisions that apply to new construction and substantial improvement or restoration of structures in flood hazard areas; design and construction are to be in accordance with Chapter 5 of ASCE 7 and ASCE 24.

7.1.1 Dam Mitigation Capabilities

All jurisdictional dams within the Commonwealth are subject to the Massachusetts Division of Conservation and Recreation's dam safety regulations at 302 CMR 10.00 which require regular dam inspection and reporting to the DCR Office of Dam Safety. Massachusetts law also requires a permit for the construction of any dam. There are 4 jurisdictional dams within the Town of Pembroke that lie within the A or AE flood zones; all are Low Hazard (**Table 5-3**).

The single Significant Hazard structure in the Town of Pembroke is the Lower Chandler Pond Dam co-owned by the Towns of Pembroke and Duxbury. Both municipalities coordinate on the inspections and maintenance of this structure to ensure proper function.

The Town CEMP requires the Department of Public Works to inspect public and private water impoundment sites. Should any of the Town dams fail, the CEMP contains evacuation provisions for those with and without personal vehicles and has designated evacuation routes and three facilities that can be used to shelter evacuees or displaced persons in emergency situations. These are the Pembroke Public Library, the Pembroke Council on Aging, and the Pembroke High School.

7.2 Wind Hazard Mitigation Capabilities

The Town of Pembroke enforces the *Massachusetts State Building Code (Ninth Edition CMR 780)* provisions that are generally adequate to protect against most wind damage. The State has adopted the 2015 International Code Council Commercial and Residential codes as of 2018. The State code sets forth design factors for snow, wind, and earthquakes in Table 1604.11.[122] The ultimate design wind speed (3-second gust) for Pembroke is 124 mph for Risk Category I (minor storage or temporary or agricultural facilities), 134 mph for Risk Category II (all structures not listed in I, III, and IV), and 145 mph for Risk categories III or IV (public/education assembly, resident care, power stations, water treatment facilities etc.); wind load calculations are based on ASCE 7-10 and are factored rather than service loads.

[122] Massachusetts CMR 780, Ninth Edition. https://www.mass.gov/doc/780-cmr-ninth-edition-chapter-16-structural-design-amendments/download

The Town Highway Department performs routine tree trimming and removal from roadways during high wind storms, blizzards, and hurricanes, using its own bucket truck. The Department coordinates with National Grid regarding planned tree inspections on both private and Town lands that have the potential to put the power grid at risk of outage.

7.3 Winter Storm Hazard Mitigation Capabilities

Snow and Ice Removal from winter storms is a 24-hour operation of the Highway Division with assistance from Water, Cemetery/Tree Divisions and outside plow contractors. When snow is forecast, residents are asked to keep all parked vehicles off streets that are plowed by the Town to expedite road clearing and sanding operations.

Town By-Law Article XX - Police Regulations - Section 17, Interference with Streets and Way, ensures that no one other than a Town employee or contractor hired by the Town may shovel, snow-blow, or plow ice or snow onto a roadway in such a way that it impedes traffic.

The Town of Pembroke enforces the Massachusetts State Building Code (Ninth Edition CMR 780) provisions that apply to snow load which include design snow drifts and sliding snow loads and roof structure snow guards. Ground snow load for the Town is 30 psf.[123]

7.4 Geologic Hazards Mitigation Capabilities

The Town of Pembroke Department of Building and Inspectional Services is responsible for providing the Town with accurate and efficient guidelines to ensure the safety of all construction and repair projects to buildings and property located within the Pembroke. The Building Inspector enforces the Commonwealth of Massachusetts Building Code and the Pembroke By-Laws. The Building Department is also responsible for the use and occupancy of all buildings, structures, and land within the Town of Pembroke and enforces the State Building Code (780 CMR).

Chapter 16 of the State Building Code governs structural design of buildings. Section 1604.11 and Table 1604.11 set forth earthquake design factors and Section 1613 presents criteria for the design and construction of buildings and other structures subject to earthquake ground motion. The stated purpose of Section 1613 is "…to minimize the hazard to life of occupants of all buildings and nonbuilding structures, to increase the expected performance of high occupancy assembly and education buildings…, and to improve the capability of essential facilities to function during and after an earthquake. Because of the complexity of and the great number of variables involved in seismic design…, section 1613 presents only minimum criteria in general terms. These minimum criteria are considered…prudent and economically justified for the protection of life safety in building subject to earthquakes and for improved capability of essential facilities to function immediately following an earthquake." Section 1613.1 further states that absolute safety and prevention of damage cannot be achieved economically in most buildings even with a reasonable probability of occurrence.[124]

[123] Ibid.
[124] Ibid.

7.5 Fire Hazard Mitigation Capabilities

Subdivision/Site Plan Approval Rules and Regulations - The Fire Department comments on subdivision and site plans for compliance with site access, water supply, and associated regulatory considerations within their jurisdiction.

Open Burn Permits - Mass DEP and the local fire department regulates open burning. Pembroke allows open burning from January 15 to May 1 as long as conditions are suitable. Pembroke residents are required to obtain a permit from the Fire Department and comply with all State regulations.

Town By-Law Article XX - Police Regulations - Section 11 allows no person having charge of any vehicle shall leave it unattended within the limits of any private or public way furnishing access to any building so as to obstruct the free passage or use of any piece of fire apparatus by or through such way.

Massachusetts Statewide Fire Mobilization Plan - The statewide Fire Mobilization Plan is outlined in Massachusetts General Law Chapter 48 Section 59A. It offers pre-determined response assets and capabilities to assist communities in the event they have exhausted their firefighting assets during an emergency.

The Town of Pembroke enforces the Massachusetts State Building Code (Ninth Edition CMR 780) provisions that relate to fire. The most recent revisions include a requirement that rooftop gardens and landscaped roofs meet fire code. Additional requirements apply to, among others, exterior walls, sprinkler protection, means of egress, and mass timber.

7.6 Extreme Temperature Mitigation Capabilities

The Town of Pembroke Emergency Management Agency has completed a Draft update of its Comprehensive Emergency Management Plan following the template developed by the Massachusetts Emergency Management Agency. For all hazards, the Town acknowledges as a Planning Assumption that, along with its response partners, it will need to provide additional/enhanced assistance to individuals with access and functional needs, including but not limited to children, elderly individuals with disabilities and/or chronic conditions.

As part of its CEMP, the Town has designated three facilities that can be used to shelter evacuees or displaced persons in emergency situations, including extreme temperature emergencies. These are the Pembroke Public Library, the Pembroke Council on Aging, and the Pembroke High School.

7.7 Drought Hazard Mitigation Capabilities

The Town has rules, regulations, and a water use restrictions bylaw to respond to drought emergencies. They include the following:

- *Rules and Regulations Governing Use of the Lakes, Ponds, and Landings (Town Bylaws, Article XXIV)* - The rules and regulations govern use of the Town waterbodies and subjects them to the State rules and regulations of any body of water used for domestic water supply.
- *Water Use Restrictions Bylaw (Town Bylaws, Article XXVII)* - This bylaw regulates water use in the Town pursuant to MGL Chapter 40 Section 69B and under Section 41A conditioned upon a declaration of water supply emergency. Its purpose is to protect, preserve and maintain the public health, safety and welfare whenever there is in force a State of Water Supply Conservation or State of Water Supply Emergency by providing for enforcement of any restrictions, requirements, provisions or conditions imposed by the Town or by the Department of Environmental Protection including outdoor watering prohibition or restriction, filling of swimming pools, automatic sprinkler use, and lawn irrigation.

- *Massachusetts General Law MGL Ch. 111, s. 122* - Local Boards of Health have primary jurisdiction over the regulation of private wells and are empowered to adopt private well regulations that establish criteria for private well siting, construction, water quality and quantity. Pembroke property owners must obtain a permit from the BOH and the Town Director of Public Works prior to installing or repairing a well.

7.8 Multi-Hazard Mitigation Capabilities

Additional municipal mitigation capabilities not previously discussed that apply to all natural hazards include the following:

- *Comprehensive Emergency Management* - The Pembroke Emergency Management Agency (PEMA) is the central municipal agency tasked with providing emergency notification and updates, storm preparation information, and public safety information, and is the local clearinghouse for power outage reporting. PEMA uses CivicReady to send emergency alerts and notifications which subscribers can receive by phone, text, and/or email. Emergency notices are also provided to WATD (95.9FM) for broadcast. PEMA, the Fire Chief, and EMS also maintain a list of special risk individuals in the event of emergency. Town residents can register through the Town website for this service. PEMA's Town website also provides information and links to the Massachusetts Emergency Management Agency (MEMA), winter weather advisories and tips, hurricane season information, and the like.

  In 2021, the Town drafted a Comprehensive Emergency Management Plan following MEMA guidance. The CEMP provides a framework for a community-wide emergency management system to ensure coordinated response to emergencies and support of certain pre-planned events. Further, the CEMP addresses the roles and responsibilities of all community departments, agencies, government organizations, volunteers and community partners that may be involved in response operations, and identifies how regional, state, federal, private sector, and other resources may be activated to address disasters and emergencies in the community.

  The Draft CEMP and MVHMP use the same hazard identification and risk assessment information and are aligned planning documents.

- *Mass Care Shelters* - The Massachusetts Statewide Mass Care and Shelter Coordination Plan (Plan) establishes a framework for the Commonwealth and other supporting agencies and organizations to successfully implement the State's shelter strategy. The Pembroke Public Library is an emergency shelter in partnership with the Pembroke Emergency Management Agency. There are 11 additional Mass Care shelters in the Town, including the Fire Department Headquarters at 172 Center Street, Town Hall at 100 Center Street, Hobomock Arena at 132 Hobomock Street, Bethel Chapel at 155 Washington Street, North Pembroke Community Club at 27 Taylor Street, Saint Thecla Church at 145 Washington Street, Bryantville Elementary School, Hobomock Elementary School, North Pembroke Elementary School, Pembroke Middle School, and Pembroke High School.

- *Partnerships* - Town agencies have developed and work to maintain partnerships to support emergency response and hazard mitigation. PEMA coordinates with the Board of Health, Public Safety and Public Works departments, Council on Aging, Commission on Disabilities, School District, area nurses, and National Grid liaisons to provide shelter, open roads, and restore power during hazard events. PEMA also collaborates with Public Library staff to update social media and town websites with news of impending storms and parking bans. The Town Health Agent, in conjunction with PEMA, organizes team trainings with the Massachusetts Office of Disabilities and the Plymouth County Public Health Emergency Preparedness Coalition. The 2019

PEMA improvement project installed a large scanner printer unit at Town Hall to make maps and scan building and site plans as part of digitizing future Town Comprehensive Emergency Plans.[125]

- *Plymouth County Public Health Emergency Preparedness Coalition* - Pembroke is a member of the County Coalition and the Town Health Agent serves on their Executive Board.
- *Backup Generators*–In the event of power outages due to downed limbs, the majority of the Town's critical buildings and facilities have backup generators. Only Town Hall has none and the Pembroke High School generator is in need of upgrade.

7.9 Summary Mitigation Capabilities

Current mitigation capabilities in the Town of Pembroke amplified above are summarized in **Table 7-2.**

Table 7-2. Summary Mitigation Capabilities, Town of Pembroke, MA

Mitigation Measure	Area Covered	Hazards Addressed	Effectiveness	Recommended Improvements
Town Bylaws revised 2019	Town-wide	All	Effective	Regularly updated
Zoning Bylaws	Town-wide	All	Effective	Regularly updated
Site Plan/Subdivision Regulations	Town-wide	All	Effective	Regularly updated
Floodplain & Watershed Protection District	District areas	Flooding, Drought	Effective	None
Water Resources & Groundwater Protection District	District areas	Flooding, Drought	Effective	None
Wetland Protection Bylaw	Wetland areas	Flooding, Drought	Effective	None
Stormwater Management Bylaw	Town-wide	Flooding	Effective	None
Building Code Enforcement (MA State Building Code)	Town-wide	Flood, Winter Storm, Wind, Earthquake	Effective	Follows State codes and updates
Police Regulations	Town-wide	All	Effective	None

[125] 2019 Town of Pembroke Annual Report, p. 93. https://www.pembroke-ma.gov/sites/g/files/vyhlif3666/f/uploads/pembroke_annual_report_2019.pdf

Mitigation Measure	Area Covered	Hazards Addressed	Effectiveness	Recommended Improvements
National Flood Insurance Program	Areas mapped on the FIRM (A, AE)	Flooding	Effective – 6 policies in force; no RL or SRL properties	Encourage participation where needed
Rules & Regulations – Lakes, Ponds, Landings	Town waterbodies and landings	All	Effective	None
Water Use Restrictions Bylaw	Town-wide	Drought	Effective	None
Private Well Regulation (MGL Ch. 111 s. 122)	Town-wide	Drought	Effective	None
Tree Trimming and Removal	Town-wide	All	Effective	Continue partnership with National Grid
Snow and Ice Removal	Town-wide	Winter Storm	Effective	None
Open Burn Regulations	Town-wide	Wildfire	Effective	None
Massachusetts Statewide Fire Mobilization Plan	Town-wide	Wildfire, Earthquake	Effective	None
Comprehensive Emergency Management	Town-wide	All	Effective	None
All-Hazards Emergency Response Plan	Town-wide	All	Effective	Update regularly
Partnerships and Emergency Communication	Town-wide	All	Effective	None
Mass Care Shelters	Town-wide	All	Effective	None
Plymouth County Public Health Emergency Preparedness Coalition	Town-wide	All	Effective	None
Backup Generators	Most Critical buildings and facilities	All	Effective	None

8. MITIGATION STATUS - 2015 OCPC REGIONAL HAZARD MITIGATION PLAN

A mitigation action is a specific project, activity, or process taken to reduce or eliminate long-term risk to people and property from hazards and their impacts. These actions from the core of the plan and are a key outcome of the planning process. Mitigation measures include creation/modification of local plans and regulations, infrastructure projects, natural systems protection, and education and awareness programs.

8.1 Recommended Mitigation Actions (2015)

The 2015 Old Colony Planning Council Regional Natural Hazard Mitigation Plan contained Mitigation Action plans for each of its 14 participating communities, including the Town of Pembroke. The Town's Action Plan covered the period from 2015 to 2020 and proposed two classes of actions - 'Mitigation Actions' and 'Preparedness, Response, and Maintenance Actions.' These are presented in **Tables 8-1 and 8-2.**

Table 8-1. Town of Pembroke 2015 Mitigation Actions

Action Category	Action	Hazard Addressed	Responsible Party	Priority	Timeframe	Benefit / Cost	Potential Funding Sources
Prevention Structural Project	Develop and implement a local flood mitigation dam management program including inspecting, maintaining, and upgrading the Mill Pond/Furnace Pond Dam and Lower Chandler Pond Dam for current function and stormwater management	Flooding	Town DPW, Private Property Owners	Medium	1-5 years	Medium / High	MA Dam & Seawall Repair or Removal Program, US Army Corps Planning Assistance Grant (public dams), General fund, Private Property Owners
Structural Project	Install outfall control structure and drainage from the Hobomock Pond down Center Street (Route 36) to alleviate flooding of homes, businesses, and Hobomock Street	Flooding	Town DPW	High	1-3 years	Medium / Medium	General fund, Bond, MEMA MVP Action Grant, FEMA HMGP/BRIC Grant Programs

Action Category	Action	Hazard Addressed	Responsible Party	Priority	Timeframe	Benefit / Cost	Potential Funding Sources
Structural Project	Enlarge Birch Street culvert at Duxbury Town Line to eliminate flooding	Flooding	Town DPW	High	1-3 years	Medium / Medium	General fund, Bond, MVP Action Grant, FEMA HMGP/BRIC Grant Programs

Table 8-2. Town of Pembroke 2015 Preparedness, Response, and Maintenance Actions

Action Category	Action	Hazard Addressed	Responsible Party	Priority	Timeframe	Benefit / Cost	Potential Funding Sources
Structural Project	Upgrade failing leach basins on Mill Pond Road	Flooding	Town DPW, Private Property Owners	Medium	1-5 years	Medium / Medium	General fund

8.2 Status of Implementation

All Mitigation Actions from 2015 have been carried forward to this MVHMP, largely due to lack of funding and are summarized in Table 8-3. However, the Town has completed additional mitigation actions not listed in the 2015 RHMP that address concerns identified in that plan.

Areas addressed since the 2015 RHMP include Glenwood Road (pump chamber installed) and Lake Shore Drive at Lower Chandler Pond where the culvert was replaced by the Town working jointly with the Town of Duxbury. Additional mitigation underway includes evaluation of the culvert at Park Street, design of the culvert at Herring Run, and completion of a drainage and alternatives analysis for Taylor Street at the ledges and Lorna Avenue in the Blake/Burr roads area. Flooding in the low-lying areas that include the Memory Care Facility “Bridges” (Route 139 and Cross Street) were addressed by installing a drainage swale four years ago.

Table 8-3. 2015 Mitigation Actions Carried Forward

Stormwater – Upgrade/replace 2 failing detention basins and 6 leaching areas on Mill Pond Road.
Stormwater - Enlarge the Birch Street culvert at the Duxbury Town Line (Pine Brook) to address flooding.
Water Supply – Complete the Center Street 16-inch water main construction to increase system resiliency.
Stormwater – Install an outfall control structure and drainage from Hobomock Pond down Center Street to alleviate local flooding.
Stormwater - Develop and implement a local flood mitigation dam management program, including inspecting, maintaining and upgrading the following dams for present functions and stormwater management potential: Mill Pond/ Furnace Pond Dam and Lower Chandler Pond Dam.

9. HAZARD MITIGATION STRATEGY

Hazard mitigation is a strategy to eliminate, minimize, or reduce loss of life, property and environmental damage, and public health impacts by implementing structural, policy, organizational, and regulatory actions. They differ from preparedness and disaster response, the need for which can be reduced by effective mitigation. Hazard mitigation actions can include the following:

- Enactment, amendment, or modification of local plans and regulations that determine how land and building structures are developed;
- Modification of existing structures and infrastructure to protect or remove them from a hazard area, and construction of new structures to reduce hazard impact;
- Natural systems protection and nature-based approaches to minimize hazard damage and loss while preserving or enhancing natural system functions; and
- Education and awareness programming to inform citizens of hazard risk and the potential to mitigate risk.

9.1 Recommended Mitigation Measures

The Town of Pembroke Hazard Mitigation Strategy is based on the CRB Workshop findings summarized in Sections 2, 4, and 5 and incorporates recommendations from Town departments that deal regularly with disaster response and damage assessments. To address the most significant risks, the Town identified priority mitigation actions, both structural and non-structural, for the near (1-2 year) and longer (3-5 year) terms **(Table 9-1)**. Per Federal regulation 44 CFR §201.6(c)(3)(ii), the Town is required to consider actions that reduce risk to existing buildings and infrastructure and limit risk to new development and redevelopment. The list of recommended actions also takes into account the following factors:

- Action effectiveness in preventing/reducing loss of life and property damage.
- Need and ability to protect critical infrastructure.
- Number of homes or businesses affected by the hazard.
- Ability to secure functional transportation and emergency routes.
- Feasibility, project useful life, and maintenance costs.
- Level of public support for the action.
- Cost/benefit (planning level).

Table 9-1 describes each of the Town's recommended Mitigation Actions by number and indicates the Mitigation Goal and hazard(s) addressed. Priority is indicated as High, Medium, or Low and is generally based on the criticality of the measure (urgency of need). Project timeframe generally reflects the complexity of the action and may depend on the level of advance work required (design, environmental review) and funding availability; all action timeframes reflect the 5-year planning horizon for the MVHMP. Responsible Entity is the Town Department, staff, or other group primarily responsible for undertaking the action but will include collaboration with additional Town personnel. The State and Federal programs most likely to support all or part of the mitigation action are identified as potential funding sources; however, because funding programs have project-specific eligibility criteria, this information is of general use only until more detail becomes available.

FEMA requires a planning level assessment of whether the cost of a mitigation action is reasonable compared to the probable project benefit. For purposes of this Mitigation Strategy, benefits are defined as population/property/

infrastructure losses avoided, population/property/infrastructure protected, quality of life, and ecosystem protection. Cost estimates are indicated only where supported by community data. Projects estimated to cost more than $100,000 were considered High Cost, those estimated to be more than $10,000 but less than $100,000 were considered Medium Cost, and those that could be implemented for under $10,000 were designated Low Cost.

Table 9-1. Town of Pembroke Recommended Hazard Mitigation Actions

Action No. & Goal	Description and Location	Hazard(s)	Respon-sible Entity	Potential Funding	Timing & Estimated Benefit/ Estimated Cost
HIGH PRIORITY					
A1 G1,6,7	**Water Supply** – Perform comprehensive water supply study to support construction of resiliency improvements to include pipe redundancy, distribution system upgrades, and development of new wells and sources to ensure adequate safe supply in future drought scenarios. Assess source quality threats and implement protections. Seek intermunicipal cooperation to assess intergovernmental reliance on Pembroke supply.*	Drought	Town DPW Water Division	MA DWSRF Program, MA MVP Action Grant Program, FEMA HMGP, Town funds	Short-term High / Medium
A2 G 1,6	**Water Supply** – Construct new water storage tank at Oak Street to add system resiliency to address climate change-related drought.	Drought	Town DPW Water Division	MA DWSRF Program, MA MVP Action Grant Program, FEMA HMGP, Town funds	Short-term High / High
A3 G1,6	**Water Supply** – Provide generators for West Elm, and Oak Street water towers.	All	Town DPW Water Division	FEMA HMGP, Town funds	Short-term High / Medium-High
A4 G1,6	**Water Supply** – Develop new water supply at the Swanberg Property to increase water security and resiliency to drought.	Drought	Town DPW Water Division	MA DWSRF Program, Town funds	Short-term High / High
A5 G1,2, 3,6,8,9	**Tree / Forest Management Study** – Conduct a Town-wide inventory of trees to identify areas for pruning/removal to mitigate power loss and areas for replanting to increase community canopy cover and provide outdoor cooling to mitigate extreme temperatures. Include assessment of parks/playgrounds for shade infrastructure needs (e.g., Ford Park).	High Wind, Extreme Temperature	Town DPW	MA MVP Action Grant Program, Town funds	Short-term High / Medium

Action No. & Goal	Description and Location	Hazard(s)	Respon-sible Entity	Potential Funding	Timing & Estimated Benefit/ Estimated Cost
HIGH PRIORITY					
A6 G1,2, 3,6	**Culverts** – Update Town-wide culvert assessment to identify and prioritize need for repair, replacement, upsizing. Specific areas to be addressed include enlarging the Birch Street at Duxbury Town Line (Pine Brook), Dwelley Street at Hanson Town Line, Congress Street, Mill Street, Herring Run (construction), Park Street (design underway), Taylor Street at the Ledges, Lorna Avenue in the Blake/Burr Ave area, Woodbine and Shepard Avenues at the beach, Brenda Lane at Plymouth Street, Mill Pond off Hobomock Street, Indian Head River Dam at West Elm Street at Hanover Town Line, Valley Street at Duxbury Town Line – Upper Chandler Pond. Assessment to Include evaluation of opportunities to incorporate green infrastructure and nature-based solutions to mitigate direct stormwater discharge into wetlands and the ponds.	Flooding	Town DPW	MA MVP Action Grant, MA, MA DER Culvert Replacement Municipal Assistance Grant Program	Short-term High / Medium-High
A7 G1,2,3,6	Install outfall control structures and address drainage from Hobomock Pond down Center Street to alleviate local flooding in coordination with the Route 36 TIP project.	Flooding	Town DPW		Short-term High / High
A8 G1,2,3,6	Upgrade/replace two failing detention basins and 6 leaching areas on Mill Pond Road.	Flooding	Town DPW	MA MVP Action Grant Program, Town funds	Short-term High / High
A9 G1,2,6,8	Improve phone/emergency communications by upgrading existing telecommunications infrastructure, including identifying locations for and constructing additional cell towers.	All	Town Select Board, Planning Commission	Town funds, HMGP	Short-term High / High
MEDIUM PRIORITY					
A10 G1,4,6	Prepare a Town-wide study to evaluate the impacts of septic systems on the Town's water resources and drinking water supply in the face of changing precipitation patterns due to climate change. Identify and evaluate areas most vulnerable to malfunction / failure under future conditions to determine the need for sewering of selected areas.	Flooding	Town DPW, Planning Commission, MA DEP	MA DEP CWSRF, Town Funds	Long-term High / Medium

Action No. & Goal	Description and Location	Hazard(s)	Respon-sible Entity	Potential Funding	Timing & Estimated Benefit/ Estimated Cost
MEDIUM PRIORITY					
A11 G1,2,3,6	Conduct a Town-wide assessment of public dams to determine level of risk in relation to climate change, evaluate emergency overflow needs, and evaluate opportunities to increase stormwater management potential at Mill Pond/Furnace Pond Dam and Lower Chandler Pond Dam. Based on assessment results, develop and implement a local flood mitigation dam management program.	Flooding	Town DPW, MA DCR	MA Dam & Seawall Repair or Removal Program, US Army Corps Planning Assistance Grant (public dams), General fund, Private Property Owners	Short-term High / Medium
A12 G1,2,3,6	Prepare a Town-wide assessment of areas of flooding to determine need to elevate roadways or otherwise identify retrofits to manage stormwater, including direct discharges to wetlands.	Flooding	Town DPW	MA MVP Action Grant Program, Town funds	Short-term High / High
A13 G1	Retrofit public buildings that serve emergency management or shelter functions during extreme temperature and other disaster events for HVAC and filters.	All	Town DPW	MA MVP Action Grant, FEMA HMGP, Town funds	Short-term High / High
ADDITIONAL PRIORITY ACTIONS					
A14 G1,3,6	Assess the quality of the Town's ponds in relation to nutrient loading, stormwater impacts, and invasive species colonization due to increasing extreme weather events. Evaluate dredging and other alternatives to correct existing problems and mitigate future impacts with an emphasis on NBS	Flooding Extreme Temperatures	Town DPW	MA MVP Action Grant, Town funds	Long-term High / Medium
A15 G1,6,8,9	Maintain and improve emergency response plans. Ensure access routes and ability to maintain them for residential services and non-mobile (no car) residents. Coordinate with food pantries to ensure adequate provision of food to vulnerable populations during disaster events.	All	PEMA	Town funds	Short-term & Ongoing High / Low
A16 G1,2,3,6	Replace Public School parking lots with impervious pavement to remediate flooding; evaluate opportunities to install stormwater trees and raingardens in these locations.	Flooding	Town DPW	MA MVP Action Grant, Town funds	Long-term Medium / Medium

Action No. & Goal	Description and Location	Hazard(s)	Respon-sible Entity	Potential Funding	Timing & Estimated Benefit/ Estimated Cost
ADDITIONAL PRIORITY ACTIONS					
A17 G1,8	Develop and disseminate public information materials to educate the community on emergency response during natural disaster and extreme weather events.	All	PEMA	MA MVP Action Grant, Town funds	Short-term & Ongoing High / Low
A18 G1	Assess Town-owned properties for retrofit opportunities to control and treat stormwater to reduce flooding and mitigation water quality impacts on Town wetlands, ponds, and watercourses.	Flooding	Town DPW	MA MVP Action Grant, FEMA HMGP, Town funds	Long-term Medium-High / Medium-High

*Referencing MassDEP 310CMR22.04(2) Construction, Operation, and Maintenance of Public Water Systems, public water supplies and other critical assets are recommended to be protected to 3 feet above the FEMA 1% annual base flood elevation.

9.2 Intermunicipal Mitigation Issues

As part of its Municipal Vulnerability – Hazard Mitigation Plan strategy, the Town of Pembroke will continue to coordinate and cooperate with neighbor municipalities with regard to infrastructure or interests within the Town that can affect hazard risk. These include the following:

- Town of Duxbury, co-owner of the Lower Chandler Pond Dam (MA00917, Significant Hazard Potential)
- Town of Abington, Great Sandy Bottom Pond Surface Water Supply (Source ID 4001000-01S)
- Brockton Water Department (draws 92% of its supply from Silver Lake, supplemented by Furnace Pond)
- Town of Marshfield (water supply interconnection)
- Town of Halifax (water supply interconnection)

Participants at the Town's CRB Workshop expressed concern about adequate water supply in the face of increasing periods of drought associated with climate change and the fact that Pembroke does not have exclusive right to its sources of water.

9.3 Regional Mitigation Issues/Partnerships

Mitigating natural hazards, particularly flooding, is optimized when communities coordinate with state agencies and local partners to resolve issues of common concern. Community drainage systems include roadway infrastructure, pump stations, dams and related facilities owned by other entities. These include the Massachusetts Department of Transportation (MassDOT) and the Department of Conservation and Recreation (MA DCR). Coordination with these agencies can provide communities the opportunity to accomplish local hazard mitigation planning goals as part of outside work plans.

The Town of Pembroke is currently coordinating with MassDOT to alleviate local flooding from Hobomock Pond down Center Street in coordination with MassDOT's Route 36 TIP project. The project consists of the resurfacing/rehabilitation and full depth reconstruction of certain areas of Route 36 (Center Street) from the intersection

with Route 27 in the south to the intersection with Route 14 to the north. Sidewalks will be constructed and reconstructed, drainage will be upgraded, and signs and pavement markings provided. This project is funded through the 2022 Transportation Improvement Program for the Old Colony Metropolitan Planning Organization with construction to begin in Spring 2022. An additional DOT project nearing completion in partnership with the Town is the resurfacing of sections of Route 53 (Washington Street) which also includes drainage upgrades.

Other major facilities within the Town owned, operated, and maintained by state or regional entities include the following and may afford opportunities to accomplish local hazard mitigation goals:

- State routes 3, 139, 14, 27, 36, and 53
- National Grid/Eversource (primary distributor of electric power to Pembroke)
- Eversource (primary provider of natural gas)

9.4 New Development and Infrastructure

Community growth and development or redevelopment can create new demands on critical infrastructure (roads, water supply, stormwater management) but can also provide an opportunity to address hazard mitigation priorities. New developments can be encouraged to bury power lines if site conditions permit, stormwater management facilities can be designed to maximize infiltration and nature based solutions to provide accessory ecological benefits.

As discussed in Section 2, growth in Pembroke is limited by natural resource limitations. While studies have indicated that there are 521 acres of developable land within the Town, they are constrained by wetlands and floodplains.[1] The Town's lack of municipal wastewater systems requires reliance on private septic systems that in turn require large minimum lot sizes. Nonetheless, Pembroke has enacted zoning bylaws, overlay protection districts (wetlands, floodplain and watershed, stormwater/drainage), and building codes sufficient to ensure that new development complies with the goals of this MVHMP (see Section 7).

[1] Community Paradigm Associates, LLC , "Town of Pembroke, Recommendations for Development of a Capital Improvement Program and FY20-24 Capital Plan and FY20 Capital Budget," March 2019.

10. PLAN ADOPTION & MAINTENANCE

10.1 Plan Adoption

The Town of Pembroke MVHMP was adopted by the Town Select Board on _____, 2021 (**Appendix F**). The Massachusetts EOEEA MVP program approved the Plan and certified the Town as an MVP Community on _____. The plan was approved by FEMA for a five-year period that will expire on _____.

10.2 Plan Maintenance and Monitoring

Following MEMA and FEMA approval of the MVHMP, the Town Steering Committee that oversaw its preparation will become the Implementation Committee and continue to be responsible for monitoring, maintaining, and updating the plan as necessary over the 5-year life of the Plan. This work will be overseen by Eugene Fulmine, Jr., DPW Director, acting as Plan Coordinator; the Committee will meet annually at minimum but as required depending on need. The Committee will maintain a record of revisions, progress on implementing recommended mitigation actions, and any related accomplishments that improve resiliency but were not identified in the plan. The Committee will note additional hazard mitigation needs to be incorporated into the 5-year MVHMP update. The City also will post notice of meetings and minutes to the Town website to ensure that the public can participate and contribute throughout the life of the document. All meetings to review and update the plan will be publicly noticed to comply with local and State open meeting laws.

10.3 Implementation and Evaluation Schedule

The Town staff and Board(s) identified as Responsible Parties in the Mitigation Actions summary will be responsible for implementing the projects. Where funding is a serious concern, the Plan Coordinator, working with the Town consultants, will identify funding opportunities in a timely fashion and will work with the responsible department to ensure competitive program applications.

In Year 3 of the Plan, the Coordinator will prepare and distribute to Committee members and interested stakeholders a survey to assess the status of Plan implementation and identify the need for revisions and/or amendments based on community conditions, recent disasters and response, and new public concerns. The survey will be posted to the Town website and the public invited to respond. The survey will be emailed directly to CRB Workshop participants to solicit their input.

The Plan is intended to govern the Town's hazard planning for a period of 5 years. Six months prior to the FEMA expiration date, the Plan Coordinator will meet with the Steering Committee to review the monitoring reports and Year 3 Survey information and outline the scope of work required to update the plan. Depending on the work required, the Committee will update the plan in-house or will contract with a provider to do so.

10.4 Integration with Other Plans

Plan integration is the process by which a community evaluates its existing planning framework to align hazard mitigation with those efforts. The Steering Committee will circulate the approved MVHMP to all municipal departments - those responsible for implementing mitigation projects and those that oversee the development of plans, ordinances, and regulations that affect hazard vulnerability – to ensure consistency. To the extent practicable, the goals of the MVHMP will be integrated into existing plans, policies, and bylaws by amendment and/or work program modification. The Plan Coordinator and Committee will disseminate the MVHMP to the Fire, Police, Public Works, Planning, Conservation, Health, Building, and Parks and Recreation departments and will discuss integrating the Plan into their

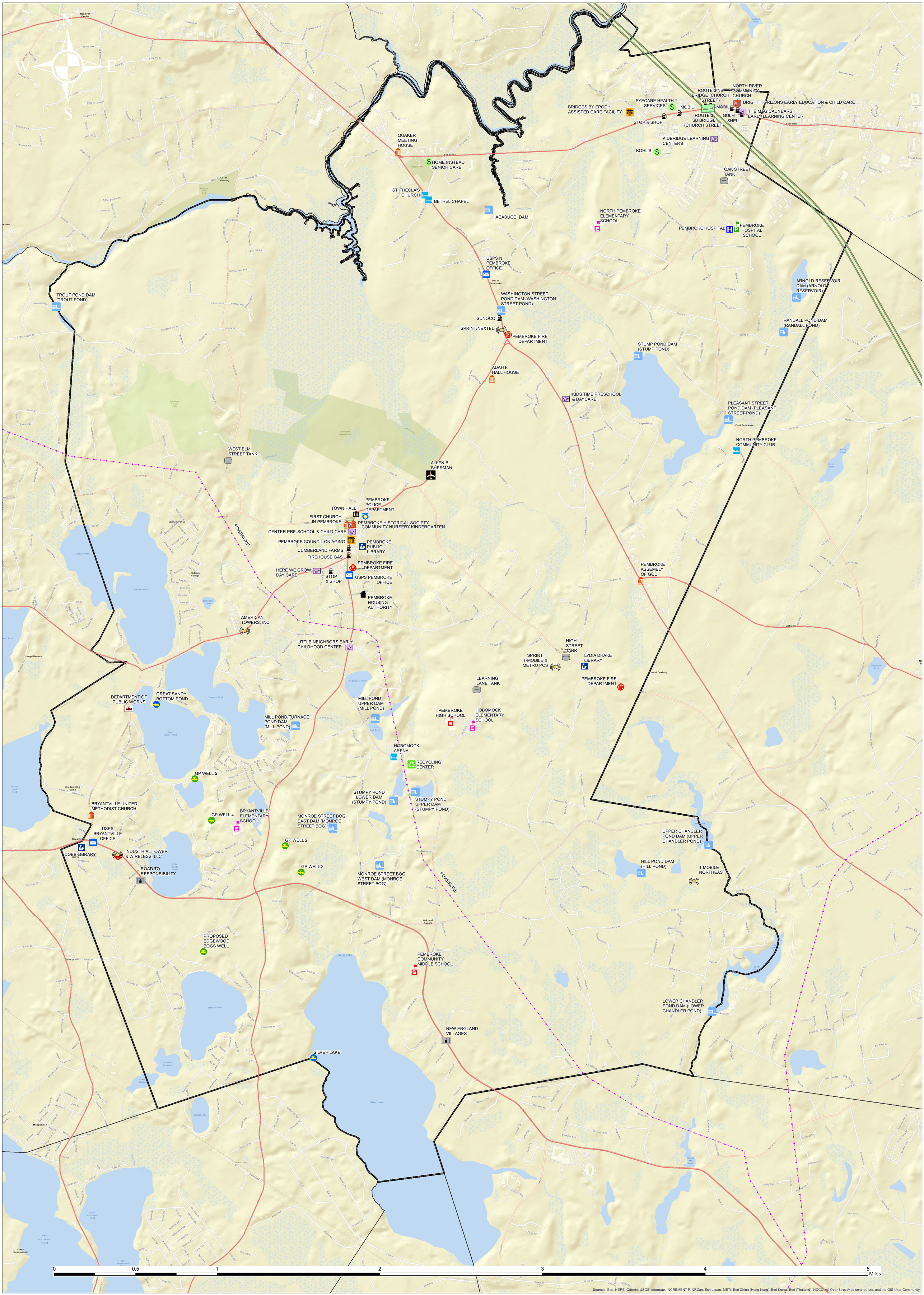
work programs. The Committee will encourage intergovernmental coordination among planners, emergency managers, engineers, and other Town staff to optimize disaster resiliency.

Section 7 outlines the Town of Pembroke's current capabilities to administer and implement the MVHMP. Appropriate sections of the Plan will be integrated if/as necessary into Town planning documents as appropriate, and the Town will consider adding hazard mitigation as a capital planning priority criterion.

TABLES

FIGURES

APPENDIX A: TOWN OF PEMBROKE HAZARD MAPS


N
S
E
W
ROUTE 3 NB BRIDGE (CHURCH STREET)
NORTH RIVER COMMUNITY CHURCH
BRIGHT HORIZONS EARLY EDUCATION & CHILD CARE
EYECARE HEALTH SERVICES
MOBIL
MOBIL
BRIDGES BY EPOCH ASSISTED CARE FACILITY
ROUTE 3 SB BRIDGE (CHURCH STREET)
GULF
SHELL
THE MAGICAL YEARS EARLY LEARNING CENTER
STOP & SHOP
KIDBRIDGE LEARNING CENTERS
KOHL'S
QUAKER MEETING HOUSE
HOME INSTEAD SENIOR CARE
OAK STREET TANK
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BETHEL CHAPEL
IACABUCCI DAM
NORTH PEMBROKE ELEMENTARY SCHOOL
PEMBROKE HOSPITAL
PEMBROKE HOSPITAL SCHOOL
USPS N. PEMBROKE OFFICE
ARNOLD RESERVOIR DAM (ARNOLD RESERVOIR)
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WASHINGTON STREET POND DAM (WASHINGTON STREET POND)
SUNOCO
SPRINT/NEXTEL
PEMBROKE FIRE DEPARTMENT
RANDALL POND DAM (RANDALL POND)
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ADAH F. HALL HOUSE
KIDS TIME PRESCHOOL & DAYCARE
PLEASANT STREET POND DAM (PLEASANT STREET POND)
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PEMBROKE POLICE DEPARTMENT
TOWN HALL
FIRST CHURCH IN PEMBROKE
PEMBROKE HISTORICAL SOCIETY
COMMUNITY NURSERY KINDERGARTEN
CENTER PRE-SCHOOL & CHILD CARE
POWERLINE
PEMBROKE COUNCIL ON AGING
PEMBROKE PUBLIC LIBRARY
CUMBERLAND FARMS
FIREHOUSE GAS
PEMBROKE FIRE DEPARTMENT
HERE WE GROW DAY CARE
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USPS PEMBROKE OFFICE
PEMBROKE ASSEMBLY OF GOD
PEMBROKE HOUSING AUTHORITY
AMERICAN TOWERS, INC.
LITTLE NEIGHBORS EARLY CHILDHOOD CENTER
HIGH STREET TANK
SPRINT, T-MOBILE & METRO PCS
LYDIA DRAKE LIBRARY
LEARNING LANE TANK
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DEPARTMENT OF PUBLIC WORKS
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PEMBROKE HIGH SCHOOL
HOBOMOCK ELEMENTARY SCHOOL
MILL POND/FURNACE POND DAM (MILL POND)
HOBOMOCK ARENA
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GP WELL 4
BRYANTVILLE ELEMENTARY SCHOOL
MONROE STREET BOG EAST DAM (MONROE STREET BOG)
USPS BRYANTVILLE OFFICE
UPPER CHANDLER POND DAM (UPPER CHANDLER POND)
GP WELL 2
COBB LIBRARY
INDUSTRIAL TOWER & WIRELESS, LLC
HILL POND DAM (HILL POND)
T-MOBILE NORTHEAST
ROAD TO RESPONSIBILITY
GP WELL 3
MONROE STREET BOG WEST DAM (MONROE STREET BOG)
POWERLINE
PROPOSED EDGEWOOD BOGS WELL
PEMBROKE COMMUNITY MIDDLE SCHOOL
LOWER CHANDLER POND DAM (LOWER CHANDLER POND)
NEW ENGLAND VILLAGES
SILVER LAKE
0
0.5
1
2
3
4
5
Miles
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Projected Average Annual Temperature

Pembroke, MA

HMP-MVP Plan

Legend

Projected Average Annual Temperature
(South Coastal and Taunton Basins, RCP8.5/4.5, Year 2030)

- South Coastal Basin
- Taunton Basin

N

0 0.5 1
Miles

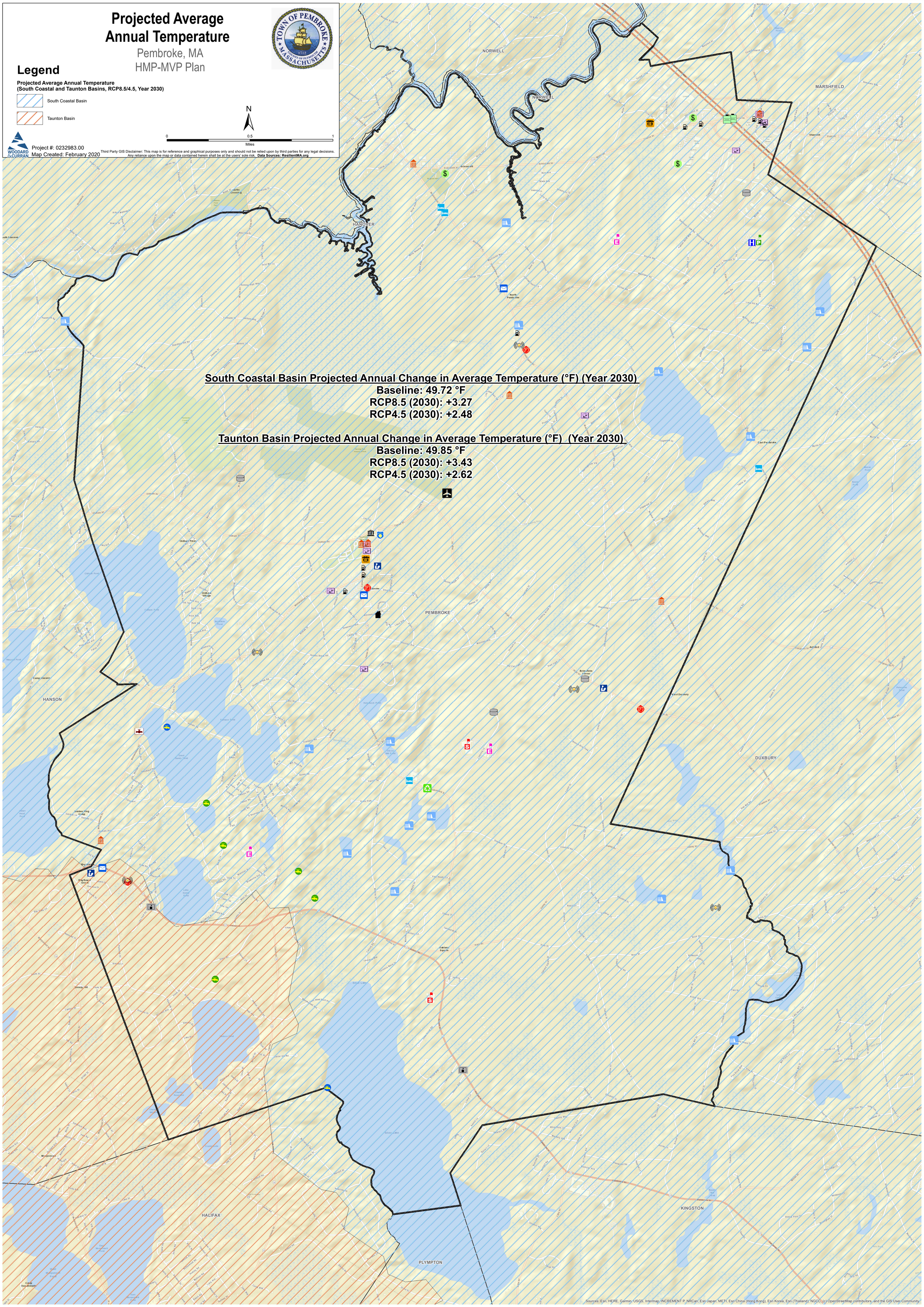
WOODARD & CURRAN

Project #: 0232983.00
Map Created: February 2020

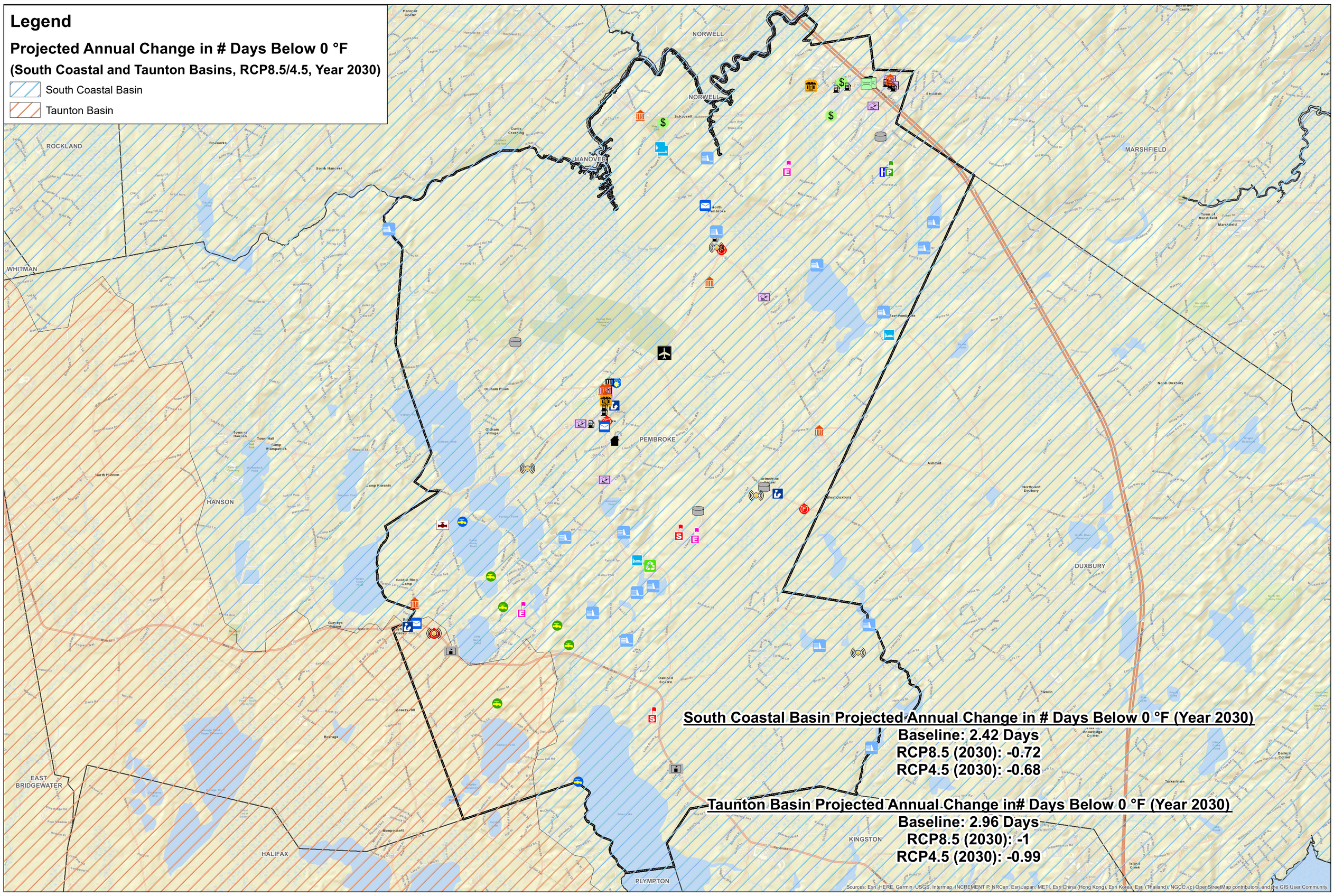
Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: ResilientMA.org**

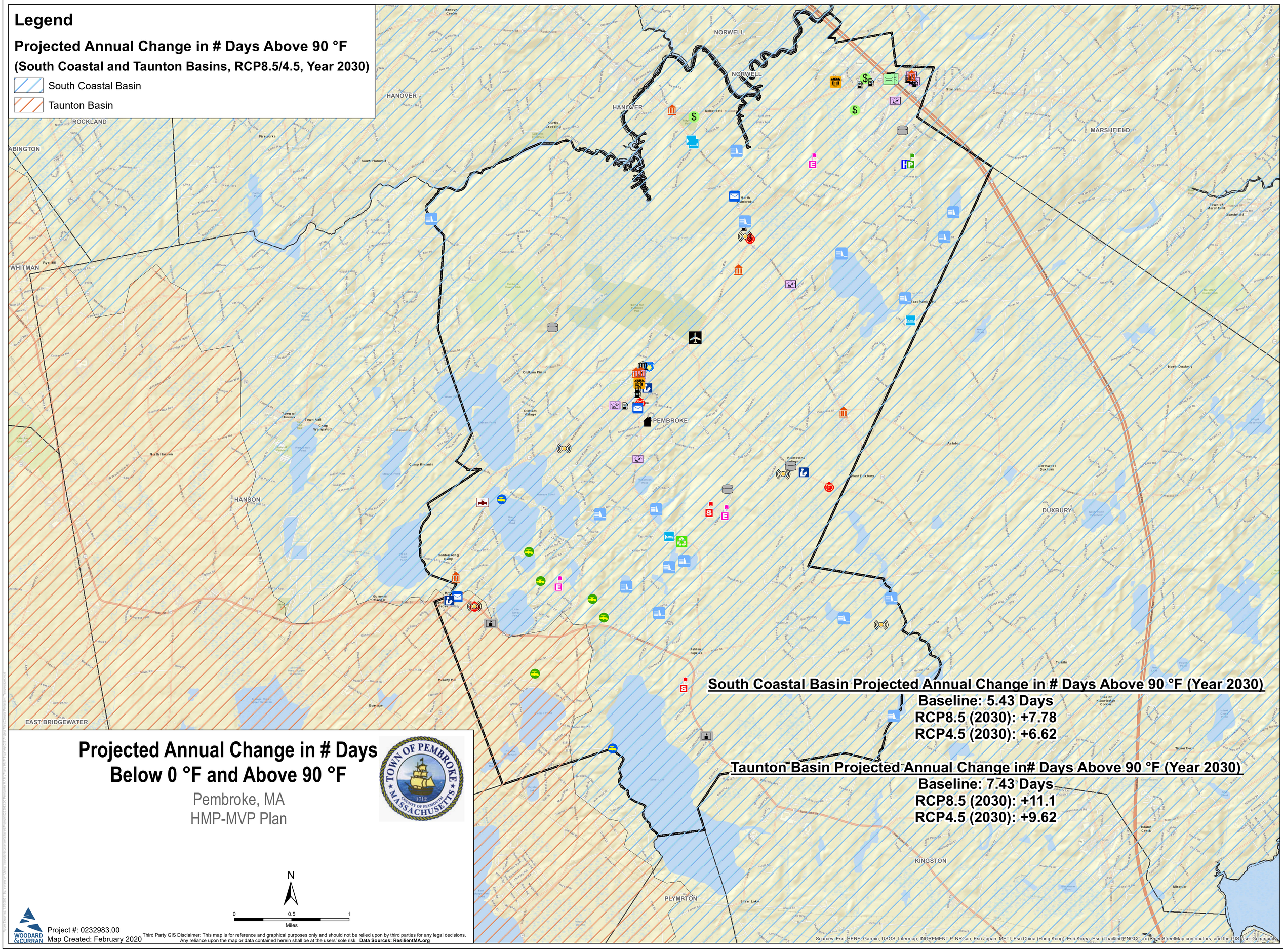
South Coastal Basin Projected Annual Change in Average Temperature (°F) (Year 2030)
Baseline: 49.72 °F
RCP8.5 (2030): +3.27
RCP4.5 (2030): +2.48

Taunton Basin Projected Annual Change in Average Temperature (°F) (Year 2030)
Baseline: 49.85 °F
RCP8.5 (2030): +3.43
RCP4.5 (2030): +2.62



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community





Projected Annual Change in # Days Below 0 °F and Above 90 °F

Pembroke, MA
HMP-MVP Plan

N

0 0.5 1
Miles

Project #: 0232983.00
Map Created: February 2020

Projected Total Annual Precipitation

Pembroke, MA

HMP-MVP Plan

Legend

Projected Total Annual Precipitation
(South Coastal and Taunton Basins, RCP8.5/4.5, Year 2030)

- South Coastal Basin
- Taunton Basin

N

0 0.5 1
Miles

WOODARD & CURRAN

Project #: 0232983.00
Map Created: February 2020

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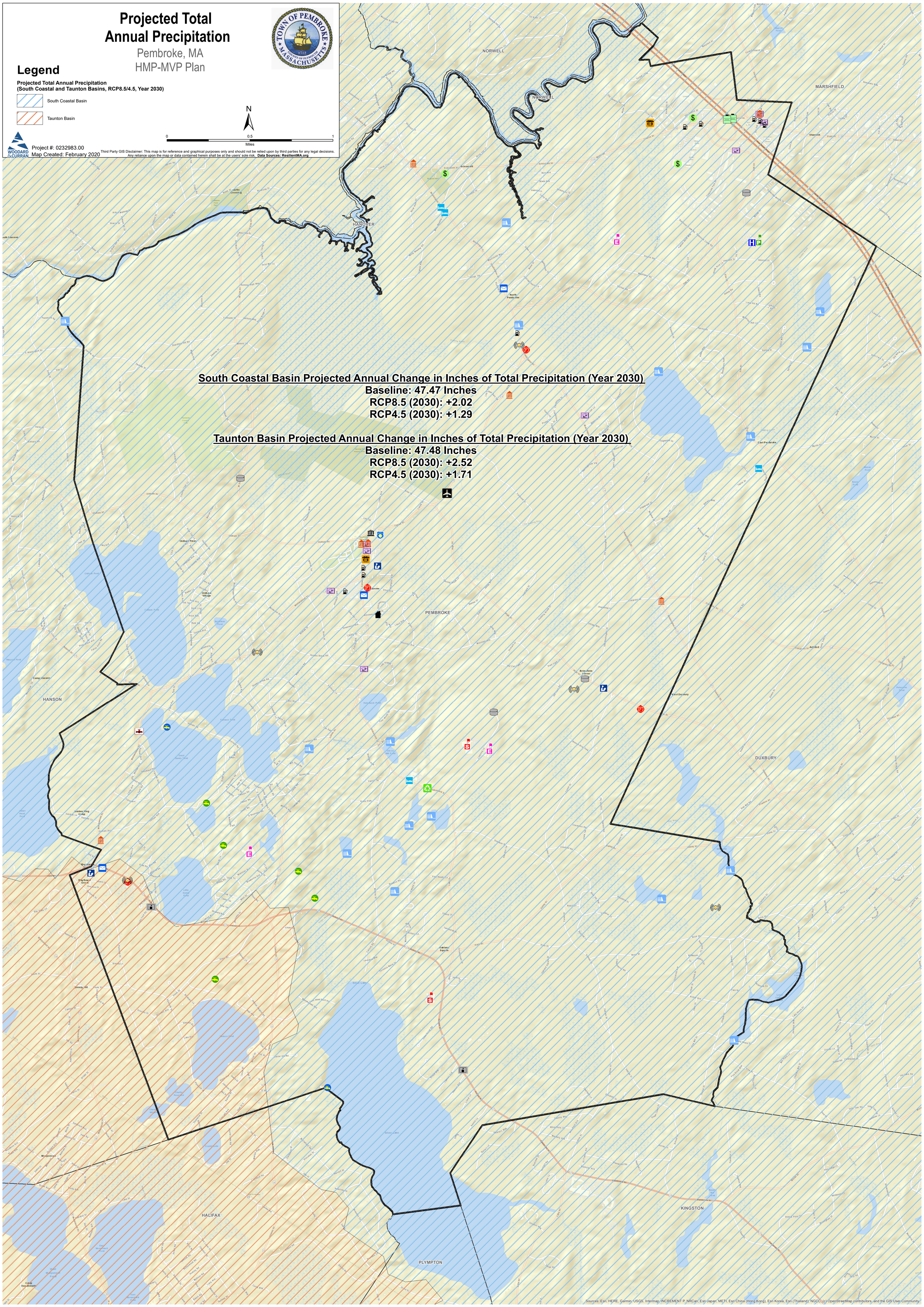
South Coastal Basin Projected Annual Change in Inches of Total Precipitation (Year 2030)
Baseline: 47.47 Inches
RCP8.5 (2030): +2.02
RCP4.5 (2030): +1.29

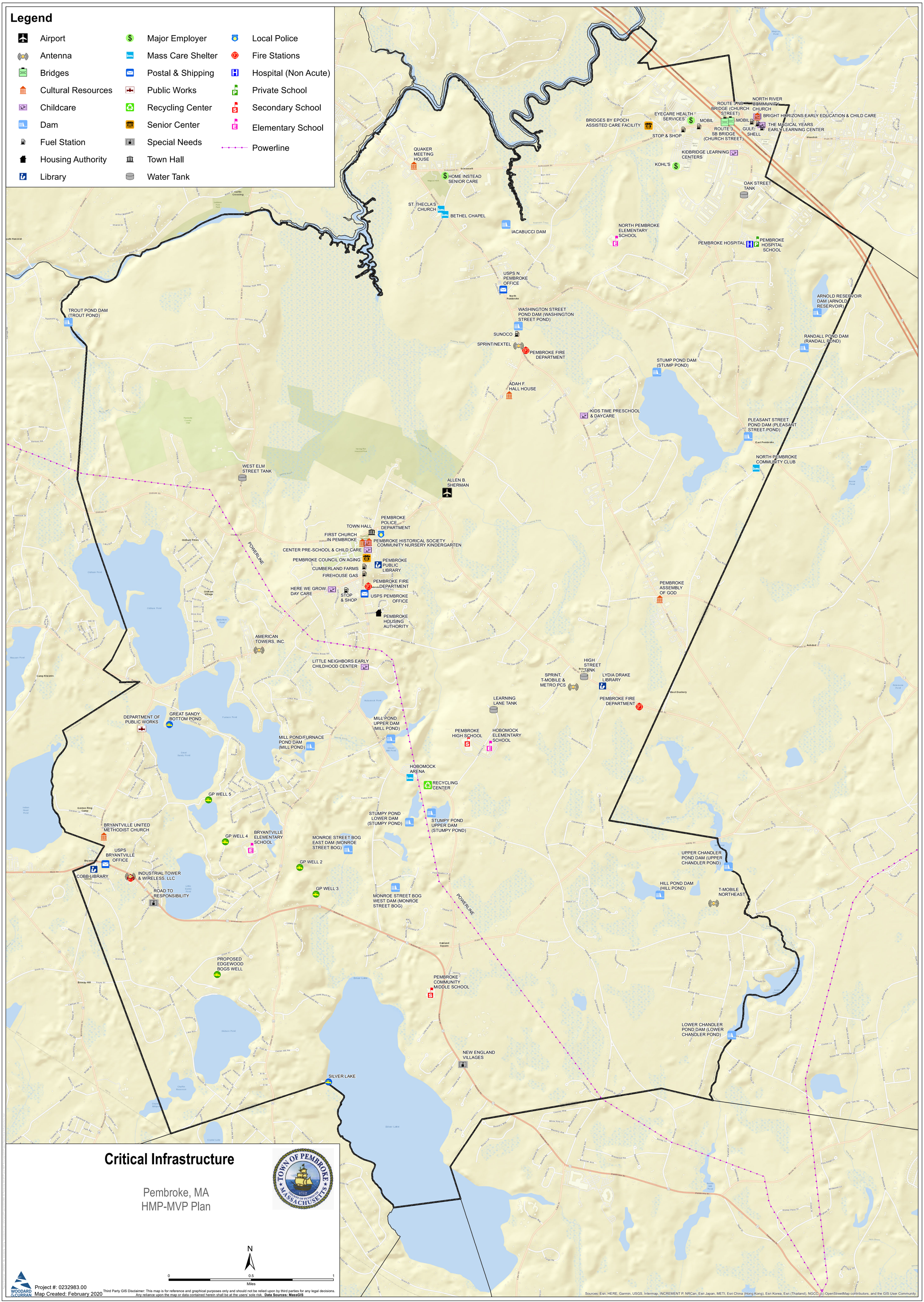
Taunton Basin Projected Annual Change in Inches of Total Precipitation (Year 2030)
Baseline: 47.48 Inches
RCP8.5 (2030): +2.52
RCP4.5 (2030): +1.71



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Legend

- Airport
- Antenna
- Bridges
- Cultural Resources
- Childcare
- Dam
- Fuel Station
- Housing Authority
- Library
- Major Employer
- Mass Care Shelter
- Postal & Shipping
- Public Works
- Recycling Center
- Senior Center
- Special Needs
- Town Hall
- Water Tank
- Local Police
- Fire Stations
- Hospital (Non Acute)
- Private School
- Secondary School
- Elementary School
- Powerline



Critical Infrastructure

Pembroke, MA
HMP-MVP Plan

N

0 0.5 1
Miles

Project #: 0232983.00
Map Created: February 2020

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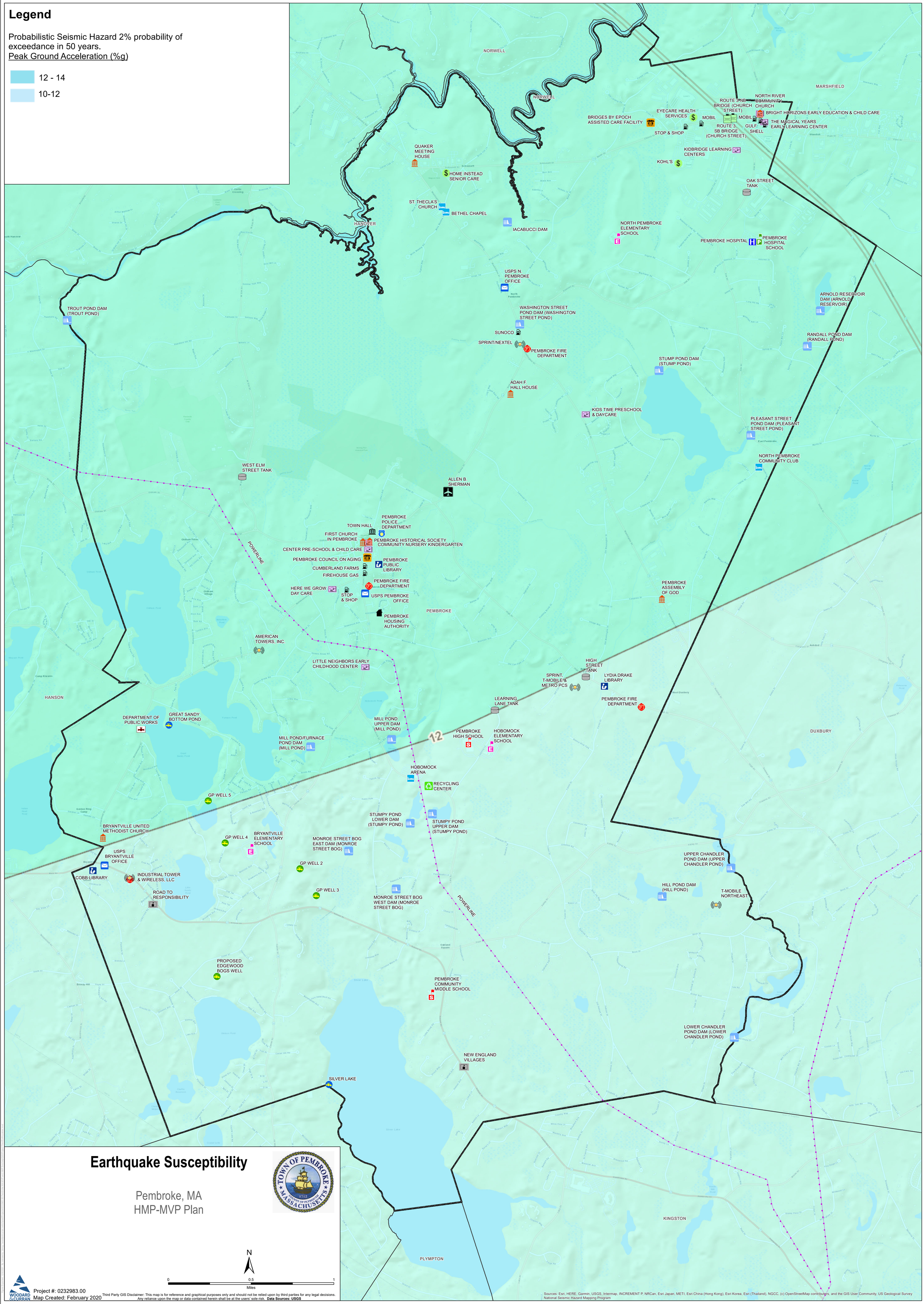
Legend
Probabilistic Seismic Hazard 2% probability of exceedance in 50 years.
Peak Ground Acceleration (%g)
12 - 14
10-12
NORWELL
MARSHFIELD
HANOVER
PEMBROKE
HANSON
DUXBURY
KINGSTON
PLYMPTON
NORTH RIVER COMMUNITY CHURCH
ROUTE 3 NB BRIDGE (CHURCH STREET)
BRIGHT HORIZONS EARLY EDUCATION & CHILD CARE
EYECARE HEALTH SERVICES
MOBIL
THE MAGICAL YEARS EARLY LEARNING CENTER
BRIDGES BY EPOCH ASSISTED CARE FACILITY
ROUTE 3 SB BRIDGE (CHURCH STREET)
GULF
SHELL
STOP & SHOP
KIDBRIDGE LEARNING CENTERS
QUAKER MEETING HOUSE
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ST. THECLA'S CHURCH
BETHEL CHAPEL
IACABUCCI DAM
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PEMBROKE HOSPITAL
PEMBROKE HOSPITAL SCHOOL
USPS N. PEMBROKE OFFICE
ARNOLD RESERVOIR DAM (ARNOLD RESERVOIR)
TROUT POND DAM (TROUT POND)
WASHINGTON STREET POND DAM (WASHINGTON STREET POND)
SUNOCO
RANDALL POND DAM (RANDALL POND)
SPRINT/NEXTEL
PEMBROKE FIRE DEPARTMENT
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WEST ELM STREET TANK
ALLEN B. SHERMAN
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PEMBROKE HISTORICAL SOCIETY
COMMUNITY NURSERY KINDERGARTEN
CENTER PRE-SCHOOL & CHILD CARE
POWERLINE
PEMBROKE COUNCIL ON AGING
PEMBROKE PUBLIC LIBRARY
CUMBERLAND FARMS
FIREHOUSE GAS
PEMBROKE FIRE DEPARTMENT
HERE WE GROW DAY CARE
STOP & SHOP
USPS PEMBROKE OFFICE
PEMBROKE ASSEMBLY OF GOD
PEMBROKE HOUSING AUTHORITY
AMERICAN TOWERS, INC.
LITTLE NEIGHBORS EARLY CHILDHOOD CENTER
HIGH STREET TANK
SPRINT, T-MOBILE & METRO PCS
LYDIA DRAKE LIBRARY
LEARNING LANE TANK
PEMBROKE FIRE DEPARTMENT
DEPARTMENT OF PUBLIC WORKS
GREAT SANDY BOTTOM POND
MILL POND UPPER DAM (MILL POND)
12
PEMBROKE HIGH SCHOOL
HOBOMOCK ELEMENTARY SCHOOL
MILL POND/FURNACE POND DAM (MILL POND)
HOBOMOCK ARENA
RECYCLING CENTER
GP WELL 5
STUMPY POND LOWER DAM (STUMPY POND)
STUMPY POND UPPER DAM (STUMPY POND)
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GP WELL 4
BRYANTVILLE ELEMENTARY SCHOOL
MONROE STREET BOG EAST DAM (MONROE STREET BOG)
UPPER CHANDLER POND DAM (UPPER CHANDLER POND)
USPS BRYANTVILLE OFFICE
GP WELL 2
COBB LIBRARY
INDUSTRIAL TOWER & WIRELESS, LLC
HILL POND DAM (HILL POND)
T-MOBILE NORTHEAST
ROAD TO RESPONSIBILITY
GP WELL 3
MONROE STREET BOG WEST DAM (MONROE STREET BOG)
POWERLINE
PROPOSED EDGEWOOD BOGS WELL
PEMBROKE COMMUNITY MIDDLE SCHOOL
LOWER CHANDLER POND DAM (LOWER CHANDLER POND)
NEW ENGLAND VILLAGES
SILVER LAKE
Earthquake Susceptibility
Pembroke, MA
HMP-MVP Plan
TOWN OF PEMBROKE MASSACHUSETTS 1712
N
0 0.5 1
Miles
WOODARD & CURRAN
Project #: 0232983.00
Map Created: February 2020
Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. Data Sources: USGS
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community, US Geological Survey National Seismic Hazard Mapping Program

Legend

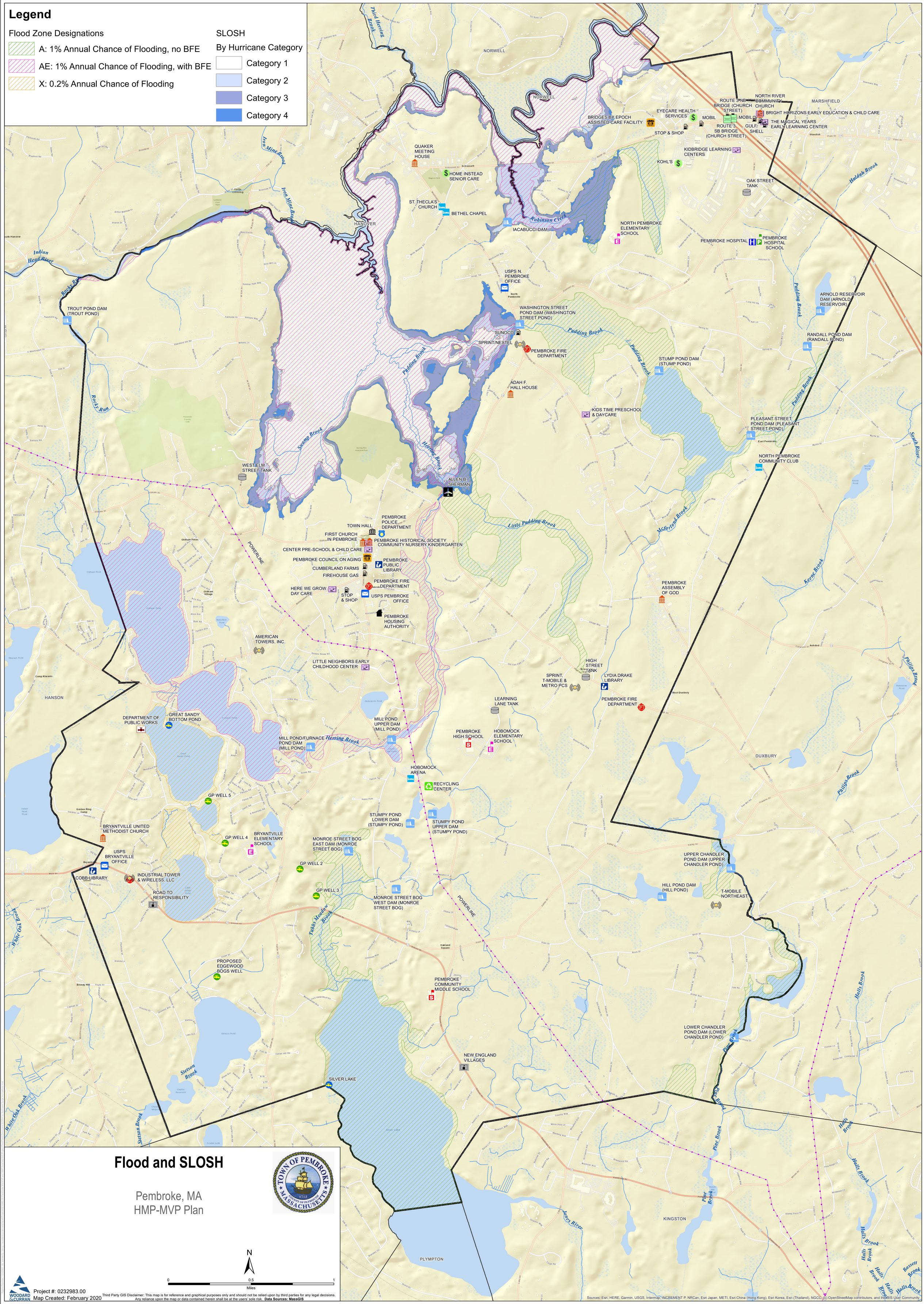
Flood Zone Designations

- A: 1% Annual Chance of Flooding, no BFE
- AE: 1% Annual Chance of Flooding, with BFE
- X: 0.2% Annual Chance of Flooding

SLOSH

By Hurricane Category

- Category 1
- Category 2
- Category 3
- Category 4



Flood and SLOSH

Pembroke, MA
HMP-MVP Plan

N

0 0.5 1
Miles

Project #: 0232983.00
Map Created: February 2020

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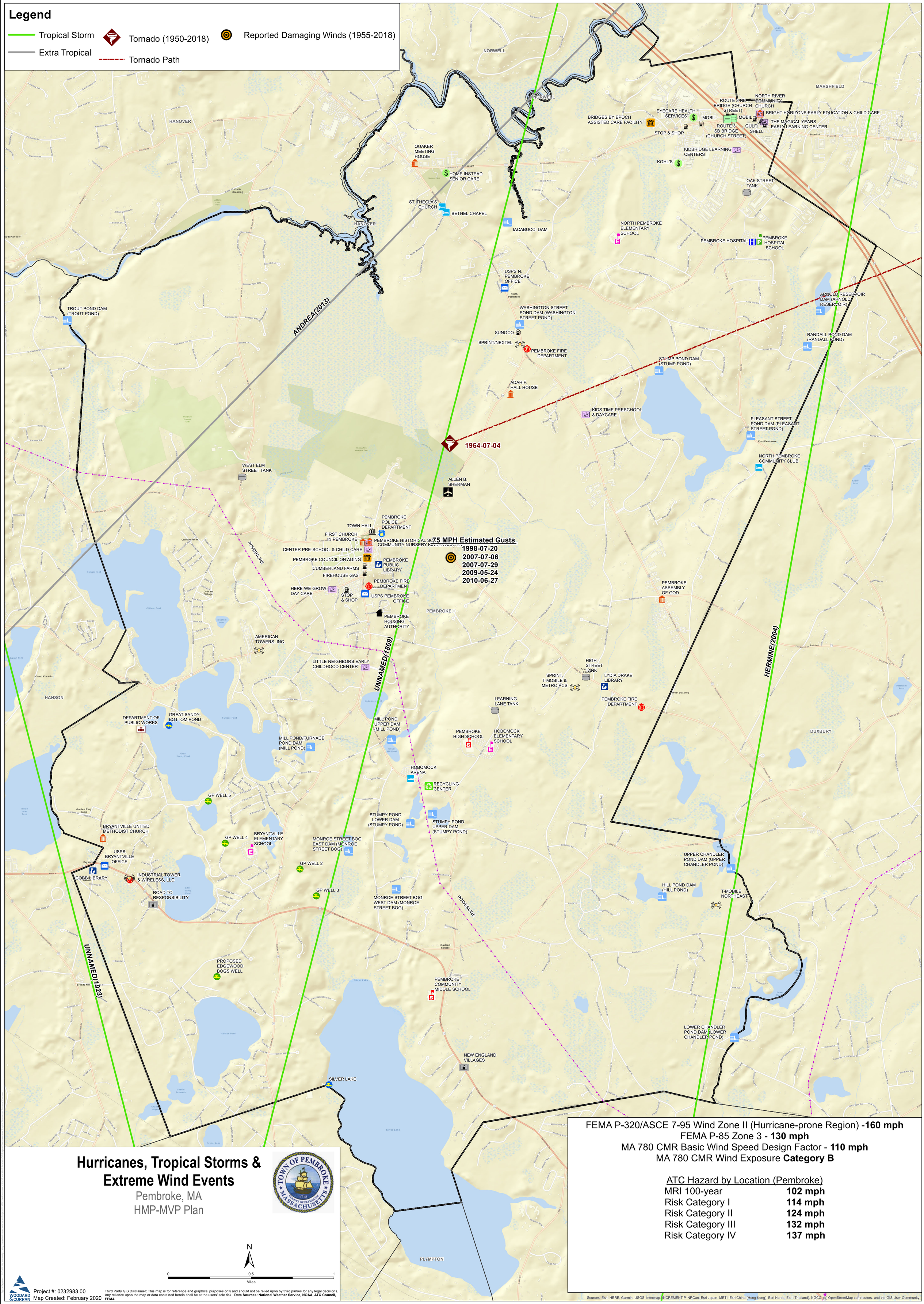
Legend
Tropical Storm
Extra Tropical
Tornado (1950-2018)
Tornado Path
Reported Damaging Winds (1955-2018)
ANDREA(2013)
1964-07-04
75 MPH Estimated Gusts
1998-07-20
2007-07-06
2007-07-29
2009-05-24
2010-06-27
UNNAMED(1869)
UNNAMED(1923)
HERMINE(2004)
POWERLINE
NORWELL
HANOVER
MARSHFIELD
PEMBROKE
HANSON
DUXBURY
PLYMPTON
SILVER LAKE
NEW ENGLAND VILLAGES
PEMBROKE COMMUNITY MIDDLE SCHOOL
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ROUTE 3 NB BRIDGE (CHURCH STREET)
ROUTE 3 SB BRIDGE (CHURCH STREET)
GULF
SHELL
NORTH RIVER COMMUNITY CHURCH
BRIGHT HORIZONS EARLY EDUCATION & CHILD CARE
THE MAGICAL YEARS EARLY LEARNING CENTER
Hurricanes, Tropical Storms & Extreme Wind Events
Pembroke, MA
HMP-MVP Plan
TOWN OF PEMBROKE MASSACHUSETTS
N
0
0.5
1
Miles
Project #: 0232983.00
Map Created: February 2020
WOODARD & CURRAN
Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. Data Sources: National Weather Service, NOAA, ATC Council, FEMA
FEMA P-320/ASCE 7-95 Wind Zone II (Hurricane-prone Region) -160 mph
FEMA P-85 Zone 3 - 130 mph
MA 780 CMR Basic Wind Speed Design Factor - 110 mph
MA 780 CMR Wind Exposure Category B
ATC Hazard by Location (Pembroke)
MRI 100-year 102 mph
Risk Category I 114 mph
Risk Category II 124 mph
Risk Category III 132 mph
Risk Category IV 137 mph
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Legend

- Forest
- Brushland/Successional
- Open Land
- Water
- Forested Wetland
- Non-Forested Wetland
- Cranberry Bog
- Nursery
- Cropland
- Pasture
- Cemetery
- Golf Course
- Participation Recreation
- Multi-Family Residential
- High Density Residential
- Medium Density Residential
- Low Density Residential
- Very Low Density Residential
- Transitional
- Urban Public/Institutional
- Commercial
- Industrial
- Transportation
- Powerline/Utility
- Mining
- Waste Disposal
- Junkyard

Land Use

Pembroke, MA
HMP-MVP Plan

N

0 0.5 1
Miles

Project #: 0232983.00
Map Created: February 2020

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Legend

Relative Slide Ranking

- High
- Moderate
- Low
- Very Low

NORWELL
NORWELL
MARSHFIELD
HANOVER
HANSON
PEMBROKE
DUXBURY
KINGSTON
PLYMPTON

NORTH RIVER COMMUNITY CHURCH
ROUTE 3 NB BRIDGE (CHURCH STREET)
BRIGHT HORIZONS EARLY EDUCATION & CHILD CARE
EYECARE HEALTH SERVICES
MOBIL
MOBIL
THE MAGICAL YEARS EARLY LEARNING CENTER
BRIDGES BY EPOCH ASSISTED CARE FACILITY
ROUTE 3 SB BRIDGE (CHURCH STREET)
GULF
SHELL
STOP & SHOP
KIDBRIDGE LEARNING CENTERS
KOHL'S
QUAKER MEETING HOUSE
HOME INSTEAD SENIOR CARE
OAK STREET TANK
ST. THECLA'S CHURCH
BETHEL CHAPEL
IACABUCCI DAM
NORTH PEMBROKE ELEMENTARY SCHOOL
PEMBROKE HOSPITAL
PEMBROKE HOSPITAL SCHOOL
USPS N. PEMBROKE OFFICE
ARNOLD RESERVOIR DAM (ARNOLD RESERVOIR)
TROUT POND DAM (TROUT POND)
WASHINGTON STREET POND DAM (WASHINGTON STREET POND)
SUNOCO
SPRINT/NEXTEL
PEMBROKE FIRE DEPARTMENT
RANDALL POND DAM (RANDALL POND)
STUMP POND DAM (STUMP POND)
ADAH F. HALL HOUSE
KIDS TIME PRESCHOOL & DAYCARE
PLEASANT STREET POND DAM (PLEASANT STREET POND)
NORTH PEMBROKE COMMUNITY CLUB
WEST ELM STREET TANK
ALLEN B. SHERMAN
PEMBROKE POLICE DEPARTMENT
TOWN HALL
FIRST CHURCH IN PEMBROKE
PEMBROKE HISTORICAL SOCIETY
COMMUNITY NURSERY KINDERGARTEN
CENTER PRE-SCHOOL & CHILD CARE
POWERLINE
PEMBROKE COUNCIL ON AGING
PEMBROKE PUBLIC LIBRARY
CUMBERLAND FARMS
FIREHOUSE GAS
PEMBROKE FIRE DEPARTMENT
HERE WE GROW DAY CARE
STOP & SHOP
USPS PEMBROKE OFFICE
PEMBROKE ASSEMBLY OF GOD
PEMBROKE HOUSING AUTHORITY
AMERICAN TOWERS, INC.
LITTLE NEIGHBORS EARLY CHILDHOOD CENTER
HIGH STREET TANK
SPRINT, T-MOBILE & METRO PCS
LYDIA DRAKE LIBRARY
PEMBROKE FIRE DEPARTMENT
LEARNING LANE TANK
DEPARTMENT OF PUBLIC WORKS
GREAT SANDY BOTTOM POND
MILL POND UPPER DAM (MILL POND)
PEMBROKE HIGH SCHOOL
HOBOMOCK ELEMENTARY SCHOOL
MILL POND/FURNACE POND DAM (MILL POND)
HOBOMOCK ARENA
RECYCLING CENTER
GP WELL 5
STUMPY POND LOWER DAM (STUMPY POND)
STUMPY POND UPPER DAM (STUMPY POND)
BRYANTVILLE UNITED METHODIST CHURCH
GP WELL 4
BRYANTVILLE ELEMENTARY SCHOOL
MONROE STREET BOG EAST DAM (MONROE STREET BOG)
UPPER CHANDLER POND DAM (UPPER CHANDLER POND)
USPS BRYANTVILLE OFFICE
GP WELL 2
COBB LIBRARY
INDUSTRIAL TOWER & WIRELESS, LLC
HILL POND DAM (HILL POND)
T-MOBILE NORTHEAST
GP WELL 3
ROAD TO RESPONSIBILITY
MONROE STREET BOG WEST DAM (MONROE STREET BOG)
POWERLINE
PROPOSED EDGEWOOD BOGS WELL
PEMBROKE COMMUNITY MIDDLE SCHOOL
LOWER CHANDLER POND DAM (LOWER CHANDLER POND)
NEW ENGLAND VILLAGES
SILVER LAKE

Landslide Susceptibility

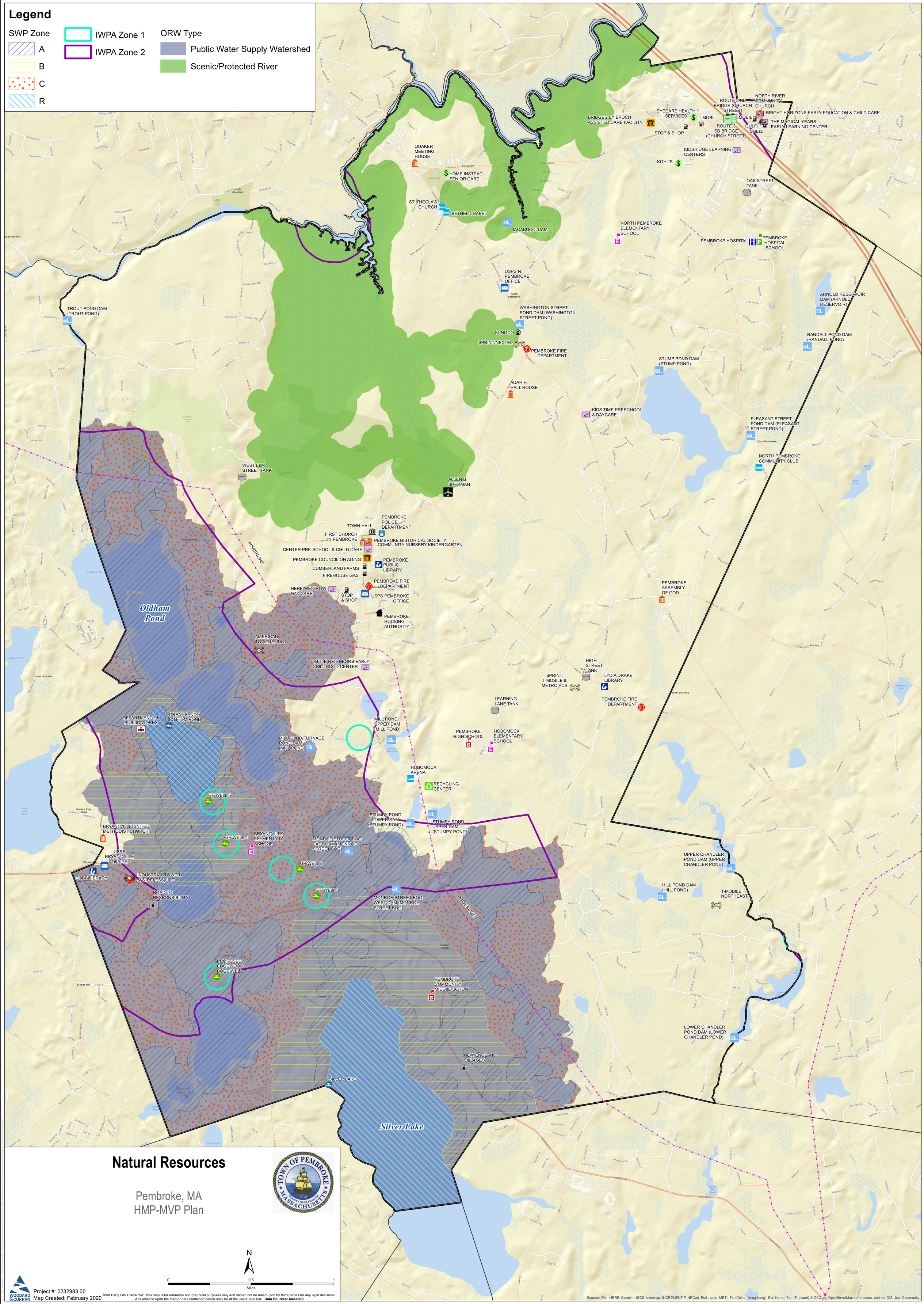
Pembroke, MA
HMP-MVP Plan

N

0 0.5 1
Miles

WOODARD & CURRAN

Project #: 0232983.00
Map Created: February 2020



Natural Resources

Pembroke, MA
HMP-MVP Plan

TOWN OF PEMBROKE MASSACHUSETTS 1712 COUNTY OF PLYMOUTH

WOODARD & CURRAN

Project #: 0232983.00
Map Created: February 2020

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Legend

Commercial Centers

- Route 14 & Route 36
- Route 3 & Route 139 Interchange

2017 ACS Census Block Group Population Density

- ≤ 1
- >1 and ≤ 2
- > 2

508101, Block Group 1
Pop. Density: 1.49

508101, Block Group 2
Pop. Density: 0.43

508101, Block Group 3
Pop. Density: 0.62

508101, Block Group 4
Pop. Density: 1.31

508101, Block Group 5
Pop. Density: 1.33

508102, Block Group 1
Pop. Density: 2.38

508102, Block Group 2
Pop. Density: 2.18

508102, Block Group 3
Pop. Density: 1.49

508200, Block Group 1
Pop. Density: 1.12

508200, Block Group 2
Pop. Density: 1.17

508200, Block Group 3
Pop. Density: 0.93

TROUT POND DAM (TROUT POND)
QUAKER MEETING HOUSE
HOME INSTEAD SENIOR CARE
ST. THECLA'S CHURCH
BETHEL CHAPEL
IACABUCCI DAM
BRIDGES BY EPOCH ASSISTED CARE FACILITY
EYECARE HEALTH SERVICES
MOBIL
STOP & SHOP
ROUTE 3 NB BRIDGE (CHURCH STREET)
ROUTE 3 SB BRIDGE (CHURCH STREET)
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THE MAGICAL YEARS EARLY LEARNING CENTER
GULF
SHELL
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KOHL'S
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PEMBROKE HOSPITAL
PEMBROKE HOSPITAL SCHOOL
USPS N. PEMBROKE OFFICE
WASHINGTON STREET POND DAM (WASHINGTON STREET POND)
SUNOCO
SPRINT/NEXTEL
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PEMBROKE HOUSING AUTHORITY
POWERLINE
Oldham Pond
AMERICAN TOWERS, INC.
LITTLE NEIGHBORS EARLY CHILDHOOD CENTER
PEMBROKE ASSEMBLY OF GOD
HIGH STREET TANK
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LYDIA DRAKE LIBRARY
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DEPARTMENT OF PUBLIC WORKS
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MILL POND UPPER DAM (MILL POND)
MILL POND/FURNACE POND DAM (MILL POND)
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HOBOMOCK ELEMENTARY SCHOOL
HOBOMOCK ARENA
RECYCLING CENTER
GP WELL 5
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STUMPY POND UPPER DAM (STUMPY POND)
BRYANTVILLE UNITED METHODIST CHURCH
GP WELL 4
BRYANTVILLE ELEMENTARY SCHOOL
MONROE STREET BOG EAST DAM (MONROE STREET BOG)
USPS BRYANTVILLE OFFICE
COBB LIBRARY
INDUSTRIAL TOWER & WIRELESS, LLC
ROAD TO RESPONSIBILITY
GP WELL 2
GP WELL 3
MONROE STREET BOG WEST DAM (MONROE STREET BOG)
UPPER CHANDLER POND DAM (UPPER CHANDLER POND)
HILL POND DAM (HILL POND)
T-MOBILE NORTHEAST
PROPOSED EDGEWOOD BOGS WELL
PEMBROKE COMMUNITY MIDDLE SCHOOL
LOWER CHANDLER POND DAM (LOWER CHANDLER POND)
NEW ENGLAND VILLAGES
SILVER LAKE
Silver Lake

Population Density

Pembroke, MA
HMP-MVP Plan

N

0 0.5 1
Miles

Project #: 0232983.00
Map Created: February 2020

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Legend

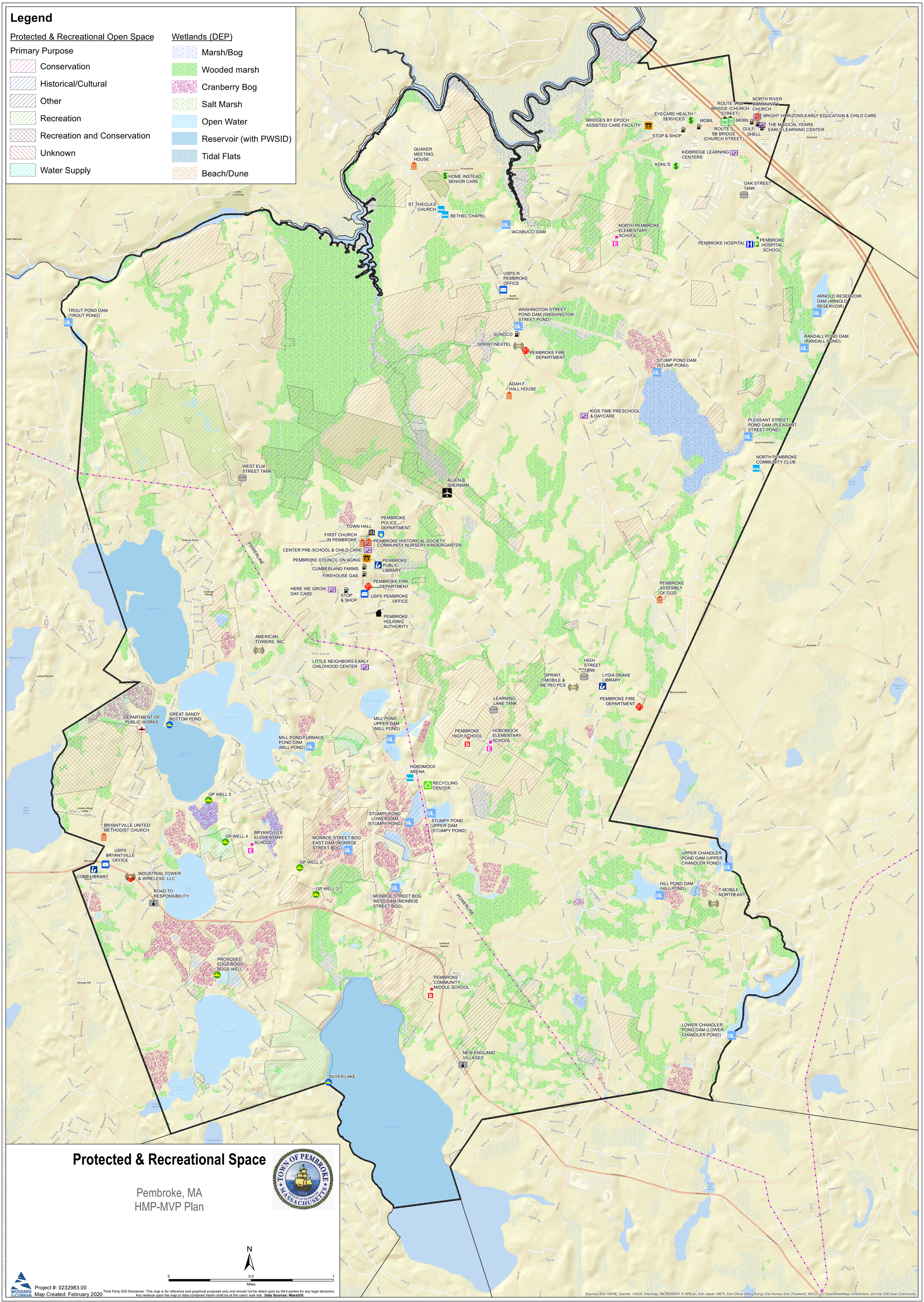
Protected & Recreational Open Space

Primary Purpose

- Conservation
- Historical/Cultural
- Other
- Recreation
- Recreation and Conservation
- Unknown
- Water Supply

Wetlands (DEP)

- Marsh/Bog
- Wooded marsh
- Cranberry Bog
- Salt Marsh
- Open Water
- Reservoir (with PWSID)
- Tidal Flats
- Beach/Dune



Protected & Recreational Space

Pembroke, MA
HMP-MVP Plan

N

0 0.5 1
Miles

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Legend

NOAA Mean Minimum and Maximum Annual Snowfall (2008-2020)

42" - 47"

Mean Annual Snowfall (2008-2020)

Pembroke, MA

HMP-MVP Plan

N

0 0.5 1 Miles

Project #: 0232983.00

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PEMBROKE
KINGSTON
PLYMPTON
POWERLINE
POWERLINE
QUAKER MEETING HOUSE
HOME INSTEAD SENIOR CARE
ST. THECLA'S CHURCH
BETHEL CHAPEL
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EYECARE HEALTH SERVICES
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THE MAGICAL YEARS EARLY LEARNING CENTER
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GULF
SHELL
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PEMBROKE HOSPITAL SCHOOL
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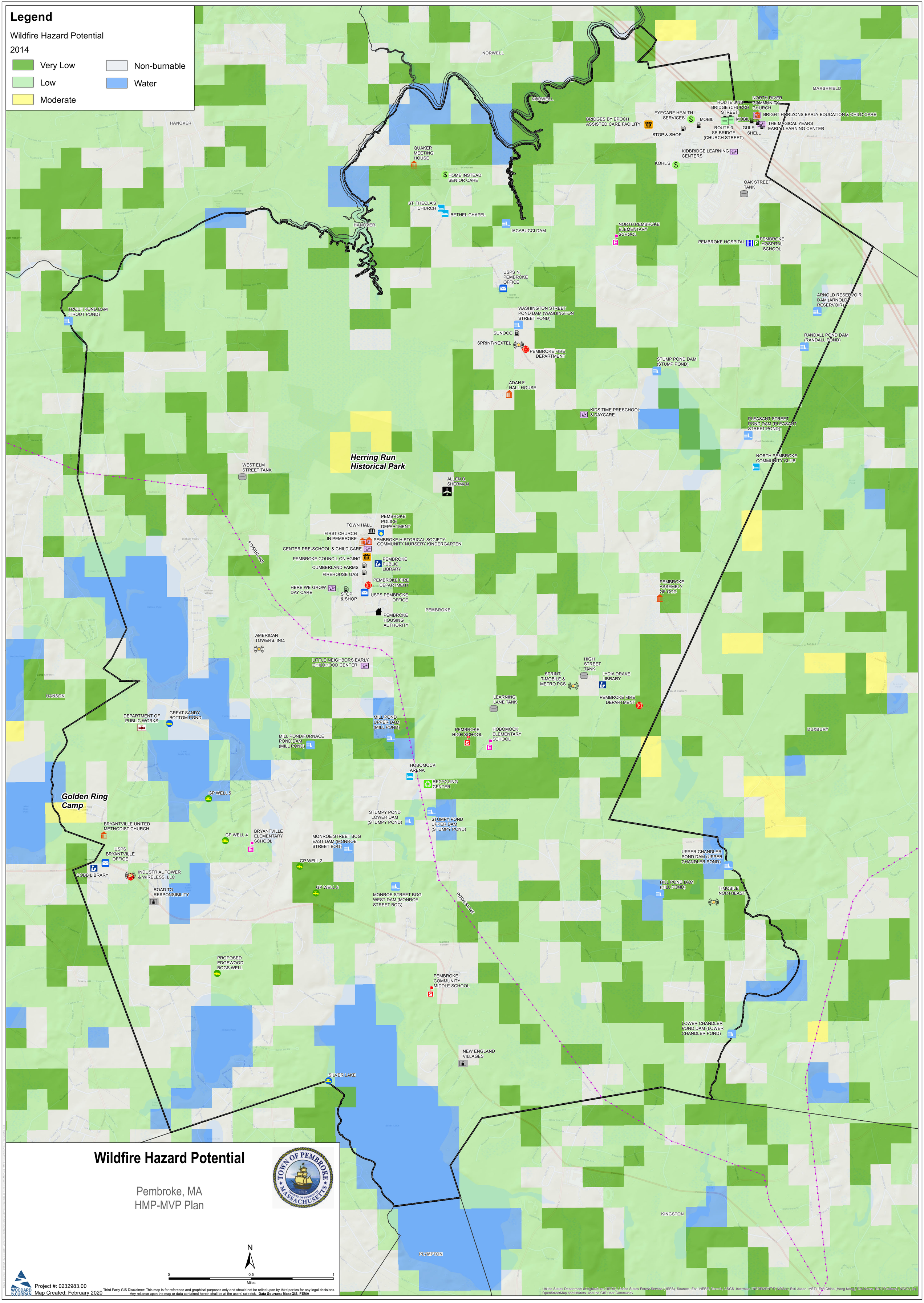
SILVER LAKE


Legend
Wildfire Hazard Potential
2014
Very Low
Low
Moderate
Non-burnable
Water
NORWELL
HANOVER
MARSHFIELD
ROUTE 3 NB BRIDGE (CHURCH STREET)
NORTH RIVER COMMUNITY CHURCH
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MASSACHUSETTS
1712
N
0
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Miles
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APPENDIX B: FLOOD PARCEL ANALYSIS TABLES

APPENDIX C: FEMA CIS DATA SHEETS, TOWN OF PEMBROKE, MA

APPENDIX D: CRB WORKSHOP MATERIALS AND PUBLIC LISTENING SESSIONS

APPENDIX E: FEMA REGULATION CHECKLIST

APPENDIX F: TOWN OF PEMBROKE ADOPTION RESOLUTION

APPENDIX G: PLAN APPROVAL

WOODARD
&CURRAN

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COMMITMENT & INTEGRITY DRIVE RESULTS